Fission-Fusion Hybrids: Proposed Advantages and Potential Concerns

LIFE	**Proposed advantages relative to LWRs**	**Potential concerns**
Mission	Extend resources, burn SNF.	Takes long time to burn SNF.
Safety	Subcritical thermal.	Fusion-driven failure modes, loss of fission blanket cooling.
Waste	Reduced requirement for actinide disposal.	Requires geological storage.
Proliferation	No enrichment, no multi-cycle reprocessing. Reduced long-term Pu storage.	Many fission fuel spheres and significant fuel handling. Covert diversion, breakout from safeguards.
Economics		Fusion system is 20% of total power.
Development Needs (not relative to LWRs)	Can use gain ~ 20 IFE systems.	Needs all other IFE development, incl. up to 5MW/m^2 neutron wall loading. Needs new fission fuel & coolant.

UT System	**Proposed advantages relative to LWRs**	**Potential concerns**
Mission	Burn TRU and possibly long-lived fission products in SNF.	Does not extend resources significantly.
Safety	Subcritical fast spectrum.	Fusion-driven failure modes, loss of fission blanket cooling.
Waste	Greatly reduced requirement for actinide disposal.	Requires geological storage.
Proliferation	Reduced reprocessing. Little long-term Pu storage.	Clandestine enrichment, reprocessing (theft), covert diversion, breakout from safeguards.
Economics		Fusion system is < 0.5% of total power, fast spectrum blanket is ~ 5%.
Development Needs (not relative to LWRs)	Can use Gain = 1-2 fusion systems with 0.5 – 1 MW/m^2 neutron wall loading.	Needs substantial MFE R&D. Needs IMF fuel, fast spectrum blanket.

Fuel Breeding + LWRs	**Proposed advantages relative to LWRs**	**Potential concerns**
Mission	Extend resources.	Does not transmute legacy SNF.
Safety	No significant fission chain reaction.	
Waste	Th 232 cycle reduces TRU's.	Requires large geological storage.
Proliferation	No enrichment, high U232/U233 after long irradiation times allowing Pa231 to build up.	Covert diversion of U233, breakout from safeguards.
Economics		Fusion system is <10% of total power.
Development Needs (not relative to LWRs)	Can use gain = 5 fusion systems.	Needs substantial MFE and/or IFE R&D, with neutron wall loading ~ pure fusion. Needs integrated fission-suppressed blanket.

Fast Reactors	**Proposed advantages relative to LWRs**	**Potential concerns**
Mission	Burn SNF, extend resources.	
Safety	Sodium-cooled fast reactors' inherent safety characteristics project to low probability of severe accidents.	Chemical reactivity of sodium. Hypothetical core dispersal accident.
Waste	Greatly reduced requirement for actinide disposal.	Requires geological storage.
Proliferation	No enrichment. Little long-term Pu storage.	Multi-cycle reprocessing (theft), covert diversion, breakout from safeguards.
Economics		Fast reactors ~ 1/3 of total power both to burn SNF and extend resources.
Development Needs (not relative to LWRs)	Significant experience base.	Difficulties with FRs in the past. Structural materials lifetime. TRU fuel development required for waste burning.

Deep Burn Thermal Reactors	Proposed advantages relative to LWRs	Potential concerns
Mission	Burn SNF, provide high-temperature heat, extend resources.	Partial transmutation of TRUs, limited extension of resources.
Safety	Ceramic fuel has large thermal margins; strongly negative temperature reactivity feedback; passive decay heat removal (helium coolant).	Air or steam ingress (helium coolant), containment may be too expensive.
Waste	Reduced requirement for actinide disposal.	Requires large geological storage.
Proliferation	High discharge burn up minimizes reprocessing.	Reprocessing of LWR SNF. Pebble fuel involves many spheres and significant fuel handling. Covert diversion, breakout from safeguards.
Economics	High temperature improves efficiency, enables alternate applications. Fluoride cooled reactors have high power density.	Helium-cooled reactors have low power density.
Development Needs (not relative to LWRs)	Modular helium reactors have substantial maturity and current development activity.	Deep burn fuel fabrication requires substantial development. Fluoride cooled reactor designs (similar to LIFE concept) exist only at conceptual level.

Pure Fusion	Proposed advantages relative to LWRs	Potential concerns
Mission	Extend resources.	Does not transmute legacy SNF.
Safety	No criticality, low afterheat.	Low enough radiological inventory to assure no need for an evacuation plan?
Waste	No geological storage.	Significant low-level waste.
Proliferation	No credible risk of clandestine production facilities, nor covert diversion from declared facilities. No weapons-usable material at breakout from safeguards, plant can then be disabled without spread of radioactivity.	1 SQ can be produced in ~ 2 months after breakout from safeguards (*vs.* 100's of SQ available immediately at breakout from safeguards in fission systems).
Economics		Fusion is 100% of power.
Development Needs (not relative to LWRs)	Much work underway internationally.	Need to develop full MFE and/or IFE technologies.

Light Water Reactors Once Through	Advantages	Potential concerns
Mission	Economic base load electricity production.	SNF generation; sustainability of fuel supply.
Safety	Extensive experience base. Licensed facilities.	Loss of reactor coolant.
Waste		Requires large geological storage.
Proliferation	No reprocessing.	Clandestine enrichment. Breakout from enrichment and SNF safeguards. Long-term Pu in repositories.
Economics	Provides current baseline.	Uncertain long term cost of fuel.
Development Needs	Well-understood commercial systems with high availability.	Manufacturing capacity, availability of skilled workforce.