Energy Multiplier Module (EM^2) – Capping the Waste Problem and Using the Energy in U-238

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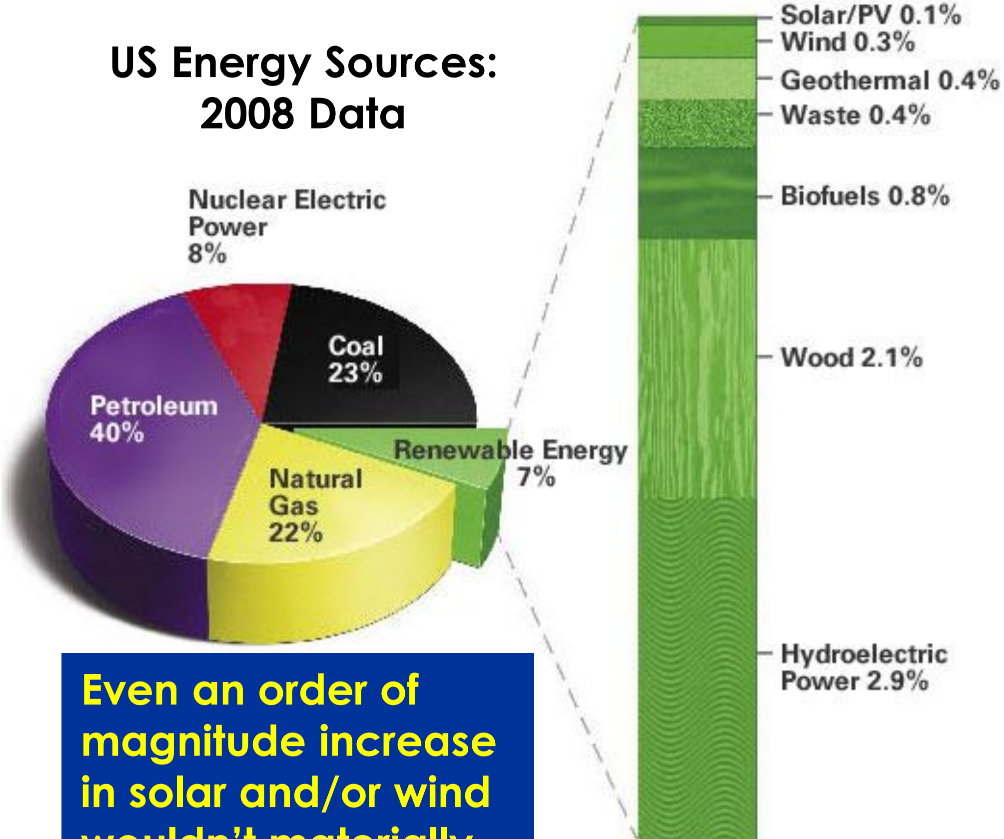
Framing the Problem of National Energy Security

US Energy Sources: 2008 Data

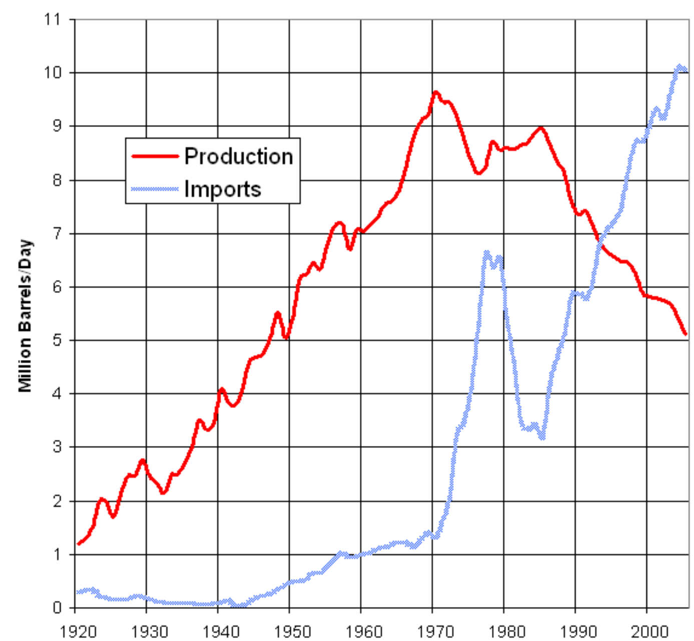


Even an order of magnitude increase in solar and/or wind wouldn't materially change this picture

How much is imported?

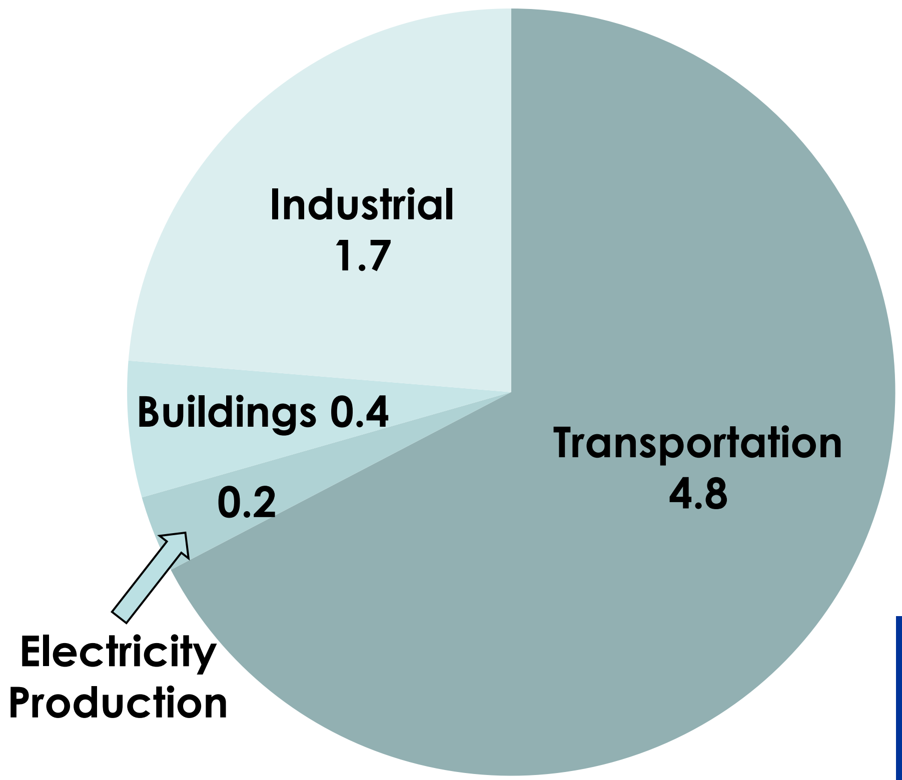
- nuclear/coal/renewable: 0%
- natural gas: 14% (declining)
- petroleum: 60% (rising) **$1B/day**

US Oil Production and Imports



The US posture in world affairs is compromised by reliance on imported oil

How Can US Dependence on Oil be Reduced?

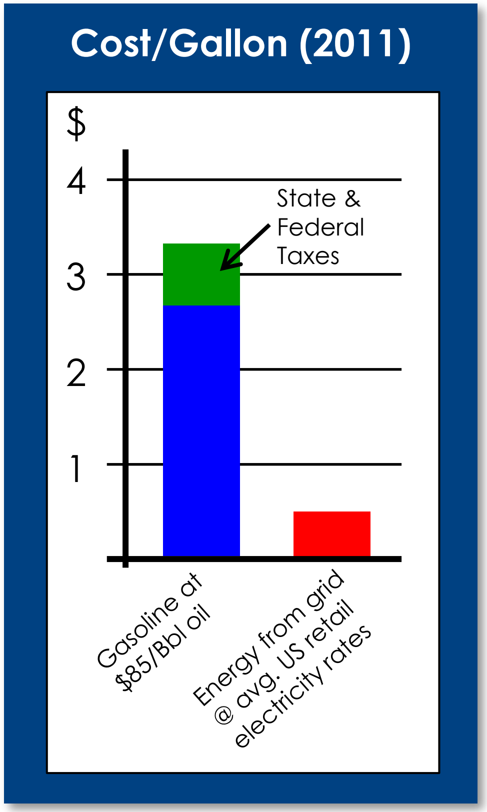


2008 petroleum-based US energy use in billions of barrels of oil equivalent

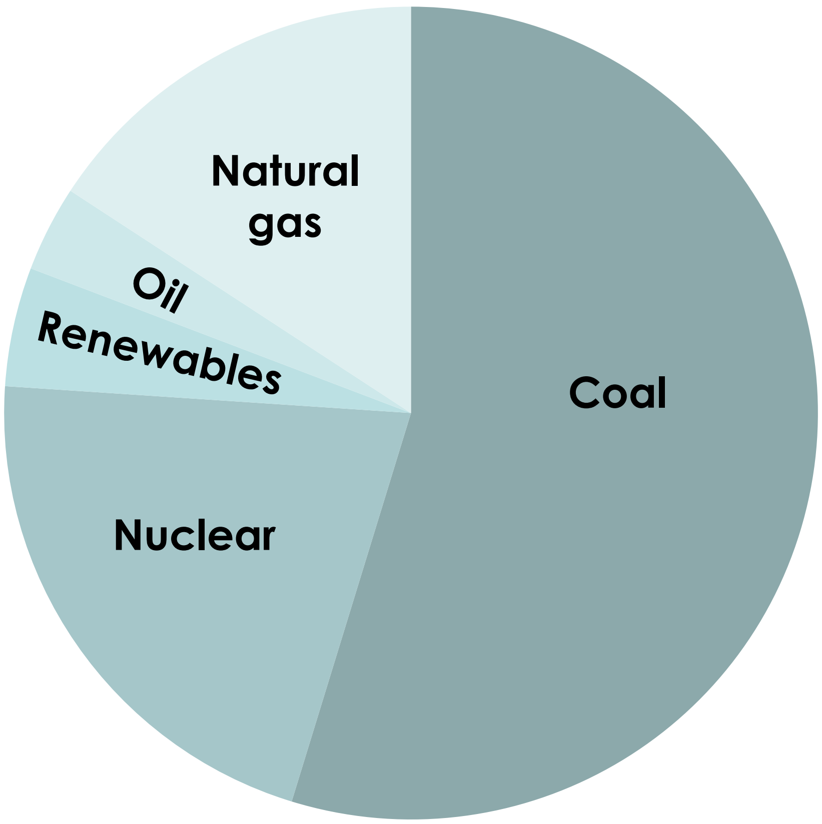
Key: Electrify Transportation

An all-electric vehicle fleet would eliminate the need for oil imports and for wealth transfer to oil exporters

Such a change would require a 20% increase in U.S. electricity production



Options for Expanding US Electricity Production



2008 US Energy Use in Electricity Generation

- **Two options are unappealing**
  - Coal, due to health/environment
  - Oil, owing to energy security
- **New sources of renewables are too expensive (but improving)**
- **The real choices are natural gas and nuclear**
  - These are the two most energy efficient options, so they also reduce overall energy use

Do such options meet long-term national needs?

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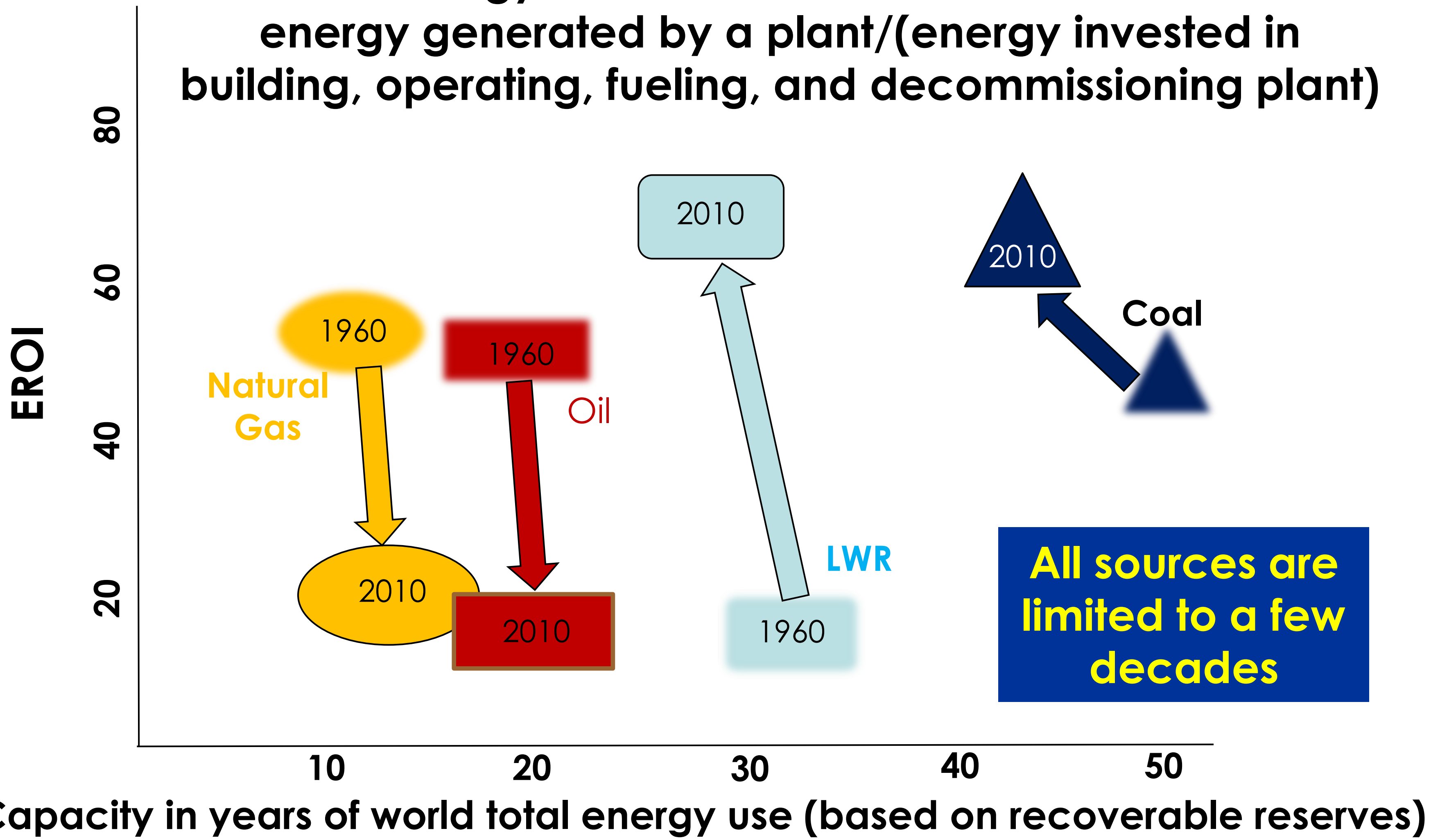
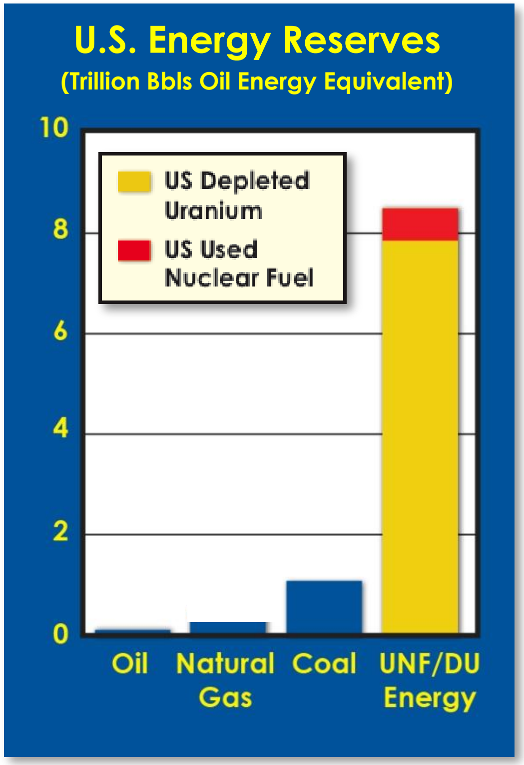
Global 50 Year Trends in Capacity and Energy ROI

Energy return on investment = EROI = energy generated by a plant/(energy invested in building, operating, fueling, and decommissioning plant)

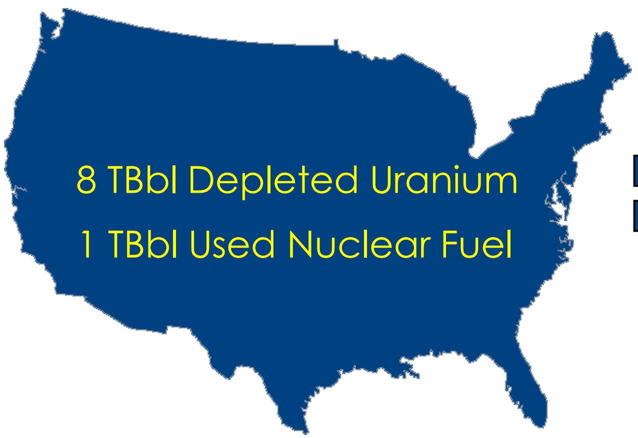


Fission is a Potentially Much Greater Resource

Today's reactors fission only about 0.5% of the uranium nuclei mined. Employing reactors that fission a substantial fraction of the uranium would dramatically expand the resource.



Depleted uranium (DU)/
used nuclear fuel (UNF) inventories



TBbl = Trillion barrels of oil (equivalent)

- Energy supply for > 300 years electric power generation

Reactor concepts in development can extract energy from waste and meet the other requirements for a competitive energy source

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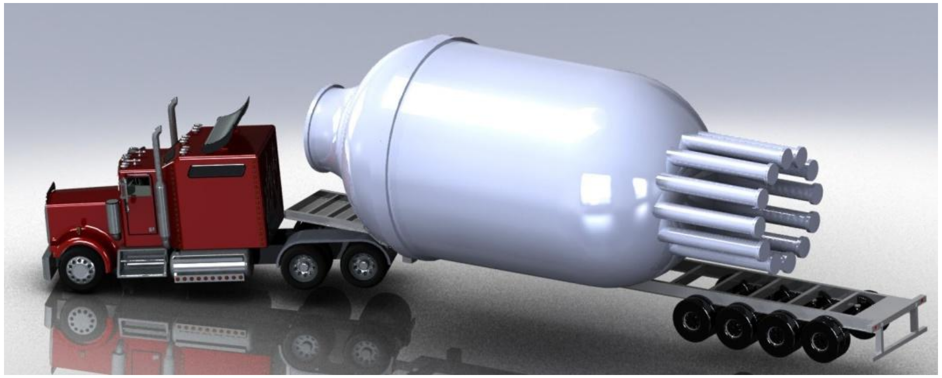
Improving the Competitiveness of Fission Power

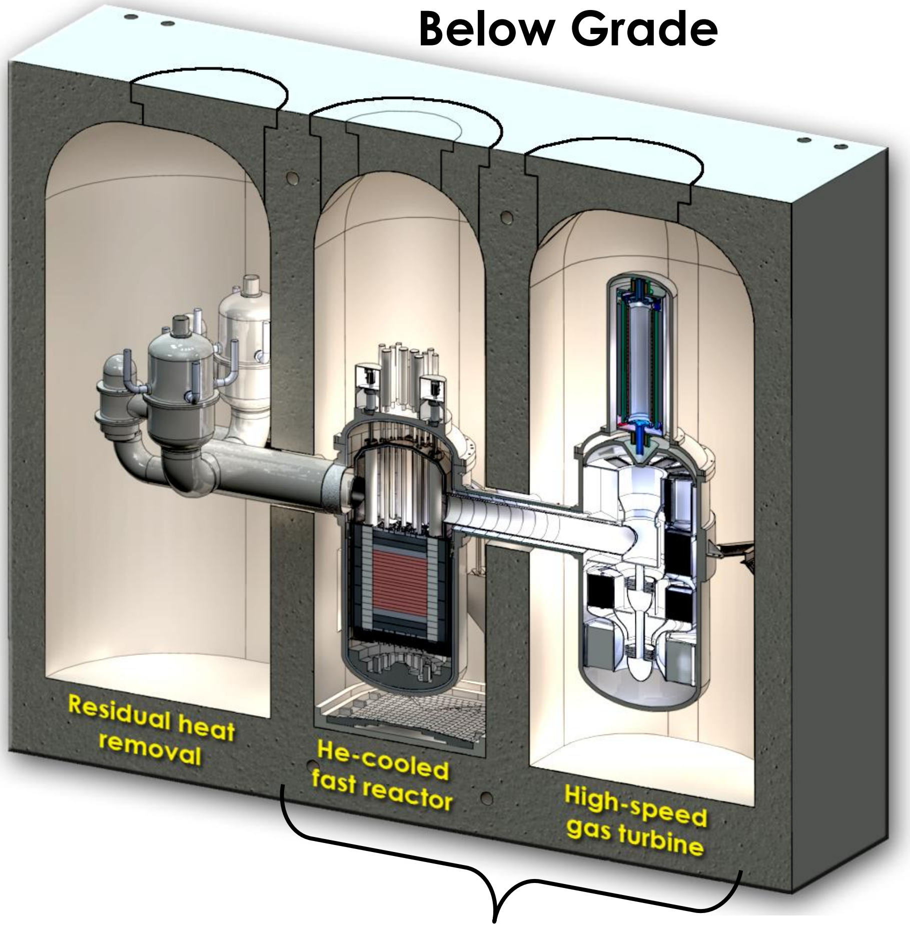
Compact Fast Reactors

- Safe modular reactors that have higher power densities, and therefore reduced material costs per installed kilowatt
- Reactors that operate at much higher temperatures, combined with a high efficiency balance of plant
- Plants that can be mass produced through manufacturing, and that can be shipped by truck to a site for final assembly
- Reactor designs which burn for decades without refueling to maximize fuel utilization and minimize fuel handling (breed and burn reactors)



A Nuclear Technology Responsive to US Energy Needs: EM^2, a 240 MWe Compact Fast Reactor

Below Grade

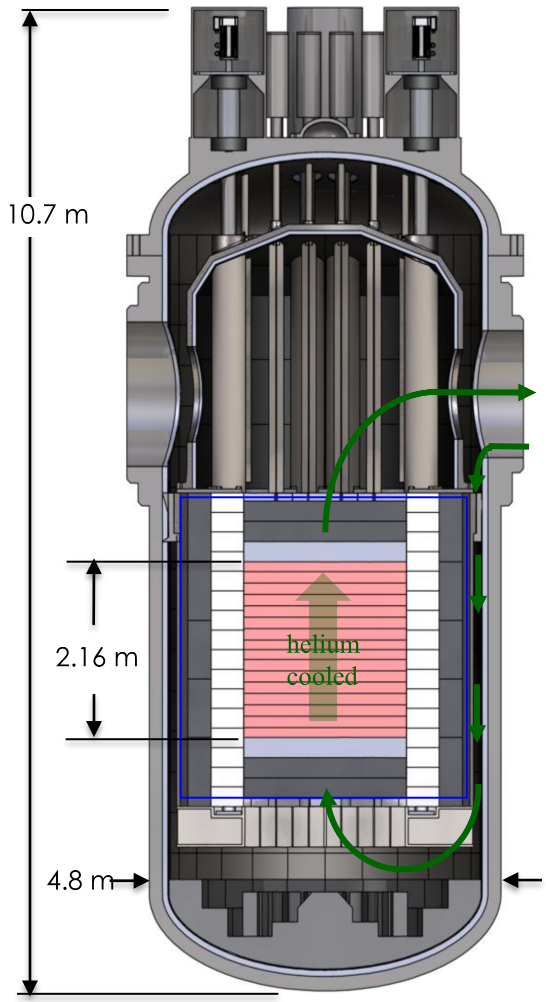


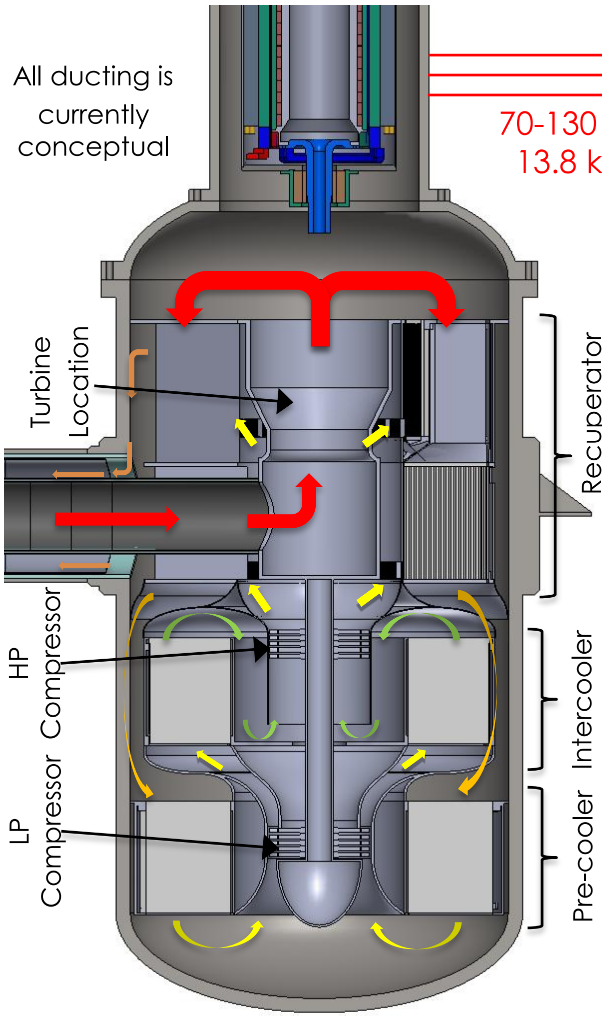
Major Reduction in Capital Cost vs. Baseline LWR

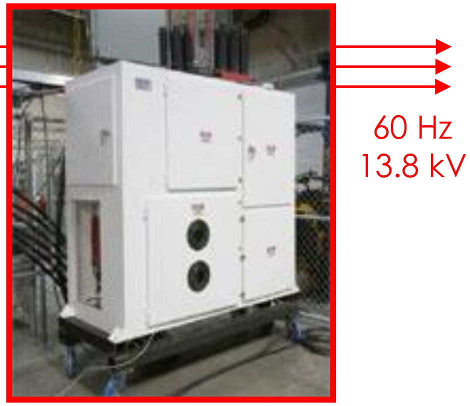
- 30 year fuel cycle without refueling
- Burns depleted uranium or spent fuel
- 50% higher thermal efficiency than LWR
- Small direct-cycle jet turbine generator system
- Factory built, truck transportable modules
- Proliferation risk reduced; no conventional reprocessing
- Passive safety
- Flexible siting

He = Helium
MWe = Megawatts of electricity

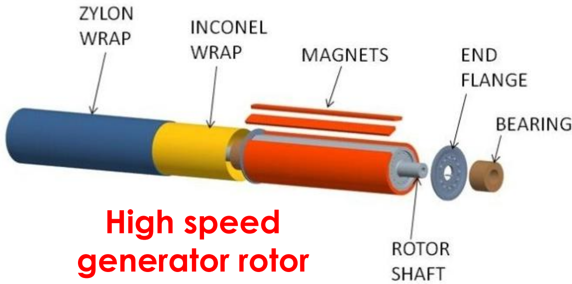
High Temp Reactor Drives a Variable Speed Gas-Turbine for High Efficiency in Small Package







variable input power inverter (>99% efficiency)



High speed generator rotor

Size compatible with factory built units

Thermodynamic Efficiency = 51%

Net Efficiency = 48%

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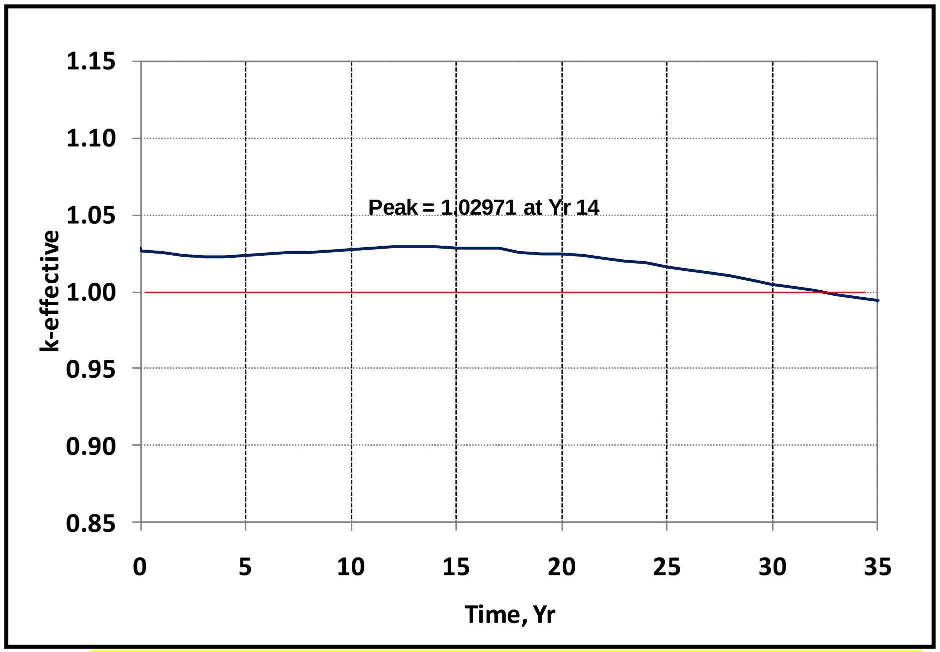
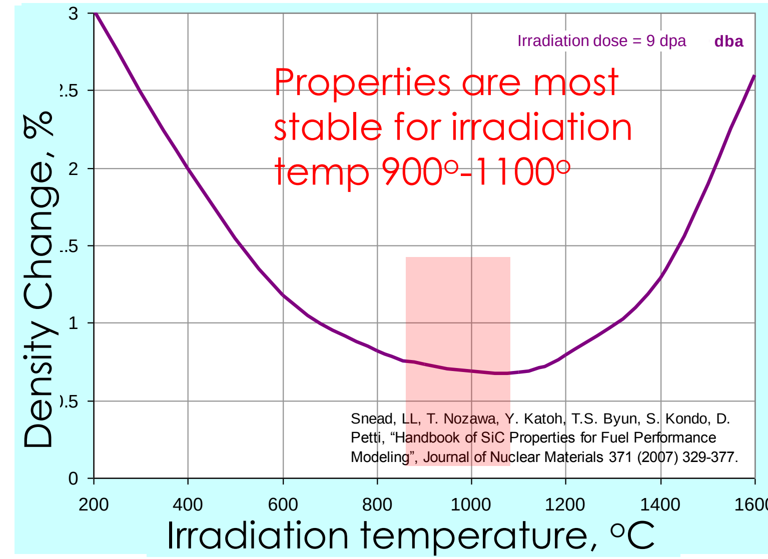
Features that Permit 30+ Year Burn Cycles

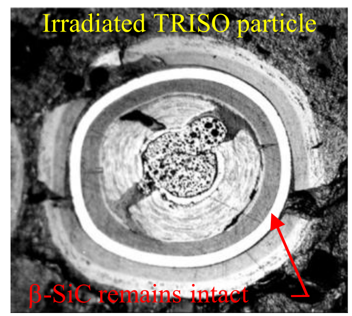
Key Characteristics

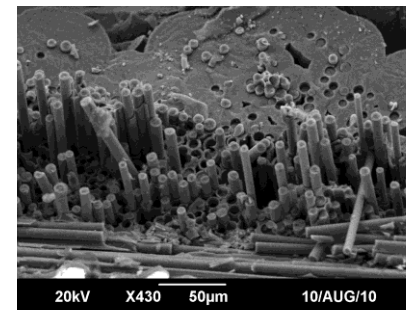
- Very low SiC transmutation rate limits swelling
- Optimum SiC dislocation/hole mobility at temp
- Core geometry permits uniform burn even as conversion fundamentally changes composition



ANL predicted longer core life and lower excess reactivity







β-SiC irradiation at HIFR (ORNL) is up to 50 dpa - no degradation in key properties

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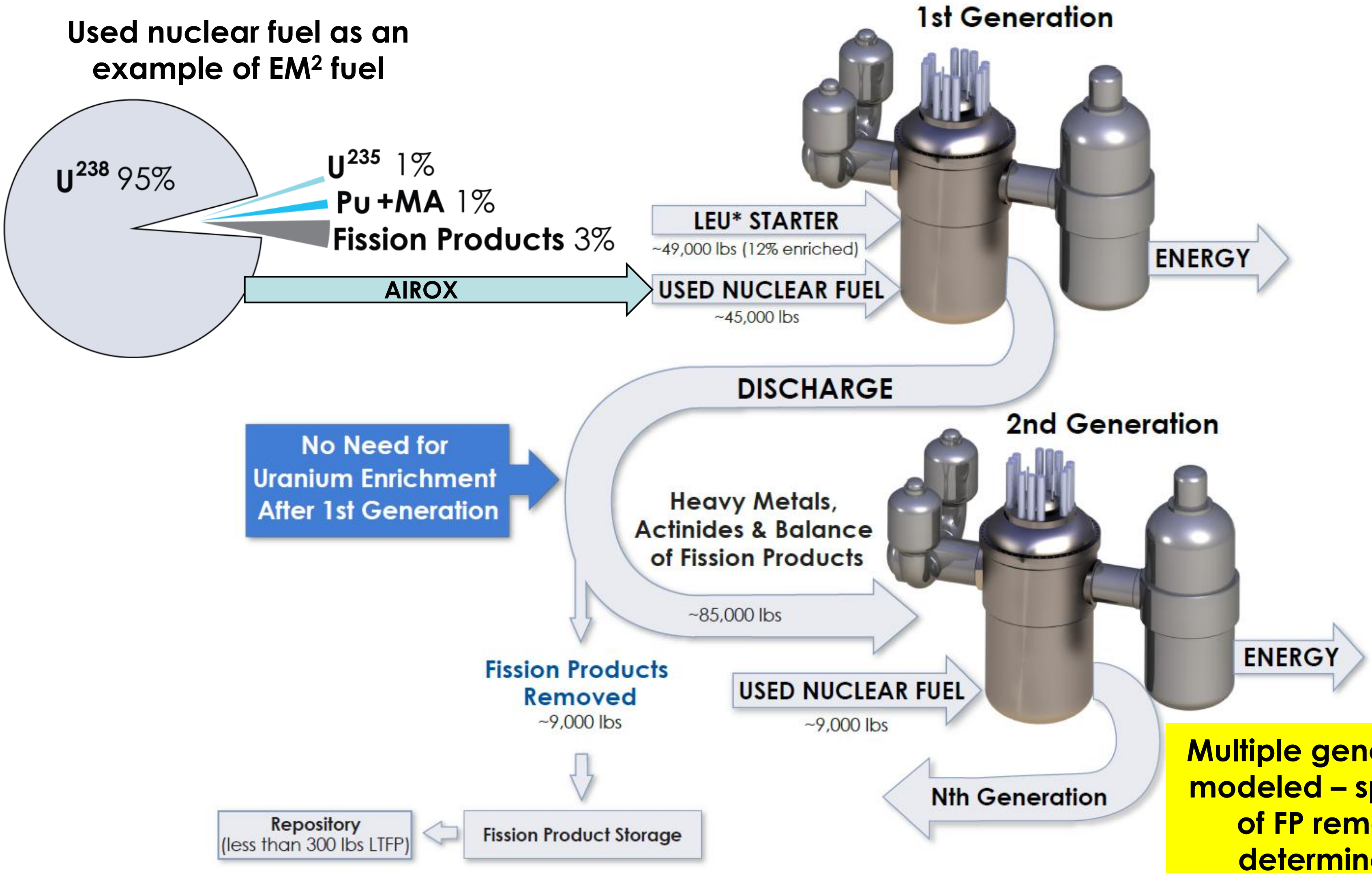
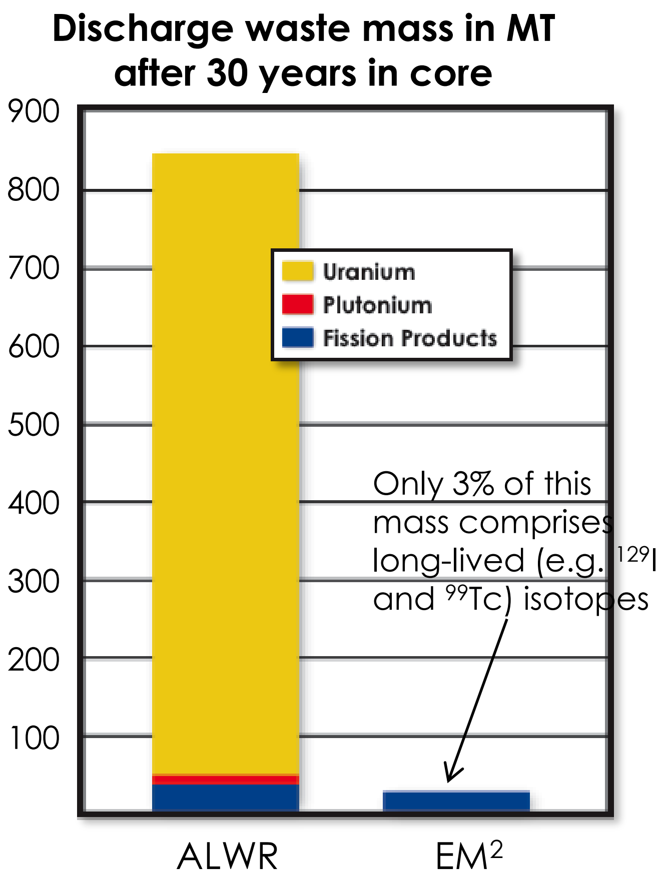
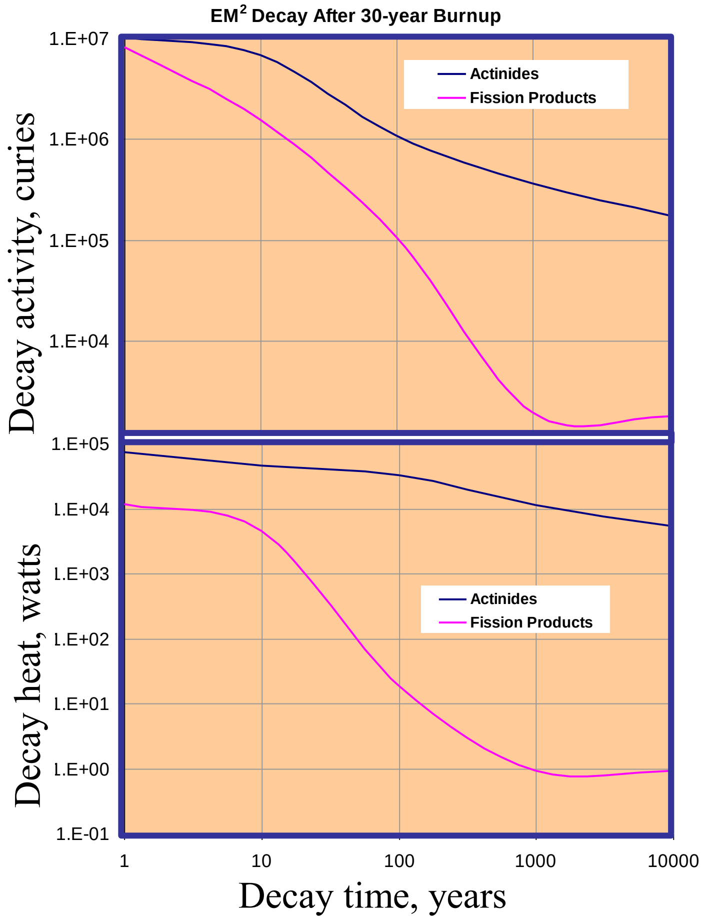
EM² Offers the Potential for Closing the Nuclear Fuel Cycle in a Proliferation Resistant Manner



Multiple generations modeled – specifics of FP removal determines N

Discharge Waste Comparison: 1200 MWe ALWR vs EM² - Mass, Radioactivity & Heat





- LRW discharge waste is primarily actinides
- EM² discharge is fission products

Fission product activity & heat generation decays much faster than actinides

The waste handling advantages grow with number of cycles

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EM^2 Addresses all the Issues Facing Fission Power

General Area	Specific Concern	Progress Attainable with Compact Fast Reactor
Economics	Massive capital tied up during lengthy construction	Small unit size; shorter assembly schedule
Safety	Consequences of loss of both power and coolant	Passive response w/o release; protect investment
Waste	NIMBY; on-site storage a public sore point	Reduce new waste; burn existing waste
Proliferation	Vulnerabilities of front and back end of fuel cycle	Reduced enrichment; no Pu separation
Infrastructure	Domestic project and supplier bases decimated	Factory fab is new start with faster learning curve

Figures of merit improved

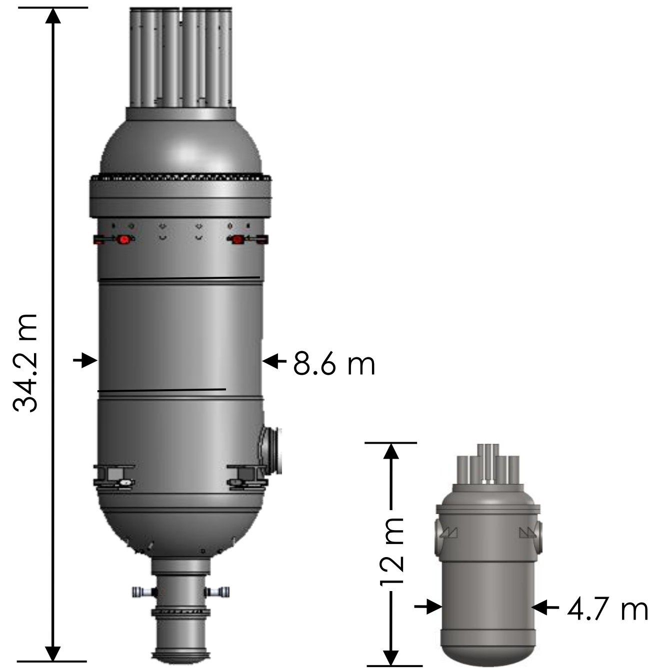
- Capacity extended to multiple centuries

- Energy return on investment >100, highest of all sources

Safety: Gas Reactors Can be Made Walk-Away Safe

Gas Thermal Reactor

- Below-grade reactor
- Non-reactive helium coolant
- Containment at particle fuel level
- Conduction core cooling to ground



500 MWt
GT-MHR

500 MWt
Compact Fast Reactor

Gas Fast Reactor

- Below-grade reactor
- Non-reactive helium coolant
- Fuel system design inhibits radioactive release
- Natural convection core cooling system

- **Meltdown proof without external power**
- **Eliminates hydrogen explosion**
- **The investment is protected**

GT-MHR could be built today. The fast reactor needs major R&D.

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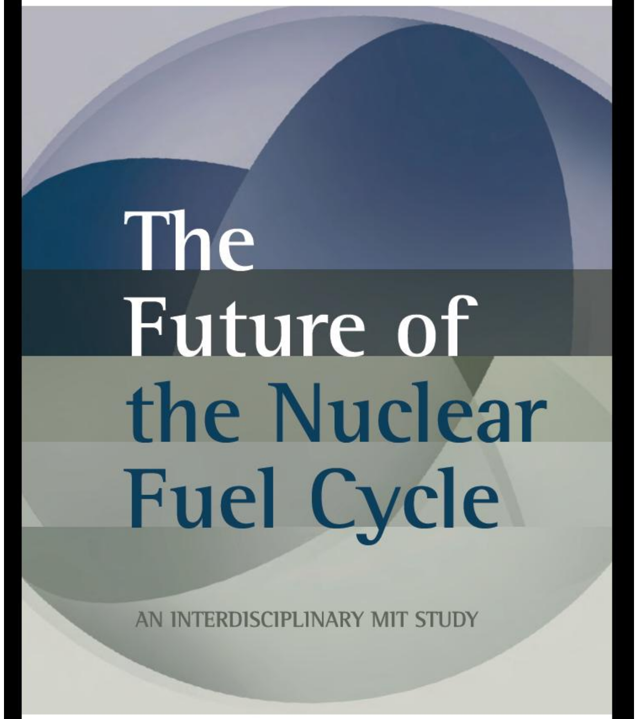
Concern: US Will be Left Behind in Advanced Fission

- No serious fast reactor work funded by DOE in 20 years
- MIT Fuel Cycle study minimizes any urgency of developing alternatives to LWRs or to addressing waste issues
- Fast reactors are largely dismissed on proliferation grounds w/o evaluating the new approaches



Expectation: advanced fission concepts, including those conceived in the US, will be developed, demonstrated, and commercialized in other countries, probably in the Far East

Community advocacy needed to make fission the best it can be

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