

Comments on
Future of Nuclear Energy
by John Ahearn

Workshop on the Economics of Technologies
to Combat Global Warming

Snowmass CO, August 3 – 4, 2009

John Steinbruner

University of Maryland

In General

- Paper provides an excellent review of the current state and currently projected evolution of the nuclear industry
 - Including the current influence of the global warming problem.
- It implicitly doubts that the current trajectory will accomplish the 3X increase in global generating capacity necessary to provide even 1 of the 7 carbon substitution wedges necessary to stabilize GHG concentrations by 2050.

Relevant Question

- What might be possible
 - If the prevailing sense of urgency regarding global warming dramatically increases,
 - And if it comes to be recognized that prudent GHG stabilization would require global expansion of nuclear power by a factor of 5 – 10 rather than merely 3 ?

- Despite uncertainties both circumstances are conceivable.
 - Possibility of demonstrable catastrophes
 - Very rapid sea rise
 - Surging release of frozen gas hydrates
 - Setting a demanding criterion of control
 - < 400 ppm
 - With competing alternatives highly constrained
 - Carbon sequestration
 - biomass

Table 1. Current and potential contributions of carbon-free energy supply

Primary Energy Production (EJ _p /y) [1 EJ = 10 ¹⁸ J ≈ 160 million barrels of oil] 500 – 900 EJ _p /y needed by 2050				
Energy Source	2001	Potential by 2050	Long-term Potential	Natural flow/ resource base (EJ _p)
Hydroelectric	28	40–60	60–100	400/y
Geothermal	0.7	5–10	5–20	10,000,000
Ocean	0.006	0–1	1–5	2,000,000/y
Nuclear fusion	0	0	?	4,000,000,000+
Nuclear fission	28	-70–220	500+	10,000,000
Biomass	4*	50–150	50–500	2,000/y
Solar	0.2	50–150	500+	3,000,000/y
Wind	0.6	20–50	100–250	40,000/y
Decarbonized fossil	0	150+	500+	250,000

Tentative Answer

- No plausible increase in urgency is likely to be sufficient to drive a 5 – 10 X expansion of nuclear power generation based on
 - Currently available reactor designs.
 - Current fuel cycle management practices.
 - Current security relationships.
- Operational safety too difficult to assure.
- Proliferation risk too substantial.

- Plausible basis for large scale expansion could be established, however,
 - by developing small, sealed, passively safe reactor designs,
 - manufactured by international consortia,
 - in few (2 – 5) heavily protected locations,
 - where all fuel processing would be consolidated.

	Reactor type	Power level	Refueling frequency	Fuel type	Fuel cycle	Special features	Time to market
IRIS (int'l consortium led by Westinghouse)	LWR	100 - 335 MWe	3.5 years	UO ₂ -- < 5 % enrichment	Once through	Integral Primary System Reactor	Applying for design cert. in 2012
AFPR (PNNL)	LWR	100 MWe	20 or 40 years if equipment brought to refuel on site to refuel once	Spherical Zr/LEU pebbles (like TRISO); could fuel w. uranium-thorium or reprocessed U (19.5% U235)	Once through or closed	TRISO fuel more robust at high temps.	10-15 years
SSTAR (Argonne)	Fast reactor, Pb or Pb-Bi cooled	20 MWe	20 years	Mixed oxide or nitride fuel, about 17% Pu	Closed		15-20 years (low level of current investment)
ENHS (UC Berkeley)	Fast reactor, Pb-cooled	50 and 75 MWe	20 years	Different options, all include about 13% Pu	Closed		15-20 years
4S (Toshiba)	Fast reactor, Sodium cooled	10 to 50 MWe	30 years	Uranium/ zirconium fuel – 17% U235	Closed w. pyro-processing	Sodium burns upon contact w. air	May be deployed in Galena, AK, but license not expected for 5-10 years

- > 50 technically plausible advanced small reactor designs have been identified
- None have yet been developed to the point of commercial availability.
- Several competing designs could be brought to that point over a 10 year period at feasible cost (about \$1 billion /design).

- Administration is in the early stages of considering a modest development project for small reactors
 - notionally \$100 million.
- Might be sufficient to select competitors for a larger scale effort.

- Criteria under discussion:
 - Transportable
 - 30 – 45 MW for rail and road.
 - up to 300 MW for barges.
 - Can operate for 20 – 40 years with a single fuel charge not including Pu or HEU.
 - Fuel sealed in the reactor for duration of operation, accessible only by the original vendor.
 - Any radiation release precluded by a passive safety system not requiring emergency intervention for at least 72 hours.
 - Can be installed in a reinforced concrete shell below grade.

- Prudent hedge against uncertain environmental risk:
 - Certainly justifies development of small reactor options.
 - Reinforces the incentive to strengthen the NPT regime:
 - Terminate active deterrent operations,
 - Establish a global explosive isotope accounting system,
 - Internationalize fuel cycle management .
 - Ultimately mandates transformation of security relationships among US, EU, Russia, China and India.