

Future Challenges for the Earth Sciences

Sustainable Development of Energy and
Mineral Resources for the 21st Century

Donald F. Schutz, BS '56, Ph. D. '64

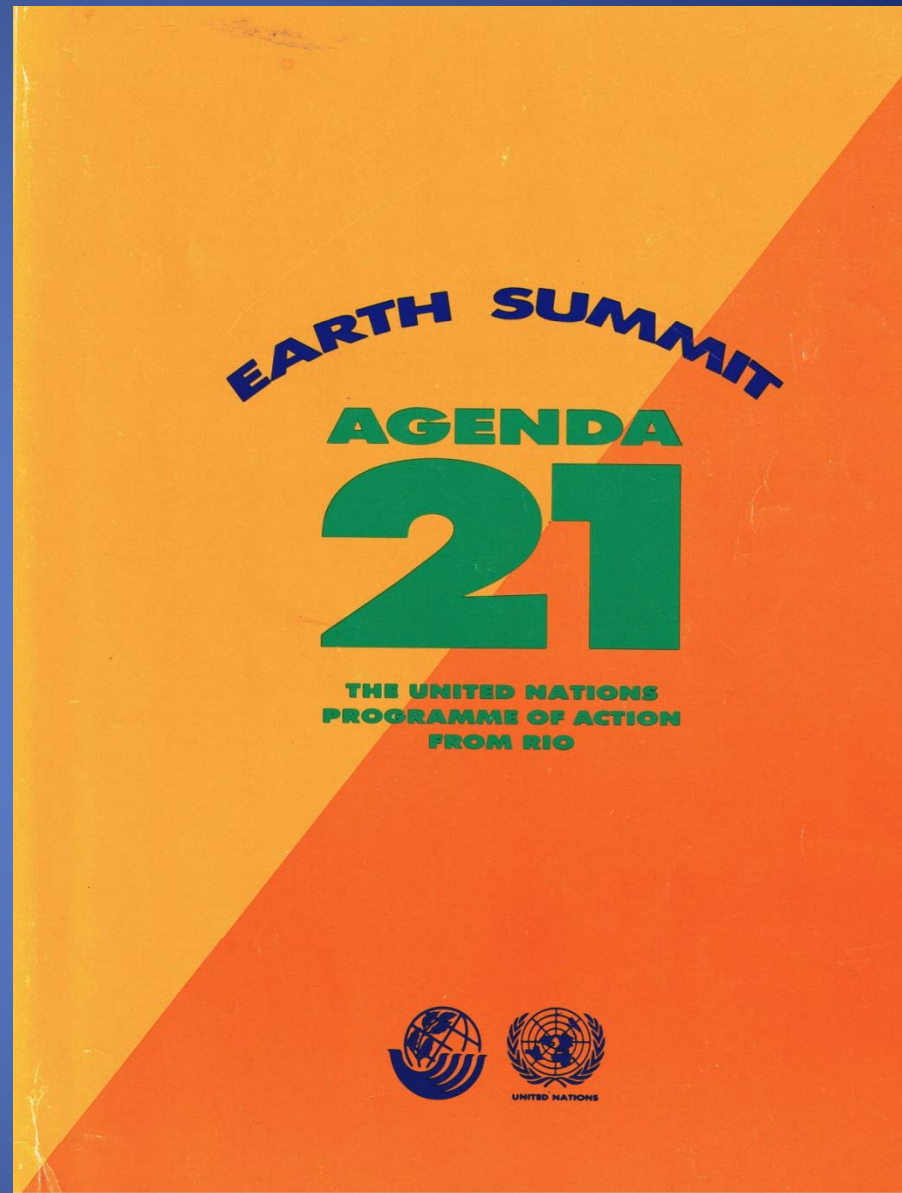
Yale Geology and Geophysics Conference
November 6-8, 2009

AGENDA 21

Global Strategic Plan for
the 21st Century

World Summit Meeting ,
Rio de Janeiro, 1992

- ❖ Framework Convention on
Climate Change (FCCC)
- ❖ UN Commission on
Sustainable development
(UNCSD)
- ❖ Kyoto Protocol
- ❖ International Panel on
Climate Change (IPCC)



Sustainability of Engineered Systems

American Institute of Chemical Engineers

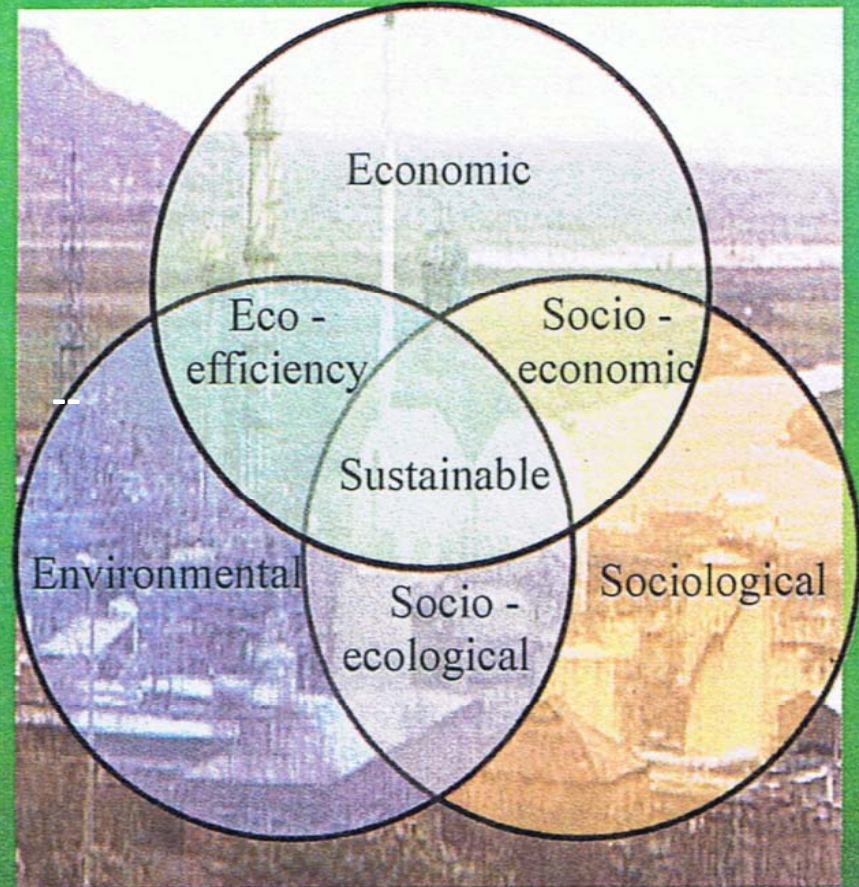
Sustainable Development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs.

-- U.N. World Commission on Environment and Development

The production and use of energy should not endanger the quality of life of current and future generations and should not exceed the carrying capacity of ecosystems.

-- Hans-Holger Rogner,
World Energy Assessment, IAEA 2000

Sustainability of Engineered Systems



Basic Parameters of Sustainability

Long-term Returns on Investments must be positive:

- EcROI=Financially profitable
- EnvROI=Environment should be improved
- EngROI=More energy produced than is consumed
- SocROI=Society is better off

Nuclear Energy

- **Significant Present**
- **Sustainable Future**
- **Nuclear Industry: Culture of Safety**
- **Environmental Impact Minimal**
- **Economically Profitable**

Positive Financial Return on Investment

Positive Energy Return on Investment (EROI)

Long Term Sustainability from Fast Breeder Reactors

Generation of 1 EJ* of Electricity Requires:

120,000,000 tons of coal

5,000 tons of U in LWR

50 tons of U in FBR

Less mining, less waste, proliferation resistant, low pollution

*EJ = 1 extajoule = 10^{18} joules = 0.95 quads

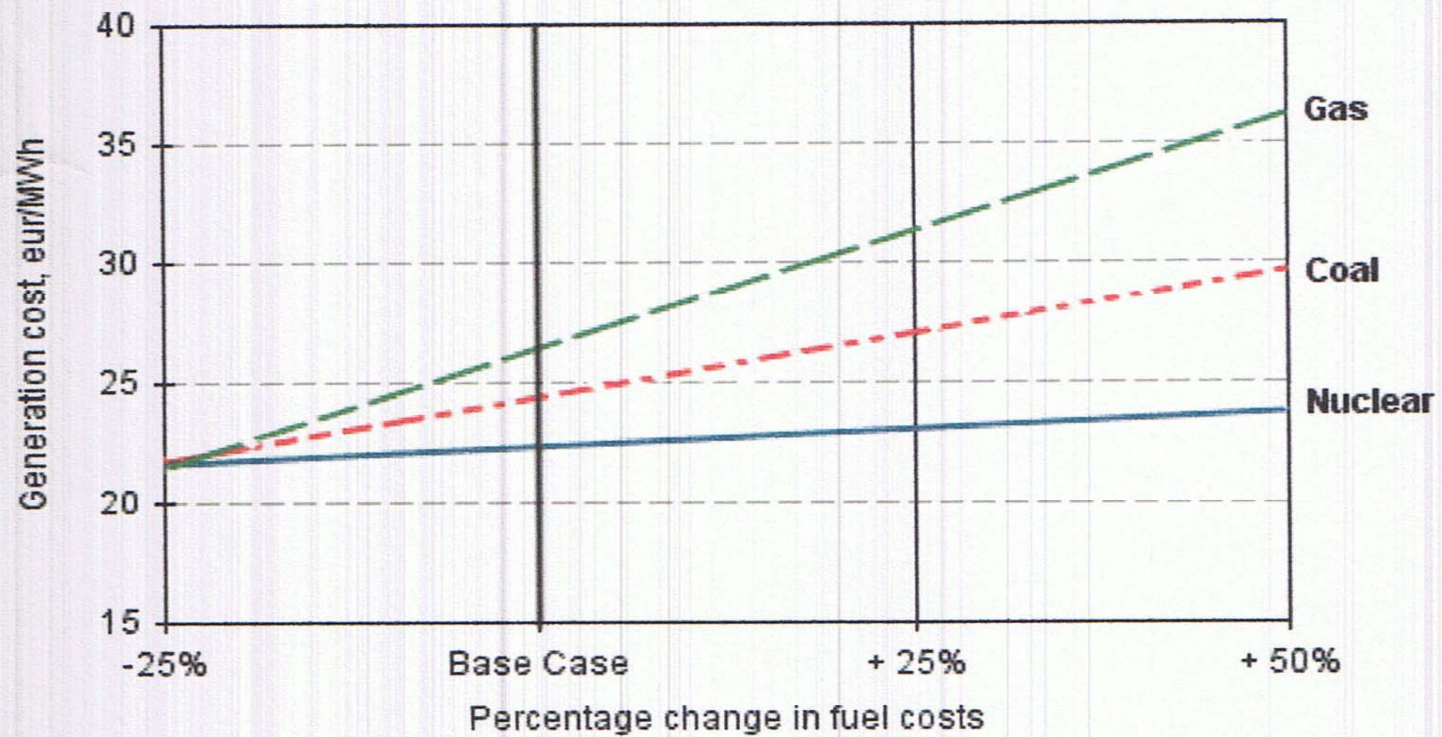
Sources and Quantities for Nuclear Fuel (000s)

Sources *resources	Reserves tons	Thermal reactor EJ	Years at 2007 consumption	Fast reactor EJ	Years at 2007 consumption
U & Th					
U-USGS	3,200	1.6	180	250	28,000
IPCC	154,000	7.7	865	1,200	135,000
Used Fuel	2,000	-	-	160	18,000
Surplus Military	Small	-	-	Small	-
Phosphate Deposits*	20,000	10.0	1120	1,600	180,000
Seawater*	4,400,000	2,200	250	317,760	> 1 million
Th-USGS	1,200	0.6	67	95	10,700

Nuclear electricity
consumption 2007=8.9EJ

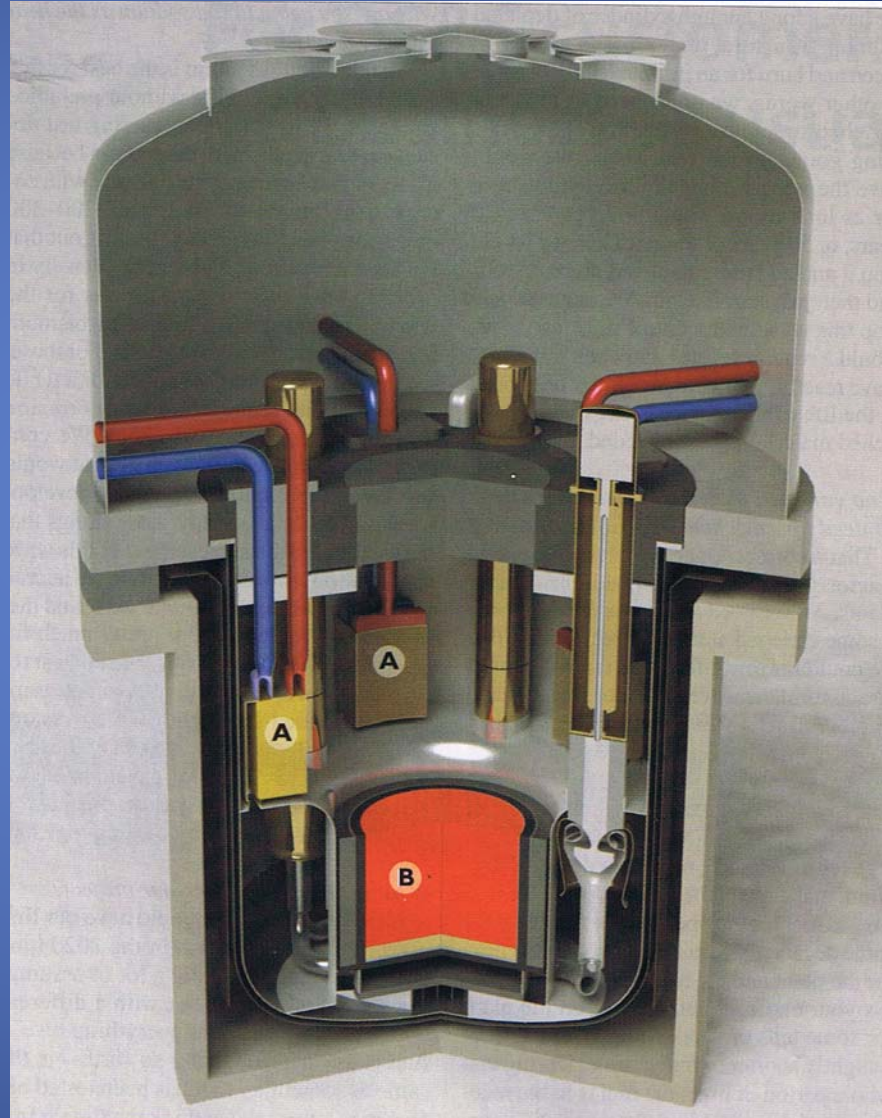
Total US energy consumption
2007=102 EJ

The impact of fuel costs on electricity generation costs.
Finland, early 2000



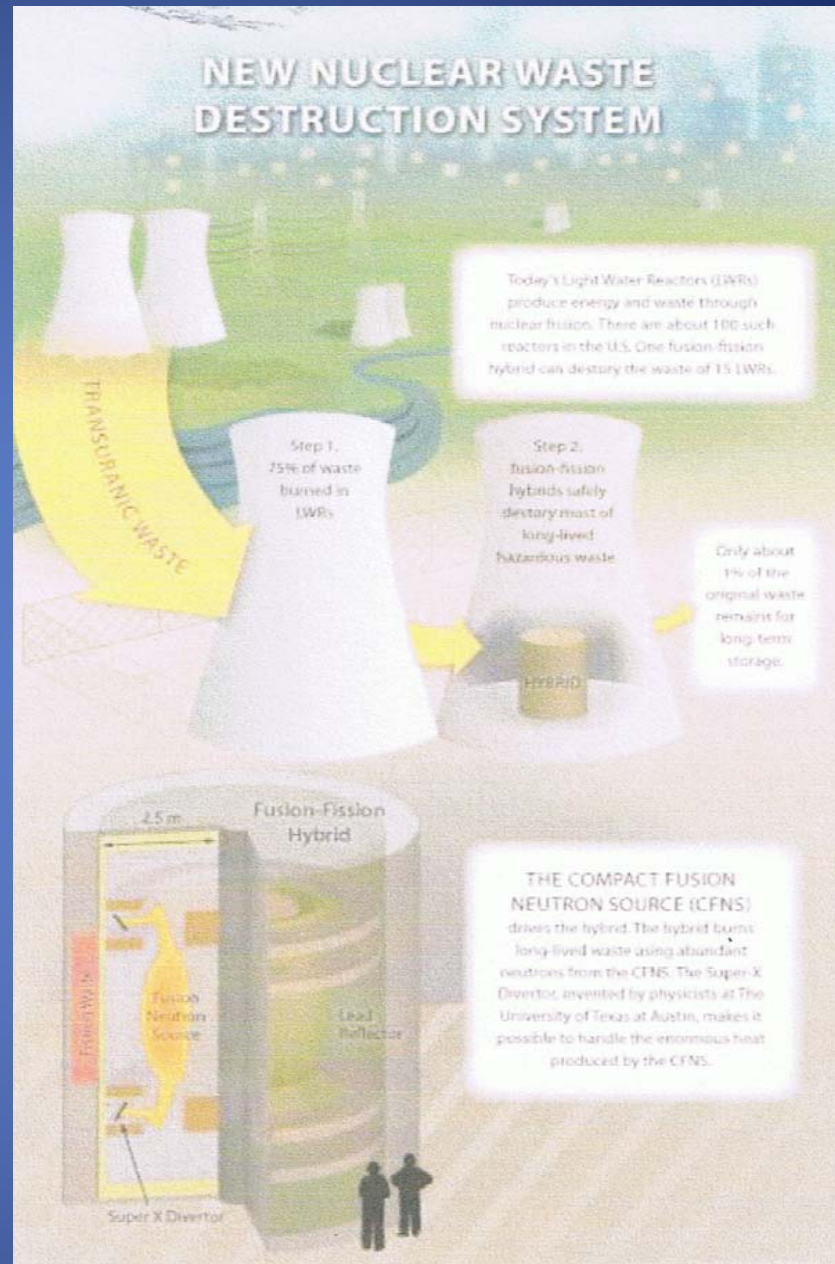
Traveling-Wave Reactor

- Burns U^{238} & Pu^{239}
- Small Size
- Produces GWe quantities in decades of operation
- Burns waste
- Proliferation secure



Hybrid Fusion-Fission Reactor

Burns fuel,
destroys waste



Resources Needed for Alternative Energy Sources

Whether or not a global run on lithium pans out as projected by the worriers, the situation highlights an underappreciated risk when it comes to alternative energy, namely securing supplies of natural resources.

In other words, if some green technologies are successful in displacing fossil fuels, there could be shortages of materials that most people never heard of before. –Martin LaMonica, Green Tech

Non-fuel “energy” Minerals

Material

Energy Use

- Neodymium, terbium, dysprosium

- Turbine gear boxes, high strength magnets

- Tellurium, indium

- Thin-film solar cells

- Lithium, lanthanum

- Batteries for electric cars*

- Platinum

- Fuel cells

- Europium

- Compact fluorescent bulbs

*No Rare Earths, no electric cars. 95% of REE production is in China.

Bolivia's Lithium-Powered Future

End product: A lithium-ion battery cell designed for use in Nissan's new generation of electric vehicles. The car market is likely to drive much of the increased demand for lithium in the coming years as governments, including the United States, push manufacturers to increase fuel efficiency.



Bolivia's Lithium-Powered Future

What the global battery boom means for the future of South America's poorest country.

Piled high: An excavator piles salt at the Uyuni Flats on Oct. 10. It is estimated that Uyuni's reserves of lithium might be as high as 100 million tons. Some are already calling Bolivia the "Saudi Arabia of lithium."

