Nuclear Energy Renaissance: Addressing the Challenges of Climate Change and Sustainability
8 MAY 2008, ATHENS

Nuclear Power Trends

Energy Economics and Sustainability

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Outline

- The Problem
- Nuclear Energy Trends
- Energy Economics
- Life Cycle Analysis
- Nuclear Sustainability
- Nuclear Energy in Greece?

The Problem

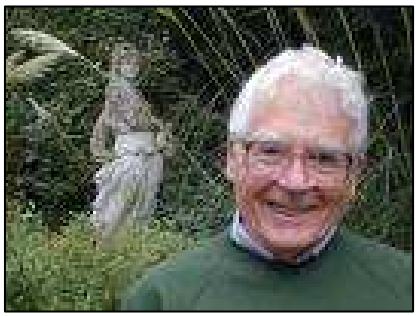
"Petroleum Man will be virtually extinct this Century, and Homo Sapiens faces a major challenge in adapting to his loss"

Dr. Colin J. Campbell, 2008
Preeminent Petroleum Geologist

A Solution

"There is no sensible alternative to nuclear power if we are to sustain civilization"

Professor James Lovelock
Father of Gaia Hypothesis
Co-Founder of Greenpeace

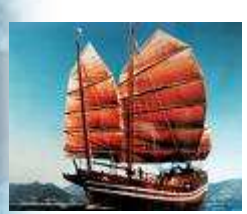


Civilization and Energy Availability



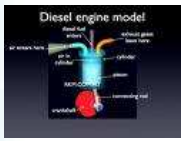










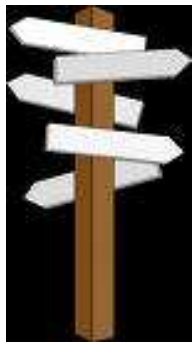




Modernity is based on ***Growth in Energy Availability!***

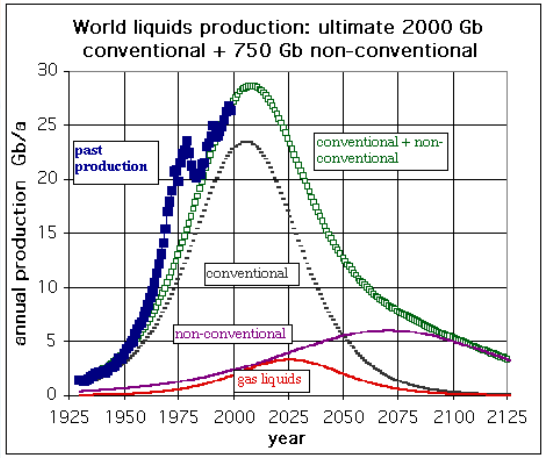
2008 Growth in Energy Availability

- Petroleum demand
- ~ 86 million barrels of oil per day
- Petroleum supply
- ~86+ million barrels of oil per day
- Market volatility
  - Stable markets need ~5% excess capacity
  - Are we witnessing the beginning of a series of oil-induced crises?



Peak in Global Oil Production?

THE HUBBERT CURVE



Bakhtiari, S. A-M. *World Oil Production Capacity Model Suggests Output Peak by 2006-07* , Oil and Gas Journal (OGJ), May 2004

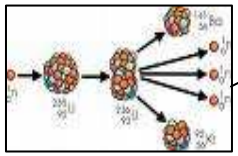
Forecasting the Peak

Sourse	**Peak**
Bakhtiari, A.M.S.	2006-07
Simmons, M.R.	2007-09
Campbell, C.	2008
Deffeyes, K.S.	2005
Laherrere, J.	2010-2020
Shell	After 2025
CERA	After 2020

Energy Economics

•Ultimately reflect fuel energy density and availability

Fuel	Energy Density (MJ/kg)	100W light bulb per 1kg fuel
Wood	10	1.2 days
Coal	32.5	3.8 days
Crude oil	41.9	4.8 days
Diesel	45.8	5.3 days
Natural Uranium	6.3×10^5	**72,000 days**

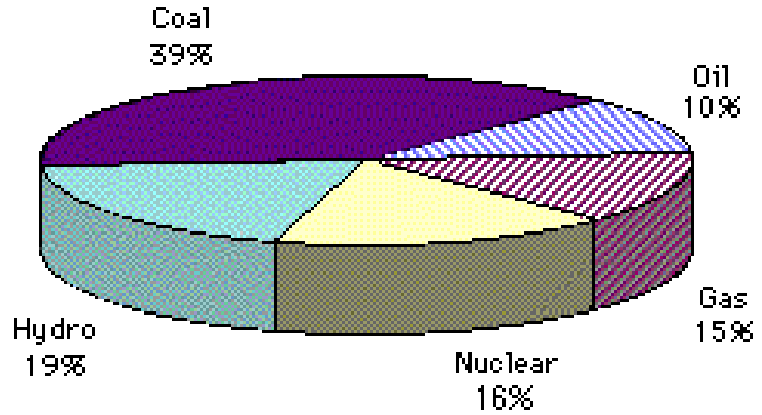


100 Watt

Source: http://www.whatisnuclear.com/

Global Nuclear Today

- 439 nuclear power reactors (31 countries)
- Over 12,000 years of operating experience
- Nuclear reactors supply 16% of the world's electricity as base-load power (372,000 MWe of total capacity)
- 284 research reactors (56 countries)
- 220 reactors for ships and submarines



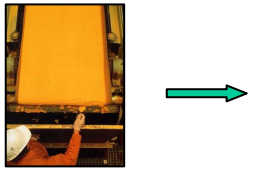
Nuclear Energy Trends

Electricity Generated	Reactors Operating	Reactors in Building Phase	On Order or Planned	Proposed
16% 2658 TWh	439 (372 GWe)	33 (27 GWe)	94 (101 GWe)	222 (193 GWe)

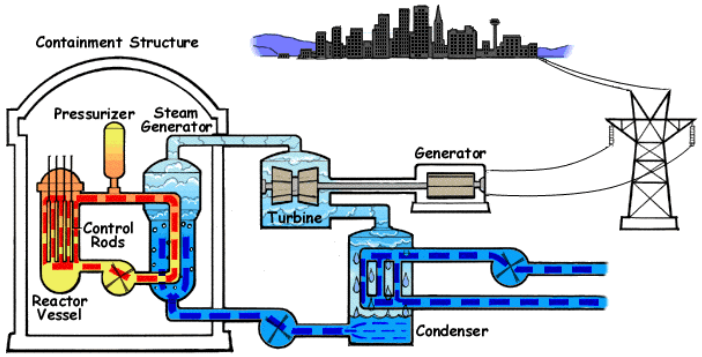
- Significant safety innovations in 3rd Generation nuclear reactors (evolutionary designs such as ABWE, EPR, AP1000, ESBWR)
- France and Japan - major forces in nuclear energy
- China to build 200 reactors by 2050!

Sources:
Reactor data: WNA to 17/10/07.
IAEA- for nuclear electricity production & percentage of electricity (% e) 5/07.
WNA: Global Nuclear Fuel Market (reference scenario) - for U. Includes first cores for new reactors.
Operating = Connected to the grid;
Building/Construction = first concrete for reactor poured, or major refurbishment under way (* In Canada, 'construction' figure is 2 laid-up Bruce A reactors);
Planned = Approvals, funding or major commitment in place, mostly expected in operation within 8 years, or construction well advanced but suspended indefinitely;
Proposed = clear intention or proposal but still without firm commitment. Planned and Proposed are generally gross MWe.
TWh = Terawatt-hours (billion kilowatt-hours), MWe = Megawatt net (electrical as distinct from thermal), kWh = kilowatt-hour

Is Nuclear Energy Renewable?



Uranium Fuel



- Yes, because a reactor produces energy and at the same time generates new fuel
  - Input fuel is U-235 (together with ~97% U-238)
  - U-235 is progressively 'burned' to produce heat (~3-5 years)
  - But about 1/3 the energy yield comes from Pu-239, which is fuel also
  - This is because the fission of U-235 causes some of the U-238 to turn into Pu-239, so about half of the U-235 used actually renews itself by producing Pu-239 from the otherwise waste material, that is, U-238
- Can U-235 be made fully renewable?
  - Yes, using Breeder Reactors to "breed" more Pu-239 than consumed (by way of U-235 + Pu-239)
- Nuclear energy can be produced indefinitely!

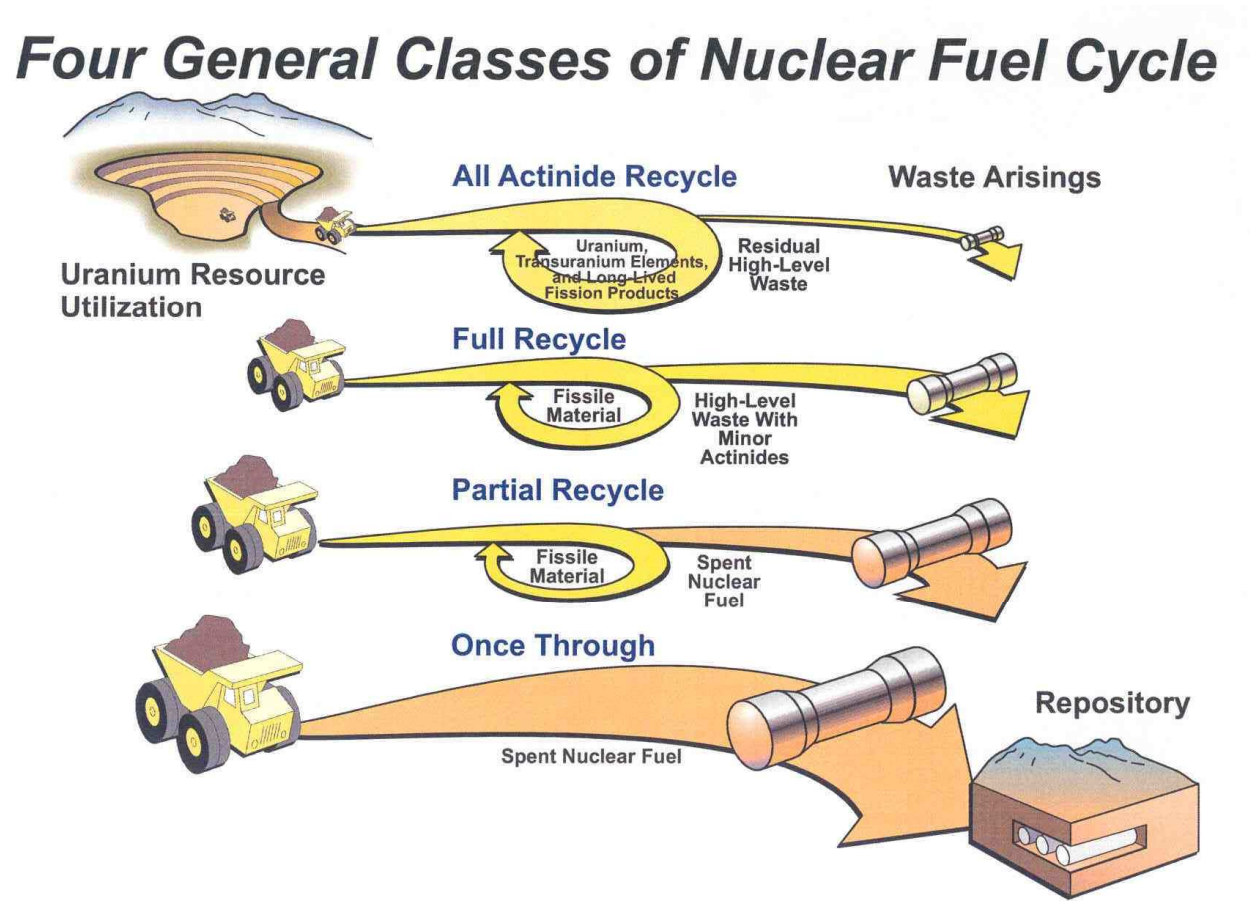
Source: http://www.world-nuclear.org/

Barriers

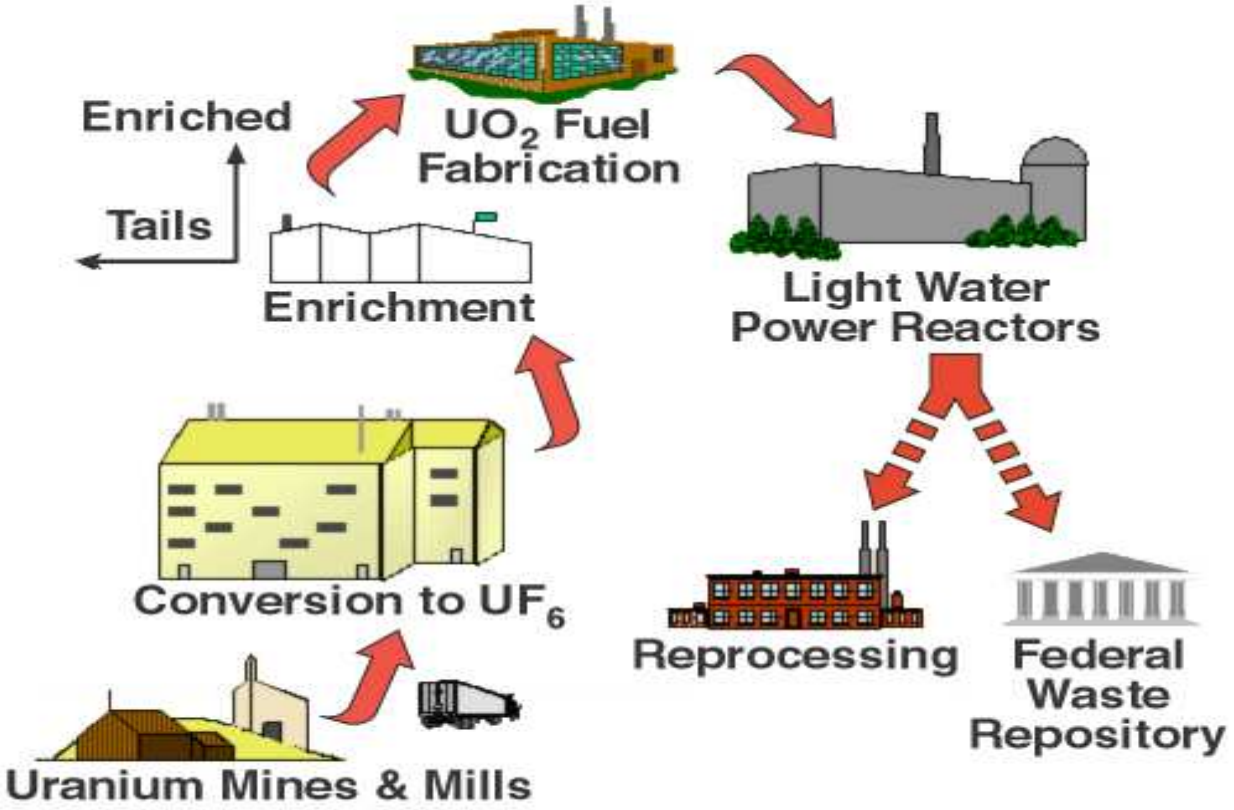
- Negative public perception
- Non-proliferation and lack of global standards
- Nuclear “waste” issues
- Limited skills and industrial capacities

- Question of the past
  - *Shall we have nuclear power in the energy mix or get as much as we can out of existing plants and phase them out?*
- Questions now asked
  - *Can we have new nuclear power?*
  - *How soon?*
  - *How do we get there?*

Nuclear Fuel Cycles



Life Cycle Analysis



- Most of the Nuclear Fuel Cycle can now run on (nuclear) electricity (no CO_2 emissions)
- No major technical barriers to recycling
- Significantly large Energy Return on Energy Investment (EROI)

Requirements For Nuclear Energy

EXCELLENCE in
TALENT, MACHINES, CODES

- Top Scientists and Engineers
- Strong regulatory agency and strong enforcement framework
- New business models with public-private financing partnerships
- Informed public dialogue

Nuclear Energy in Greece?

- Over 20 million tons of CO_2 per year above Kyoto cap
- CO_2 savings alone may finance 2 EPR-type reactors (in less than 10 years?)
- Each reactor earns more than $1B gross annually from electricity sales
- Major benefits to:
  - Improved environmental quality
  - Nurturing engineering and scientific human capital
  - Competitive construction, cement, and metals (including ship-building) industries
  - Electrification of transportation
  - Informatics
  - Financial industry