Emerging Lead-cooled Fast Reactor (LFR)
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Enhanced Safety of Lead-cooled Fast Reactors derived from 80 reactor-year operating experiences of 15 reactors including seven (7) “Alfa Class Submarines”

Accident by
- Internal
- External

- Inert (no H2)
- Neg. Pressure
- FP Retention

B.P. = 1743 C
Nat. Circulation
\( \rho(\text{Pb}) \sim \rho(\text{UO}_2) \)

- Dry-out
- Melt-down

- Recriticality

- Hydrogen
- Explosion

- Off-site Rad.
- Release

Lead-Bismuth cooled reactor: Successful experiences of “Lira”

“Lira” (NATO name Alfa) 
~ 41 knots (~76 km/hr)

GIF Roadmap 2013
Innovative and Ready Materials (FeCrSi, FeCrAl)

- Corrosion-resistant cladding on Code-Certified Materials
- S.G. Tubing → Double-wall → Leak-Before-Break (LBB)
- Coolant Chemistry Management (impurity, particles)
- Employing pure Lead (Pb) to suppress Polonium-210

**Corrosion rate of test alloys in LBE at 600°C**

- **11Cr (HT9)**
- **MIT**

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Fe₃O₄ (Fe, Cr, Al)
(Cr, Al) oxide
Al₂O₃

11Cr-2.5Al-0.9Nb
(Alloy-1b, 1c, 1d)

14Cr-2.5Al-0.9Nb
(Alloy-1f)
Zero-radius Emergency Planning Zone (EPZ)

- Underground LFR ➔ Security and Seismic Resistance
- No Steam Generator Tube Rupture by Leak-Before-Break
- Main Steam Line Break ➔ Negative Reactor Pressure
- No Radiation Release ➔ All Coal Plant Sites are Suitable for LFR

Lucens UNPP (1969)

Solar & Wind Above Ground & On Harbor

Hybrid Modular Reactor Underground
Market Attractiveness of Underground LFR

- High Steam Temperature $\rightarrow$ Coal Plant BOP can be Reused.
- Large Thermo-Mechanical Margin $\rightarrow$ Load Follow for Renewables
- 30 year life for reactor and fuel $\rightarrow$ No Refueling Cost
- Economies of Multiples & Low Financial Risk

Diagram: Serial Production and Economics (1)

- At least 15% for second-of-a-kind plant
- At least 5% for each n-th-of-a-kind plant

Mathematical representation for cost reduction:
- $\text{Cost} = f(\text{Plant number})$
- $\text{Demand} = \text{Supply SMR}$

Market Friendliness

Large Unit
Security, Safeguards, Sustainability & Wastes

- Underground Rugged Facility ➔ Security
- No On-site Refueling or Spent Nuclear Fuel Storage ➔ Safeguards
- Initial <20% U-235 ➔ Future Recycled TRU Fuel ➔ Sustainability
- Recycling: Future Multinational Cooperatives ➔ No HLW produced!

“CRADLE-TO-GRAVE”
- IFNEC (OECD/NEA-USA)
- INPRO (IAEA-RF)

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