DeepCore Power

Modular Underwater Nuclear Power Plant
with Integrated Passive Safety

Technical Disclosure & Defensive Publication

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Abstract

This paper presents DeepCore Power, a modular underwater nuclear power plant architecture designed for enhanced passive safety, attack resilience, and minimal environmental footprint. The system places reactor modules, steam generators, and condensers in concentric toroidal rings beneath an artificial lake. Each module produces 50 MW of electrical power, with clusters of up to five modules sharing surface infrastructure for a total output of 250 MW.

The architecture introduces a dome-breach flooding mechanism as an ultimate failsafe: in the event of core meltdown, automated systems flood the reactor chamber from the lake above, entombing all contamination underground with zero atmospheric release. This inverts the Fukushima failure mode — where active pumping was needed to bring water to the reactor — by passively placing the reactor inside the water supply.

The cooling subsystem is modular and site-adaptive, supporting passive lake cooling, underground air-cooled condensers (ACC), evaporative tunnel systems, or cogeneration heat extraction depending on location and climate. The architecture is reactor-technology agnostic, compatible with PWR, BWR, SMR, MSR, and liquid-metal-cooled fast reactor designs.

Economic analysis suggests a CAPEX of approximately EUR 250-400 million per 50 MW module, with LCOE competitive with advanced SMR designs. Target applications include defense installations, island nations, remote industrial sites, urban cogeneration, and any scenario requiring invisible, hardened baseload power.

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1. Introduction and Problem Statement

Conventional nuclear power plants are large, visible surface installations requiring extensive land, security perimeters, and cooling infrastructure (typically river access or hyperbolic cooling towers up to 200 meters tall). These characteristics generate public opposition, create vulnerability to natural disasters and military/terrorist attack, and limit siting options to remote areas far from load centers.

Historical incidents — Chernobyl (1986), Three Mile Island (1979), Fukushima Daiichi (2011) — have demonstrated that conventional designs are vulnerable to cascading failures, particularly loss-of-coolant accidents where active pumping systems fail. In all major incidents, the fundamental failure was inability to maintain cooling when external power or mechanical systems were compromised.

Emerging Small Modular Reactor (SMR) designs such as NuScale, Rolls-Royce SMR, and BWRX-300 address some concerns through reduced scale and factory fabrication, but remain surface-mounted, visually prominent, and vulnerable to external threats. No current design offers complete underground containment with passive flood-to-entomb emergency response.

DeepCore Power addresses these limitations through a fundamentally different architectural approach: placing the entire nuclear island underground beneath an artificial lake, using the water body itself as both thermal management medium and ultimate safety containment.

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2. System Architecture

2.1 Concentric Toroidal Ring Configuration

Each DeepCore module consists of three concentric toroidal rings excavated and constructed beneath the lake bed at a depth of approximately 8 to 15 meters below the lake floor:

- **Ring 1 — Reactor Core** (innermost): diameter ~3-4 meters. Contains the nuclear reactor vessel, primary coolant loop, and control rod mechanisms. Sealed within a reinforced containment dome.
- **Ring 2 — Steam Generator** (middle): diameter ~10-12 meters. Houses the primary-to-secondary heat exchanger where radioactive primary coolant transfers thermal energy to the clean secondary water loop without mixing.
- **Ring 3 — Condenser** (outer): diameter ~18-20 meters. Contains the condensation system where expanded steam from the turbines is cooled back to liquid water for recirculation.

Annular service corridors (element 18 in figures) provide maintenance access between rings. All primary radioactive systems are confined within Rings 1 and 2; the secondary circuit (Ring 3, turbine hall, and condenser) carries only non-radioactive steam and water.

2.2 Dual Thermal Circuit

The system operates on a simplified dual-circuit Rankine cycle. The primary circuit contains potentially radioactive coolant circulating between the reactor core and steam generator, completely sealed underground. The secondary circuit carries clean, non-radioactive steam from the steam generator up to surface turbines and back down through the condenser. This separation ensures that no radioactive material reaches the surface under any normal operating condition.

2.3 Surface Infrastructure

Above ground, the only visible structures are the turbine hall (element 5), administrative buildings (elements 14-16), and the artificial lake itself. The turbine hall houses two turbine-generator sets (element 5a/5b) per module. Steam arrives via vertical shafts from the underground steam generator and returns as condensate. A dedicated radioactive material reception area (element 6) and underground storage/recycling vaults (elements 7a/7b) handle fuel logistics via shielded elevators (element 19).

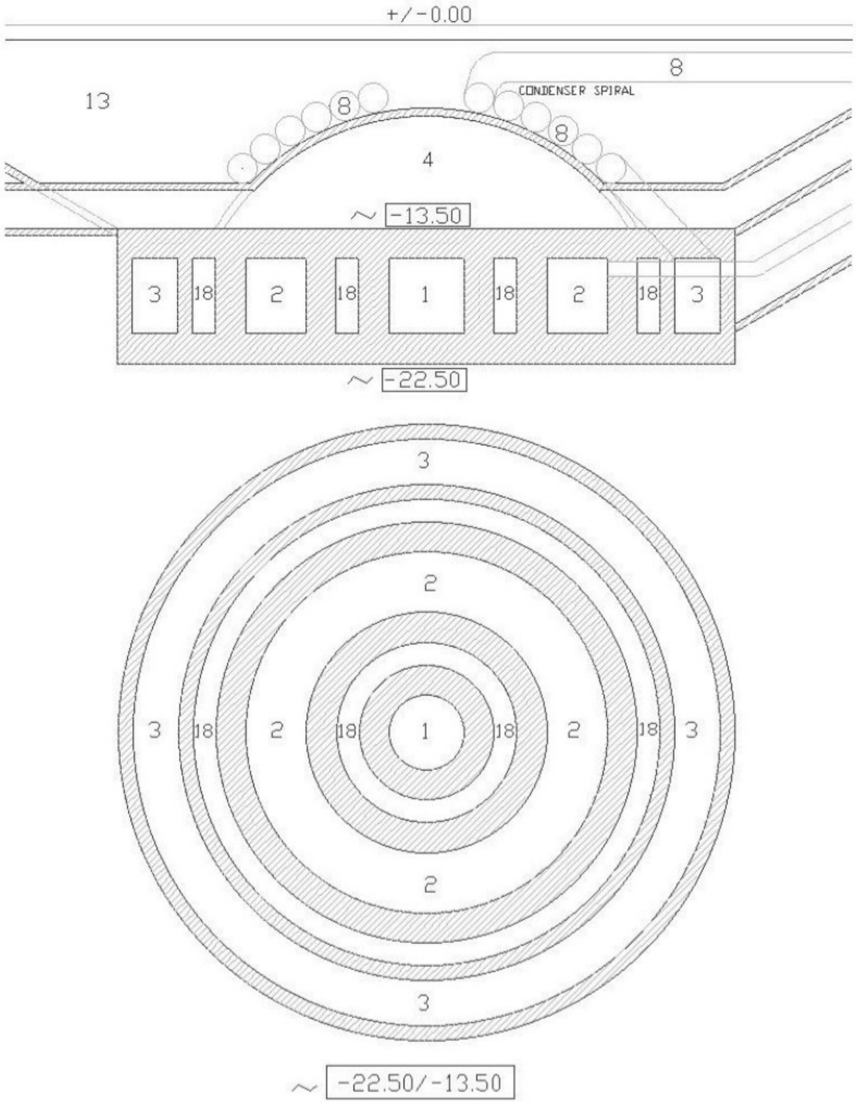

Figure 1. *Cross-section (top) and plan view (bottom) of a single DeepCore module. Numbers 1-3 indicate the concentric rings: reactor core (1), steam generator (2), and condenser (3). Element 4 is the reactor containment dome. Element 8 shows the condenser spiral on the lake bed. Depth range: -8m to -15m below lake surface.*

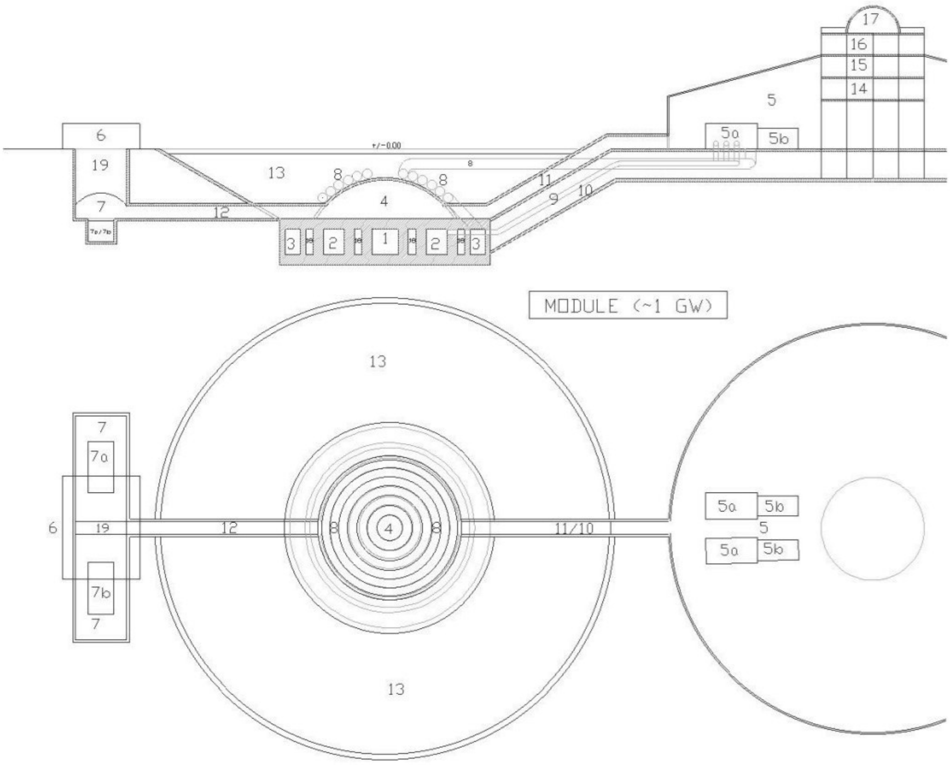

Figure 2. *Complete single-module facility (~50 MW) showing plan and cross-section. Includes turbine hall (5), radioactive material reception (6), storage vault (7a), recycling facility (7b), steam circuit (9), technical tunnel (10), access tunnel (11), radioactive material tunnel (12), artificial lake (13), and administrative areas (14-17).*

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3. Modular Scalability

DeepCore modules are designed as independent units that can be clustered on a single site. Each module has its own lake (or shared lake body), reactor, and underground infrastructure, while sharing surface facilities such as turbine halls, transmission equipment, and administrative buildings.

Modules can be operated, maintained, and refueled independently. One module can be shut down for maintenance while others continue operating. Control systems are interconnected but capable of autonomous operation per module.

Configuration	Modules	Electrical Output	Typical Application
Single	1	50 MW	Military base, remote mine, small island
Dual	2	100 MW	Medium city district, industrial zone
Triple	3	150 MW	Large industrial complex, data center campus
Quad	4	200 MW	Regional power supply

Configuration	Modules	Electrical Output	Typical Application
Full cluster	5	250 MW	Major city (e.g., Granada, Cyprus, Singapore district)

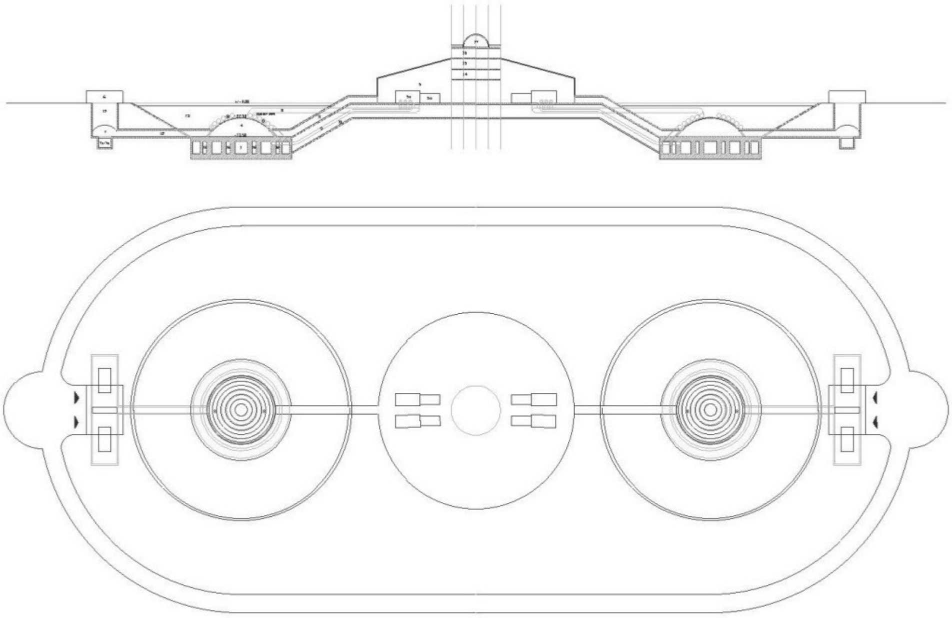

Figure 3. *Dual-module configuration (~100 MW) — plan and cross-section views. Modules share surface infrastructure while maintaining independent underground systems.*

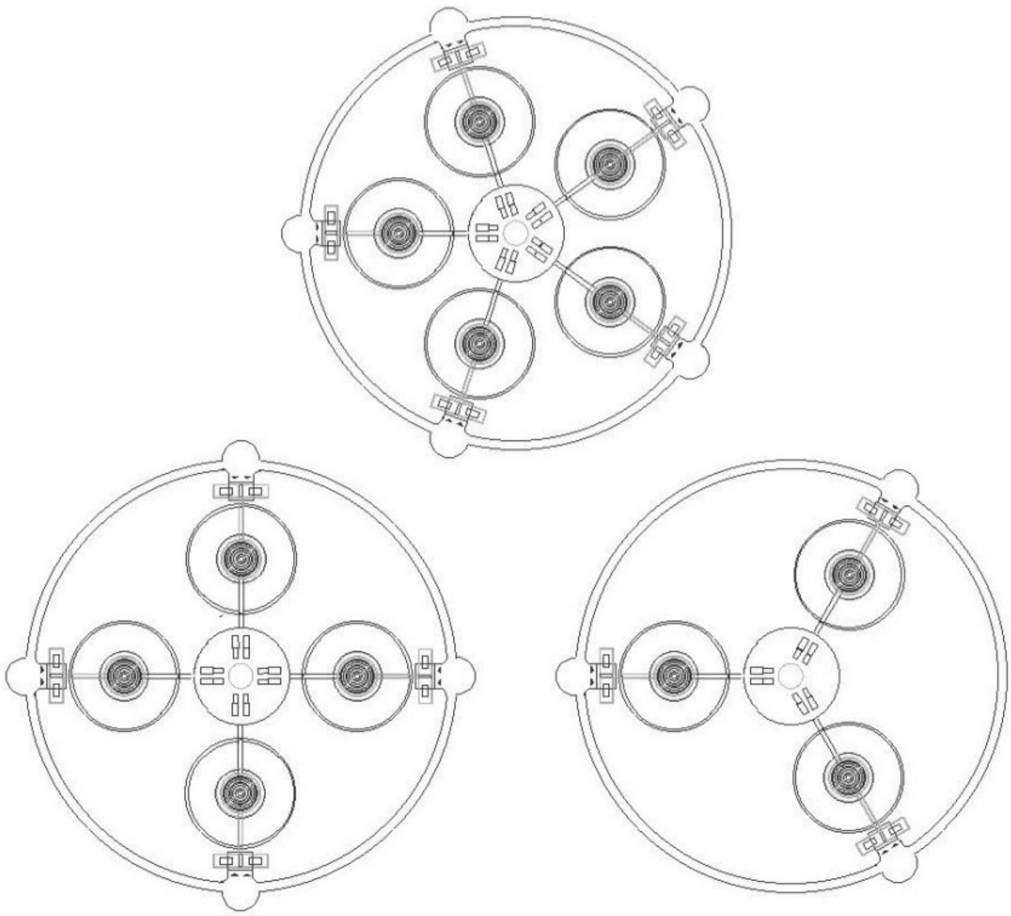

Figure 4. *Multi-module cluster configurations: 5 modules (~250 MW, top), 4 modules (~200 MW, bottom left), 3 modules (~150 MW, bottom right). Circular containment perimeter encloses shared infrastructure.*

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4. Passive Safety System

4.1 Inherent Safety by Design

DeepCore's safety philosophy inverts the conventional approach. Rather than designing systems to prevent water from reaching the reactor (as in surface plants), DeepCore places the reactor inside a water body and designs the ultimate emergency response as controlled flooding.

Under normal operation, the reactor dome (element 4) seals the reactor chamber from the lake above. The concentric ring structure provides multiple containment barriers. The lake water serves as a permanent, passive thermal buffer requiring no active pumping.

4.2 Dome-Breach Flooding Mechanism

In the event of a core meltdown or loss-of-coolant accident, redundant automated systems activate sacrificial valves in the reactor dome, allowing lake water to flood the reactor chamber. This achieves several simultaneous safety objectives:

- Immediate quenching of the molten core with thousands of cubic meters of water
- Containment of all radioactive material within the sealed underground toroidal structure
- Zero atmospheric release — contaminated water has no path to the surface
- Self-sealing sarcophagus — the flooded underground chamber becomes permanent containment

This mechanism directly addresses the failure mode observed at Fukushima Daiichi, where active pumping systems failed after the tsunami disabled backup power. In DeepCore, the water supply is gravity-fed from the lake above — no pumps, no external power, no human intervention required.

4.3 Additional Safety Features

- **Physical attack resistance:** All critical components are buried underground beneath a water body, providing natural shielding against aerial attack, missile strike, and ground-level sabotage.
- **Seismic considerations:** Underground structures generally experience reduced seismic acceleration compared to surface structures. The toroidal ring geometry distributes loads uniformly.
- **Localized contamination:** Even in worst-case scenarios, radioactive contamination is confined to the sealed underground chambers and the contained lake. No public evacuation required.

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5. Adaptive Cooling Subsystem

A 50 MW electrical module at approximately 33% thermodynamic efficiency produces ~150 MW of thermal energy, rejecting approximately 100 MW of waste heat. Managing this heat is the primary engineering challenge. DeepCore addresses this through a modular, site-adaptive cooling interface with four selectable configurations:

5.1 Option A — Passive Lake Cooling

The condenser spiral (element 8) sits on the lake bed, transferring waste heat directly into the lake water. The lake surface dissipates heat through evaporation, convection, and radiation. For a 50 MW module, a lake of approximately 500-600 meters diameter and 10-12 meters depth provides adequate thermal capacity in wet climates where rainfall partially compensates evaporative losses. Best suited for northern Europe, tropical regions, or any location with reliable precipitation.

5.2 Option B — Underground Air-Cooled Condensers (ACC)

Large underground chambers house air-cooled condenser arrays — finned metal radiators with forced or natural draft ventilation. Air enters through disguised intake vents (shaped as natural rock formations or landscape features) and exits warm through separate exhaust vents. For 100 MW waste heat, approximately 15,000-20,000 m^2 of fin surface area is required. The lake shrinks to ~200 meters diameter, serving only as emergency flooding reserve. Best suited for arid regions, deserts, or military installations requiring zero water consumption.

5.3 Option C — Underground Evaporative Tunnel

A TBM-bored spiral tunnel (~6 meters diameter, 3-5 km length) at 15-20 meters depth houses condenser pipes with internal spray nozzles. Lake water is sprayed onto condenser surfaces, evaporating and removing heat through latent heat absorption. Forced air circulation carries humid exhaust to surface vents. Requires water replenishment (~4,000 m^3/day for 50 MW) from external source. Suitable for coastal sites with seawater access.

5.4 Option D — Cogeneration Heat Extraction

Waste heat is piped to productive uses: district heating, seawater desalination, industrial process heat, greenhouse agriculture, or aquaculture. This can absorb 50-80% of waste heat, drastically reducing cooling infrastructure requirements. The lake can be as small as 100-200 meters diameter. Best suited for urban/industrial deployments where heat has economic value.

Enhanced condensation: All configurations benefit from internal copper or alloy mesh structures within condenser pipes, promoting dropwise condensation (5-10x improvement in steam-side heat transfer) and enabling more compact condenser designs with reduced excavation volumes.

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6. Thermal Engineering Analysis

6.1 Energy Balance (50 MW Module)

Parameter	Value	Notes
Thermal power	~150 MW	Reactor output
Electrical output	50 MW	33% Rankine cycle efficiency
Waste heat	~100 MW	Must be rejected to environment
Working fluid volume	~50-100 m^3	Closed loop, never consumed
Cooling water evaporation	~1,600 m^3/day	If passive lake cooling (Option A)

6.2 Lake Sizing (Option A — Passive Cooling)

Atmospheric heat dissipation from a lake surface occurs primarily through evaporation (~60%), convection (~25%), and long-wave radiation (~15%). Under typical conditions, a lake surface dissipates 300-400 W/m^2 with a 15-20 degrees C temperature differential above ambient.

For 100 MW waste heat: required surface area = 100,000,000 W / 350 W/m^2 = ~286,000 m^2, corresponding to a circular lake of ~600 meters diameter. At 10 meters depth, this provides ~22 million m^3 of thermal buffer — sufficient to absorb transient load changes without dangerous temperature spikes.

6.3 Comparative Water Consumption

All thermal power plants consume water for cooling. DeepCore's consumption is identical to conventional plants per MW but managed within a contained system with no river thermal pollution or contamination risk:

Plant Type	Cooling Method	Water Use (L/MWh)	Contamination Risk
Conventional PWR	River once-through	100,000-150,000	Thermal + radioactive
Conventional PWR	Cooling tower	2,000-3,000 (evap.)	Thermal (airborne)
NuScale SMR	Air-cooled condenser	~0 (dry)	None
DeepCore (Option A)	Contained lake	~2,500 (evap.)	None (contained)
DeepCore (Option B)	Underground ACC	~0 (dry)	None
DeepCore (Option D)	Cogeneration	~500 (reduced)	None

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7. Comparison with Existing Nuclear Technologies

Feature	Conv. PWR (AP1000)	NuScale SMR	Rolls-Royce SMR	Russian AKU	DeepCore Power
Output (MWe)	1,117	77/module	470	70	50/module
Location	Surface	Surface	Surface	Floating barge	Underground
Visible footprint	Large	Medium	Medium	Large (ship)	Minimal (lake)
Passive cooling	Partial	Yes	Partial	Seawater	Yes (multiple options)
Meltdown containment	Containment bldg	Pool immersion	Containment bldg	Hull flooding	Dome-breach flooding
Attack resistance	Low	Low	Low	Low (ship target)	High (underground)
Zero atm. release	Not guaranteed	Partial	Not guaranteed	Not guaranteed	By design
Reactor agnostic	No (PWR only)	No (PWR)	No (PWR)	No (PWR)	Yes (any reactor)
Fuel cycle integration	External	External	External	External	Integrated on-site
Scalable clustering	No	Yes (up to 12)	No	No	Yes (up to 5)
Cogeneration ready	Limited	Limited	Limited	Limited	Integrated option

8. Economic Analysis

8.1 Capital Expenditure (CAPEX) — Single 50 MW Module

Component	Estimated Cost (EUR M)	Notes
Reactor vessel + nuclear island	80 - 120	Factory-fabricated SMR vessel
Underground excavation + civil works	60 - 90	Toroidal rings, tunnels, dome
Lake construction	15 - 30	Excavation, lining, filling
Turbine hall + generators	25 - 40	2x 25 MW turbine-generator sets
Cooling subsystem	20 - 40	Varies by option (A/B/C/D)
Fuel storage + handling	15 - 25	Underground vaults, elevator, shielding
Control systems + instrumentation	10 - 20	Redundant automated systems
Licensing + engineering	20 - 35	Site-specific regulatory approval
TOTAL per module	**245 - 400**	**EUR 4.9 - 8.0 M/MW installed**

8.2 Operating Expenditure (OPEX)

Item	Annual Cost (EUR M)	Notes
Fuel (enriched uranium)	3 - 5	18-24 month refueling cycle
Operations staff (30-50 FTE)	3 - 5	Reduced vs conventional (automated)
Maintenance + inspection	2 - 4	Scheduled subsurface access
Insurance + regulatory	2 - 3	Lower risk profile may reduce premiums
Decommissioning fund	1 - 2	Annual provision
TOTAL annual OPEX	**11 - 19**	

8.3 Revenue and ROI

A 50 MW module operating at 90% capacity factor produces ~394 GWh/year. At an average wholesale electricity price of EUR 60-80/MWh (European average 2024-2025), annual revenue is approximately EUR 24-32 million. With annual OPEX of EUR 11-19 million, net operating income is EUR 5-21 million/year.

Simple payback period: 12-25 years depending on construction costs and electricity prices. With cogeneration revenue (heat sales for district heating, desalination), payback can be reduced to

10-18 years. Plant design lifetime: 40-60 years, yielding substantial lifetime value.

8.4 LCOE Comparison

Technology	LCOE (EUR/MWh)	Source
Conventional nuclear (new build)	65 - 120	IEA/OECD 2024 estimates
NuScale SMR (projected)	70 - 100	Company projections
Onshore wind	30 - 55	IRENA 2024
Solar PV (utility)	25 - 50	IRENA 2024
Natural gas CCGT	50 - 80	IEA 2024
DeepCore Power (projected)	75 - 130	Author estimate, first-of-kind premium
DeepCore + cogeneration	55 - 90	With heat revenue offset

First-of-a-kind (FOAK) costs are expected to be at the high end. Series production of standardized modules would drive costs toward the lower range through learning curves and factory fabrication, following the trajectory projected for other SMR designs.

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9. Integrated Fuel Cycle Management

Unlike conventional plants that rely on external fuel transport and off-site spent fuel storage, DeepCore integrates the complete fuel cycle within the facility:

- **Fresh fuel reception** (element 6): surface-level reception area with shielded elevator (element 19) for transfer to underground storage vaults
- **Fresh fuel storage** (element 7a): underground vault adjacent to the reactor module
- **Spent fuel processing** (element 7b): optional pyrochemical reprocessing facility for partial fuel recycling, reducing waste volume and extending fuel utilization
- **Long-term waste storage**: dedicated underground chambers for vitrified high-level waste, benefiting from the same geological containment as the reactor

This integration eliminates the security risks and logistics costs associated with nuclear fuel transport on public roads, and enables potential transition to closed fuel cycles as MSR or fast reactor technology matures.

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10. Reactor Technology Compatibility

The DeepCore architecture is explicitly designed as a reactor-agnostic platform. The concentric ring layout, dual-circuit thermal design, and underground containment can accommodate any current or emerging reactor technology with appropriate engineering adaptation:

Reactor Type	Adaptation Notes	Efficiency
PWR (Pressurized Water)	Direct compatibility, most mature technology	31-33%
BWR (Boiling Water)	Single-circuit possible, simplified piping	32-34%
SMR (Small Modular)	Factory-fab reactor vessel fits Ring 1 directly	31-33%
MSR (Molten Salt)	Higher temperatures, special materials for Ring 2	42-45%
LMFR (Liquid Metal Fast)	Sodium/lead coolant, enhanced secondary shielding	38-42%
HTGR (High Temperature Gas)	Helium primary circuit, suited for cogeneration	40-47%

MSR and HTGR technologies are particularly promising for DeepCore as their higher operating temperatures (600-900 degrees C vs 300 degrees C for PWR) improve thermodynamic efficiency to 42-47%, significantly reducing waste heat and thus cooling infrastructure requirements. A 50 MW MSR-based DeepCore module would reject only ~60-70 MW of waste heat versus ~100 MW for a PWR-based module, enabling proportionally smaller lakes or ACC installations.

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11. Hybrid Renewable Integration

The artificial lake surface provides an opportunity for floating solar photovoltaic (PV) installation. Approximately 30-40% of the lake surface can be covered with floating PV arrays (higher coverage reduces evaporative cooling capacity). For a 600m diameter lake, this yields approximately 85,000-113,000 m^2 of PV surface, generating 12-17 MW peak solar power.

The floating PV serves multiple functions: auxiliary power generation (reducing parasitic loads during construction and startup), evaporation reduction (extending lake water autonomy), and visual screening (reducing visibility of the lake surface from aerial observation).

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12. Target Applications

- **Defense and military installations:** Invisible, hardened baseload power for bases, command centers, radar installations. Attack resistance is a primary differentiator.
- **Island nations and territories:** Energy independence for Singapore, Cyprus, Malta, Pacific islands. Combined with desalination for water security.
- **Remote industrial sites:** Mining operations, Arctic/Antarctic stations, offshore platforms requiring independent power supply.
- **Urban cogeneration:** Electricity + district heating for dense cities, with minimal surface footprint. Particularly relevant for cold-climate cities.
- **Data center campuses:** Guaranteed 24/7 baseload for hyperscale computing facilities requiring 50-200 MW with high reliability.

• **National grid backbone:** Clustered modules providing 100-250 MW as dispatchable baseload complementing variable renewable generation.

13. Construction Methodology

Construction follows a dry-excavation sequence. The site is excavated to full depth using conventional or AI-piloted heavy machinery operating from blueprints. The toroidal ring structures and reactor containment dome are built in situ from reinforced concrete with steel liner. The reactor vessel (factory-fabricated) is installed before the dome is sealed.

Once the underground structure is complete and sealed, the excavation is backfilled and the artificial lake is created by flooding from an external water source. Service tunnels (elements 10, 11, 12) provide permanent subsurface access for operations and maintenance without disturbing the lake.

The modular nature of the design allows phased construction: a first module can begin generating power while additional modules are under construction on the same site.

14. Drawing Legend

#	Element	#	Element
1	Reactor core	11	Access tunnel
2	Steam generator (toroidal)	12	Radioactive material tunnel
3	Condenser (toroidal)	13	Artificial lake
4	Reactor containment dome	14	Technical staff quarters
5	Turbine hall	15	Engineering offices
5a	Turbines	16	Control center
5b	Generators	17	Amenity terrace
6	Radioactive material reception	18	Service and maintenance corridors
7	Radioactive material vault	19	Radioactive material elevator
7a	Fresh fuel storage		
7b	Spent fuel recycling		
8	Condenser spiral		
9	Pressurized steam circuit to turbines		
10	Technical tunnel		

15. Conclusions

DeepCore Power presents a fundamentally new architectural approach to nuclear power generation that addresses the primary obstacles to nuclear energy adoption: public safety concerns, vulnerability to attack and natural disaster, visual impact, and radioactive contamination risk.

By placing the entire nuclear island underground beneath an artificial lake and designing the ultimate emergency response as controlled flooding rather than active intervention, the architecture eliminates the failure modes that caused every major nuclear incident in history. The dome-breach flooding mechanism ensures zero atmospheric release under any conceivable scenario, including simultaneous earthquake, tsunami, and total loss of external power.

The modular design (50 MW per module, scalable to 250 MW) with adaptive cooling subsystems makes the concept deployable across diverse climates and applications — from arid military installations to urban cogeneration to island energy independence.

This disclosure is published as prior art to ensure the DeepCore architecture remains available for open implementation by any government, organization, or entity pursuing safer, more resilient nuclear energy infrastructure.

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