

# decarbonized & decentralized energy.

NAAREA, a French company, produces and sells decarbonised energy generated by nuclear microgenerators installed close to industrial consumers and local authorities

### NAAREA IS THE WINNER OF THE « INNOVATIVE NUCLEAR REACTORS » CALL FOR PROJECTS FROM THE FRANCE 2030 INVESTMENT PLAN

NAAREA is the winner of the « Innovative Nuclear Reactors » call for projects from the France 2030 Investment Plan. This significant participation by the state reflects a strong recognition of Generation IV molten salt and fast neutron reactors by the French authorities.

This label is obtained through an independent evaluation and selection process, which demonstrates the trust of the public authorities in NAAREA's solution to meet France's objectives of energy sovereignty, decarbonization, and energy mix by 2050. The funds allocated for this initial phase of the call for projects, combined with the private capital previously raised by NAAREA, will accelerate the implementation of the design and associated testing, as well as support the increase in staff from 140 employees in May 2023 to 200 by the end of the year.

#### About France 2030

Presented on October 12, 2021 by the french President, France 2030:

✓ **Embodies a dual ambition: transform key sectors** of our economy (such as energy, automotive, healthcare, aerospace, and space) through technological and industrial innovation and **position France not only as a participant but as a leader in the world of tomorrow.** From fundamental research and the emergence of ideas to the production of new products or services, France 2030 supports the entire lifecycle of innovation until its industrialization.

✓ It is unprecedented in its magnitude: €54 billion will be invested to ensure that our companies, universities, and research organizations fully succeed in their transitions in these strategic sectors. The objective is to enable them to competitively address the ecological challenges and attractiveness of the future world and to foster the emergence of future champions in our areas of excellence thereby strengthening French sovereignty and independence in key sectors. 50% of the expenditures will be devoted to decarbonizing the economy, and 50% will be allocated to emerging actors driving innovation with no adverse impact on the environment (in line with the Do No Significant Harm principle)

✓ It will be implemented collectively: the plan is designed and deployed in consultation with economic, academic, local, and European stakeholders who have contributed to determining its strategic directions and flagship actions. Project leaders are invited to submit their proposals through open, rigorous, and selective procedures to benefit from state support.

t is led by the General Secretariat for Investment on behalf of the Prime Minister and implemented by the French Agency for Ecological Transition (ADEME), the National Research Agency (ANR), Bpifrance, and the Caisse des Dépôts et Consignations (CDC).

For more information, visit: https://www.gouvernement.fr/france-2030





# NAAREA JOINS THE FRENCH TECH 2030 PROMOTION

After being recognized as the winner of the «Innovative Nuclear Reactors» call for projects from the France 2030 Investment Plan, NAAREA, a pioneering French fourth-generation nuclear company, has been labeled as «French Tech 2030,» an accompanying program created by the French Tech mission, the General Secretariat for Investment, and Bpifrance.

Thanks to this label, which aims to support the emergence of innovations in key strategic sectors, NAAREA will benefit from specific support (regulatory, customs, or industrial property issues, monitoring, cybersecurity, administrative authorizations, visibility, international delegations) from all government and territorial services, coordinated by the French Tech Mission.

#### About the French Tech promotion

The French Tech 2030 program is an ambitious new initiative, led by the General Secretariat for Investment, with support from the French Tech Mission and the expertise of Bpifrance. The 125 selected startups will benefit from one year of support from the French Tech Mission, with the aim of promoting the development of disruptive solutions that address our societal and sovereignty challenges.

#### The 2023 promotion consists of:

- 125 emerging actors aligned with the verticals of France 2030:
- Ecological transition (38%), health (20%), digital (19%), agri-food (14%), new frontiers (8%), and education (2%).
- 34% of the winners are industrial startups, and 68% are deeptech companies.
- 42 companies already have a factory (33.6%)
- 44 companies have a factory project (35.2%).
- 86 companies (68.8%) have either a factory or a factory project.
- Over half of the winners have their headquarters located outside of Île-de-France.
- The promotion reflects the commitments of the French Tech Mission:
- 52% of the laureates are dedicated to the ecological transition
- 14% of CEOs and 30% of (co-)founders are women.

#### The selection criteria

- A total of 844 applications were received, out of which 125 were selected as winners
- The selected emerging actors address the challenges targeted by the 10 objectives and 6 levers of France

2030, with special attention given to solutions that strengthen our industrial and technological sovereignty

• The targeted areas include ecological transition, health, digital, agri-food, and new frontiers (marine, space, quantum), as well as education.

• The selected companies demonstrate economic and technological maturity, enabling them to benefit from the proposed support services.

• The minimum eligibility requirement was to have obtained funding of at least €5 million and have revenues of €5 million.

• The selection process involved representatives from the General Directorate for Enterprises, the General Directorate for Research and Innovation, the Defense Innovation Agency, the Health Innovation Agency, and the General Commission for Sustainable Development.

#### The ambition:

• In a context of increasing international competition, it is necessary for France to develop global technological leaders.

• By fostering this new generation of innovation, it ensures technological sovereignty and the resulting economic, social, and employment benefits.

• This technological sovereignty also aims to create the industrial champions of tomorrow. The program seeks to contribute to the dynamic process of industrial revitalization that energizes all our territories and enhances the competitiveness of our entire economic fabric.

## «GREAT HOPE FOR THE 21ST CENTURY»



« The dawn of a new energy era is breaking over the world. In a few years' time, everything will be different. Not only will we be able to overcome scarcity, but the planet will also undergo depollution, while the energy sovereignty of France and Europe becomes a reality

Contrary to the hasty conclusions of some or the Malthusian mindset of others, the innovative capacity of the human spirit is boundless. A new generation of energies, particularly nuclear, allows us to consider the future without falling into naive optimism. An economic and societal revolution is now within reach. Therefore, it can be assumed that a new technology utilizes green nuclear energy and can produce electricity in large quantities at a very low cost.

Furthermore, it can be assumed that this technology utilizes waste from conventional nuclear energy as fuel, effectively contributing to cleaning up the planet. Finally, let us assume that the deployment of this technology does not take decades but only a few years.

Contrary to the incredulity that these assumptions may provoke, such technology does exist. It falls under what specialists refer to as fourth-generation reactors. It is based on the Advanced Modular Reactor (AMR), which includes six types, one of which employs molten salts, as well as the Small Modular Reactor (SMR.

SMR/AMRs are flexible and can be scaled up or down. They are adaptable, particularly in geographical areas that are incompatible with large reactors, such as small electricity markets, isolated areas, or sites with limited access to water. They are simple because they are manufactured in large series in a factory and then transported to the site, making them cheaper to build. They are also safe as they use smaller quantities of fuel and significantly reduce risks.

Among those pursuing the race for green nuclear energy, NAAREA represents a major and original breakthrough. Unlike large-scale projects in China or the United States, this young company specializing in SMR/AMR proposes a very small modular reactor called XSMR (Extra Small Nuclear Reactor) and XAMR (Extra Advanced Nuclear Reactor). The design of these reactors allows for the safe generation of several dozen megawatts using used radioactive materials, of which there is already a high quantity available.

Consequently, a radical new approach to energy supply will be established: access to decarbonized, decentralized, and non-intermittent electricity, based on the utilization of used fuels. This will be made possible through the installation of pocket power stations, which are very small and easily deployed, capable of supplying any geographical area, as well as economic sectors and populations that are not connected to a power grid.

Click here to read the full article, published on 14 November 2022 on the Robert Schuman Foundation website





The NAAREA XAMR® (for eXtrasmall Advanced Modular Reactor) is an innovative fourth-generation low-power fastneutron molten salt nuclear microreactor that can be deployed as close as possible to industrial electrical or thermal energy consumers, both in France and abroad.

Nuclear power is undergoing a revival, as it meets the needs of Europe and the world to reduce greenhouse gas emissions from human activities, by providing a green, stable energy production solution to mitigate the intermittency of renewable energies. Technological developments now allow secure control throughout the nuclear industry. The leading countries, aware of the exponential need for electricity generation, positioned themselves very quickly.

France has positive advantages and achievements, but delays in the EPR make additional deployments essential to consolidate our energy independence and meet the energy needs of the world's population. Control of decentralized energy production brings operational and strategic advantages. It contributes to strengthening sovereignty through autonomy, offers an undisputed operational advantage, a vector of performance and resilience, and makes a significant contribution to achieving the objectives of energy transition and sustainable development. NAAREA (Nuclear Abundant Affordable Resourceful Energy for All) aims to mass produce these micro power plants and position itself as an operator in order to sell the energy produced to industrial consumers

The project is developed in close collaboration with undisputed nuclear research organisations, companies, and personalities. The technology is based on a molten salt reactor producing energy from used nuclear fuels that are currently stored for recycling, and depleted uranium. It enables abundant, decarbonised, and decentralised energy to be produced with an autonomous mechanism, at a lower price per kWh lower than coal or other fossil fuels such as oil and gas

The NAAREA microgenerator is a single molten salt reactor operating under atmospheric pressure and not cooled with water. Within it, an intrinsically selfregulated fission reaction occurs at high temperature (approximately 700°C). This self-regulating aspect of the reaction could give this technology the highest passive safety profile among the 4th-generation fast-neutron technologies.

This reactor has a set of radiation protection systems that require no special precautions outside the reactor. It will meet all safety and security constraints and legislation in force.

NAAREA will develop, design, construct, install, operate, maintain and carry out the recycling, reprocessing, and decommissioning of its microgenerators. The production plant could produce the first microgenerators as early as 2027, then gradually increase production for 5 years until reaching a production capacity of 50 GW per year. To do this, NAAREA proposes an ambitious development schedule structured in 3 parallel phases that will be marked by the finalization of a digital twin in 2023, paving the way for compiling the safety options dossier for the commissioning of the prototype by 2028. NAAREA is aiming for series production by 2030.

The final phase will be the construction of the series manufacturing plant, which will basically be an automated nuclear facility. This plant will consist of two modules: a manufacturing plant and a deconditioning/reprocessing plant for recycling microgenerators



Phase 1, with a timeline of 18 months of pre-design, includes the production of a complete digital twin. This allows for the validation of key decisions, functionalities, and sizing. It facilitates the coordination of interfaces between different subsystems and the integration of the overall system. Additionally, it provides a tool for use by safety and security authorities.

#### Phase 2

Phase 2, with a timeline of 24 months, includes laboratory tests and the production of physical prototypes, followed by 12 months of operational monitoring based on feedback.

#### Phase 3

Phase 3, with a timeline of 36 months, will enable the development of the first units of the industrial series and the refinement of all manufacturing parameters. This will be followed by a twelve-month trial period to conduct final tests and gather feedback





All the challenges facing humankind, especially the 17 Sustainable Development Goals, are based directly or indirectly on energy, the overarching vector.

Clean energy solutions exist, but their large size (conventional nuclear), their dependence on energy transmission networks, or their intermittency (renewables) mean they can only provide a partial and inadequate response in the face of the huge and evergrowing demand. NAAREA calculates that electricity demand is likely to increase four-fold by 2050, reaching 100,000 TWh per year. This energy demand is the result of the digital hypergrowth combined with demographics. Soon, eight billion people will aspire to the same lifestyle as the Western middle class enjoys today. If the global economy wants to meet this aspiration, the demand for energy will continue to grow. At the same time, the sustainability of our planet today means that we need to decarbonize the production of this energy and end the intensive extraction of natural resources

# Changing the paradigm to resolve the energy trilemma

We need another form of energy. The World Energy Council has defined this challenge by specifying that it must be:

- durable, to combat climate change
- equitable, for universal access to development;
- safe, for the sovereignty of territories and nations.

This is what is called the energy «trilemma.» Its resolution will determine the collective response we will be capable of providing in the face of major economic and ecological challenges that humanity will confront in the coming century.

Due to its density, controllability, and low-carbon nature, nuclear energy is naturally the best candidate to meet all of these criteria. However, the conventional nuclear sector still suffers from shortcomings that need to be addressed in order to play a role: the new nuclear must be at the forefront of competitiveness to be able to compete based on cost-benefit considerations, especially compared to fossil fuels. It must also become completely clean, meaning it should ultimately lead to the complete closure of the fuel cycle. To achieve this, it must make technological developments in its own industry to gradually become better than the existing technology. To support its competitiveness, it must question its own historical choices without taboos and, if necessary, change the paradigm. Finally, on a day-by-day basis, it needs to address the challenge of an environmentally-friendly virtuous energy serving all audiences, needs, and situations.

NAAREA's XAMR® addresses the challenges of the energy trilemma in its economic, ecological, and societal aspects.

First of all, for households, so they can benefit from clean energy accessible anywhere in the territory, at all times and consistently, without fear of an interruption in supply. This ability to provide reliable, on-demand generation is crucial for making energy an essential contributor to household well-being. Households must be free to choose their energy, and socio-economic criteria should not obstruct the deep desire to access clean energy. Households should have confidence in their energy choices for the preservation of the planet and also for the future of their loved ones. For manufacturers too, who, more than ever today, are seeing energy as an unstable parameter in their development strategy. By ensuring they have reliable, accessible, and affordable access to energy, NAAREA is promoting the development of a long-lasting and sustainable industry, increasing the resilience of territories, reforming the economy, encouraging new generations of entrepreneurs, and expanding the scope of possibilities. As a result, manufacturers can plan their activities and production without their energy choices affecting their market position in the face of competition. Manufacturers can also align their development strategy with their CSR strategy.

Lastly, for the public authorities, whose legitimacy depends on their capacity to provide the citizens they represent with sovereign, low-carbon energy to meet current and future demand, and on their ability to provide universal access to reliable energy, whether for domestic or commercial use. By offering clean, abundant, and affordable energy, the public authorities address a common desire to mitigate and avoid potential environmental harm and climate change impacts while promoting integration and social justice.



NAAREA microgenerators consist of a miniaturised fission reactor and its ancillary components (exchangers, turbo-generator unit, power converters, control system, safety and redundancy, etc.) integrated in a small volume.

Depending on its power range and usage profile, its autonomy varies from three to around ten years. The fully controllable NAAREA microgenerator can be controlled remotely 24/7 and requires no heavy maintenance on site.

#### Safety and security

The molten salt reactor is inherently safe, based on a design using a high negative thermal counter-reaction coefficient (as the temperature increases, reactivity decreases): the reaction regulates itself, ensuring passive safety against reactivity swings.

Conversely, when it cools, its density in the core increases, and the probability of fission increases, as does its ability to generate heat. These two effects give the reactor its character of inherent stability. The equilibrium temperature is around 700°C. These effects also give the reactor its flexibility in terms of power, which is simply controlled by the flow rate of the heat transfer salt through the exchanger.

Another advantage lies in the absence of a significant rise in pressure leading to a mechanical breakdown of the fuel circuit. EThe molten salt reactor operates at a pressure close to atmospheric pressure because the heat-transfer and fuel salts remain in the liquid phase at high temperature.

En outre, les sels fondus utilisés ont des points d'ébullition très élevés (1600°C), ce qui signifie que même une élévation de température transitoire de quelques centaines de degrés n'entraine pas d'augmentation sensible de pression. Enfin, les réacteurs à sels fondus de petite taille n'utilisent pas d'eau (donc aucun risque de dégagement d'hydrogène) dans le réacteur ce qui limite également le risque d'explosion.

#### Flexibility and operational simplicity

The liquid state of the fuel allows great reactivity to power demands and a possible emptying in the event of an emergency stop. All these features give this technological solution a high passive safety profile, having a direct impact on the system design by reducing the need for safety components.

The heat produced by this reactor is converted into mechanical energy by a supercritical CO2 turbine, which drives an electricity generator. This technology means the size of the turbine can be significantly reduced compared to steam turbines, and improves energy efficiency.

#### Waste-to-energy and energy sovereignty

NAAREA has opted to develop a fast-neutron reactor. Like the Phenix and Superphenix reactors and the Astrid project, this type of reactor does not slow down the neutrons ejected after each fission, «burning» all the heavy nuclei present in the fuel. They also allow fertile material (i.e. heavy nuclei whose neutron composition prohibits fission) to be «over-generated» into fissile material by neutron capture. Together, these two characteristics open the way to a fuel utilisation rate of almost 98%, compared with 0.5% in current reactors.

Used radioactive material stored in the territory can provide a reserve for at least several hundred years.

Finally, a fast-neutron reactor can to generate energy from the most radiotoxic nuclei, including plutonium and minor actinides, which, with no other opportunity for reprocessing, are destined to be buried until eventually neutralised (more than 10,000 years). France currently has more than 300,000 tonnes of depleted uranium.

#### Unique in the market

NAAREA's business model is that of an energy supplier with a performance contract. NAAREA will remain the owner of the microgenerators at all times in order to guarantee their safety, security, maintenance, and proper operation.

All activities covered by NAAREA will be as follows: manufacturing, transport, and delivery to the site, implementation, connection, training, safety, insurance, operations and maintenance, emergency interventions including neutralizing or deactivating the microgenerators, and managing their end of life. The electricity and heat produced by the XAMR® are either consumed by local users or fed back into the distribution network. All fixed and variable manufacturing, maintenance, operation, and fuel costs will be borne by NAAREA. Customers will only be charged for usage.





The choice of disruptive nuclear, its small size, the utilization of spent nuclear fuel and its humanistic approach provide a decarbonized solution to society's energy needs.

Thanks to rapid development, NAAREA will be able to replace high-GHG-emitting activities such as industrial operations, electricity production in isolated areas, heavy and light mobility, agriculture, as well as the development of smart and sustainable cities and buildings.

While environmental protection is the most urgent issue, NAAREA's approach goes beyond that and encompasses all human impacts on the environment. By opting for small-scale molten salt reactors, NAAREA significantly reduces the footprint of energy production facilities, thereby avoiding impacts on surrounding ecosystems.

By choosing the fast neutron spectrum, NAAREA harnesses the energy contained in the used nuclear fuel currently stored awaiting permanent disposal. This aspect limits the need for mining, drastically reduces reliance on natural resources, and provides a solution for the long-lived nuclear waste. Similarly, by replacing a number of current polluting uses, NAAREA reduces pollution of aquatic environments and air pollution. Among the possibilities offered by the NAAREA XAMR®, maritime transport could change its mode of propulsion from heavy fuel oil (responsible for almost 60,000 premature deaths/year, and air pollution) to sustainable micronuclear power or ammonia production.

With regard to social impacts, NAAREA will be able to provide decarbonised, accessible and secure energy to everyone, even populations in the least developed countries that currently have no electricity network. As a reminder, energy is strongly correlated to economic development and the challenge of sustainable growth entails decoupling economic activities and greenhouse gas emissions.

This issue must have a profound impact on societies, which will see their quality of life improved. So far this has been offered by industrial society, but is much too dependent on hydrocarbons. Moreover, because of its decentralised nature, the NAAREA XAMR® boosts societal adaptation to climate change by generating electricity and heat completely autonomously, without the use of water for its operation.



Since 2005, the two founders of the project, Jean-Luc Alexandre and Ivan Gavriloff, have been collaborating successfully, enabling different professions to work together creatively

#### JEAN-LUC ALEXANDRE

Jean-Luc Alexandre is a graduate of France's Ecole Technique Préparatoire pour l'Armement, Central-Supelec (engineering, class of 92) and INSEAD. He began his career at Spie Batignolles in the engineering and construction of complex railway systems. He became Infrastructure Director at Alstom Transport in 2007. In 2013, he became Managing Director of Degrémont. In addition, until 2019 he was Chief Technical Officer for Infrastructure of the Suez Group. Fifteen years of working abroad has given him extensive knowledge of the international situation. This international experience in the field has made him keenly aware of social inequalities, daily sufferings in developing countries, and the devastating effects of climate change on these populations.

#### **IVAN GAVRILOFF**

Ivan Gavriloff, X81, is an entrepreneur and founder of KAOS Consulting. An expert in creativity and innovation, he has taught the "Think Differently" approach since 2012 at the CHEM, Ecole de Guerre, EMSST, CFMD, had a support mission with the Officier Général Transformation Digitale des Armées (OGTDA) for 18 months (2017–2018), and is a Colonel (AIR) in the military reserve (ADER). He leads creativity groups ranging from ten to several hundred people. His know-how helps seemingly disparate groups develop innovative solutions, thanks to methods of collective intelligence proven with 1,000 customers, including some from CAC40 companies



Inspired and professionally committed to achieving the seventeen Sustainable Development Goals (SDGs) signed in Paris in September 2015 by 193 countries, Jean-Luc Alexandre and Ivan Gavriloff published a book titled «Oui, c'est (encore) possible» (Yes, it is (still) possible) in December 2019, based on their analyses and insights on this issue. Their work emphasizes the importance of «Protecting our planet and the diversity of life» and highlights that climate is a shared heritage for which we bear responsibility towards future generations. NAAREA is led by Jean-Luc Alexandre as its Chairperson and Chief Executive Officer, with Ivan Gavriloff serving as the Chair of the Supervisory Board.



The radish is a natural element found worldwide, from China to Mexico, India, Africa, and Europe. It is a food source with abundant energy reserves and is rich in minerals and trace elements. Economical and accessible to all, it symbolizes the shared abundance that NAAREA aims to achieve.

Similar to NAAREA, radishes generate minimal waste as every part of the plant is consumed, whether raw or cooked: microgreens, roots, leaf stalks, greens, flowers, siliques, and seeds (oil and germination). Whether small or large, radishes grow rapidly, usually within 3 to 4 weeks, and their growth reflects the condition of the soil they are planted in. Radishes are particularly sensitive to irradiation, so if they have grown in contaminated soil or air, they may have effectively removed toxic heavy metals by concentrating them. Being able to consume radishes from such environments is an indication of their safety from radiation.

Therefore, the presence of the radish in the NAAREA logo symbolizes safety and security.

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