America's Energy Security

in a Resource-Constrained, Globally competitive, Carbon-Capped World

GENERAL MOTORS—Hydrogen Pathways—Nuclear

28 July 2006

Harold McFarlane

President, American Nuclear Society

&

Deputy Associate Laboratory Director for Nuclear Programs, INL

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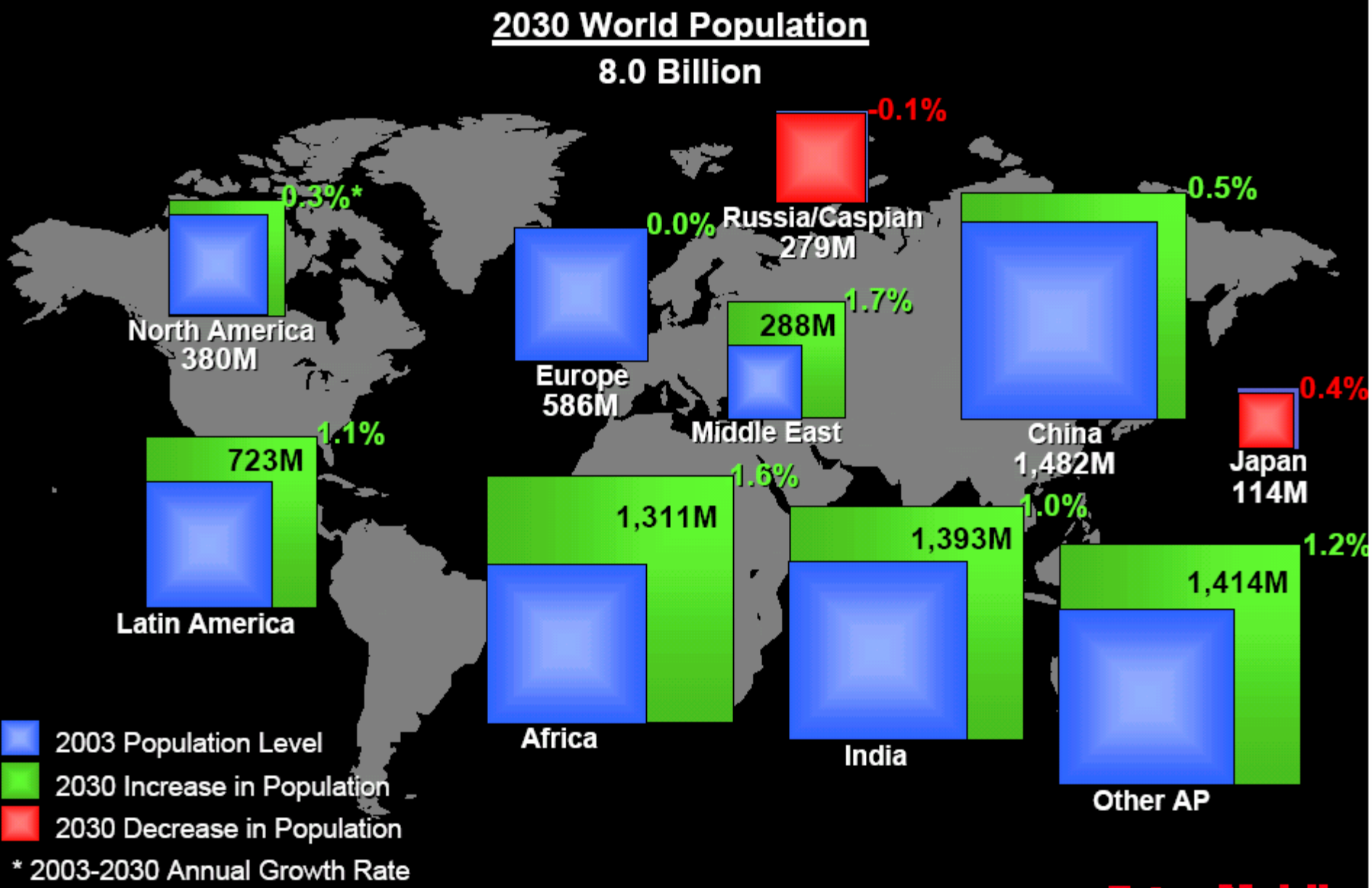
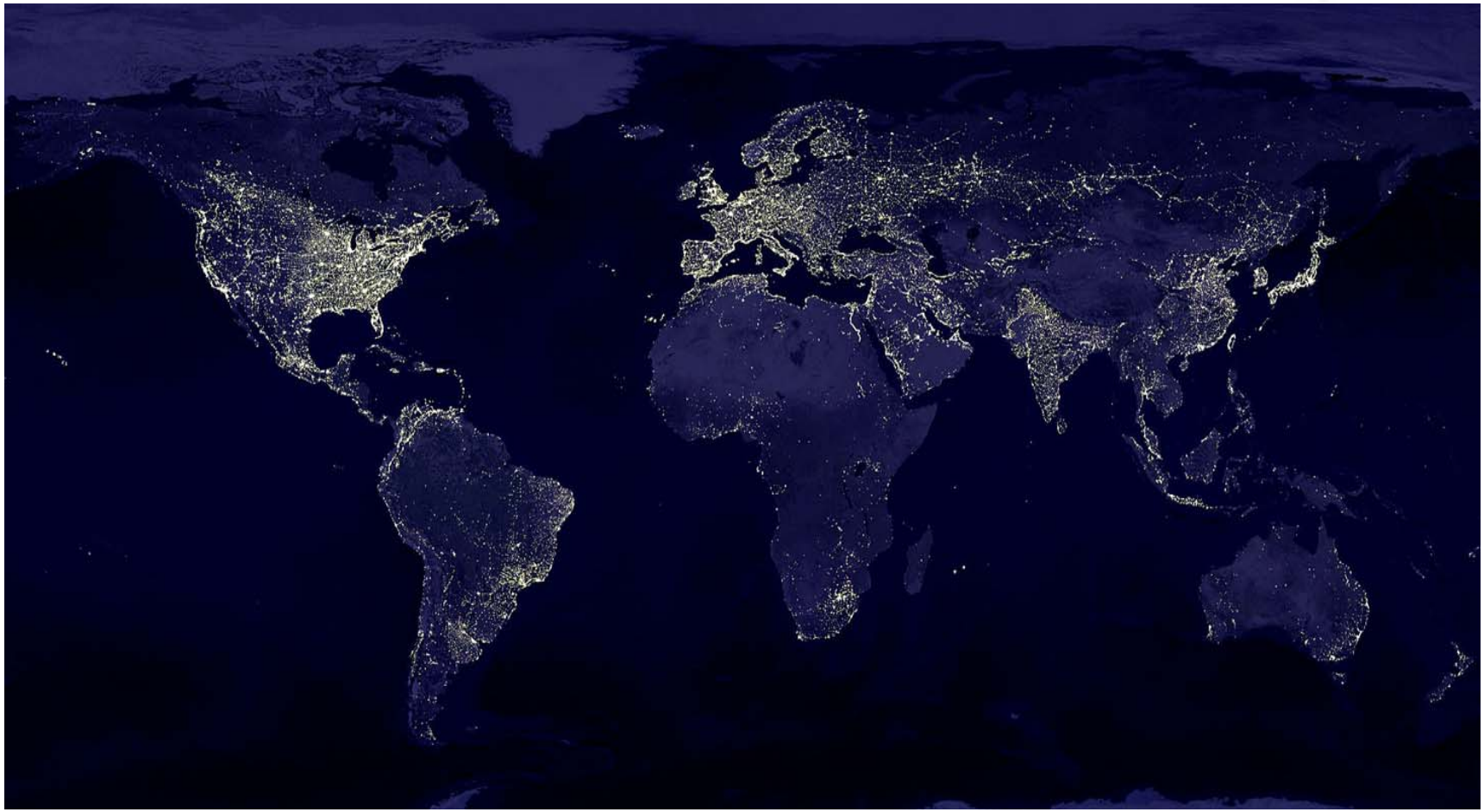
Population Grows 27% by 2030



ExxonMobil

2 billion people sitting at home in the dark



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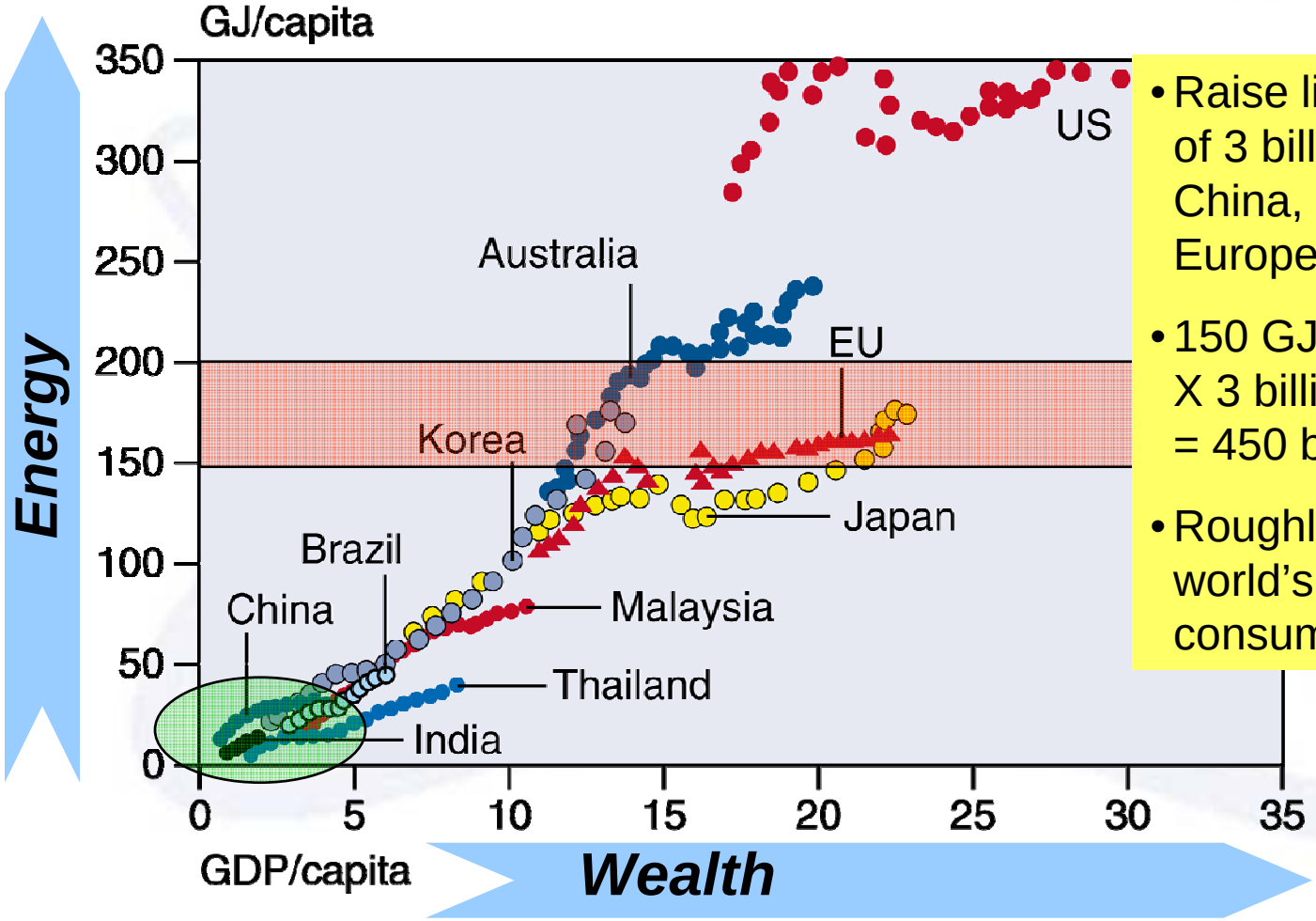
Energy is the fuel of national prosperity



- Raise living standard of 3 billion people in China, India to West European level
- 150 GJ/capita X 3 billion folks = 450 billion GJ, or
- Roughly doubles the world's energy consumption.

Source: Royal Dutch Shell, "Exploring the Future - Energy Needs, Choices and Possibilities

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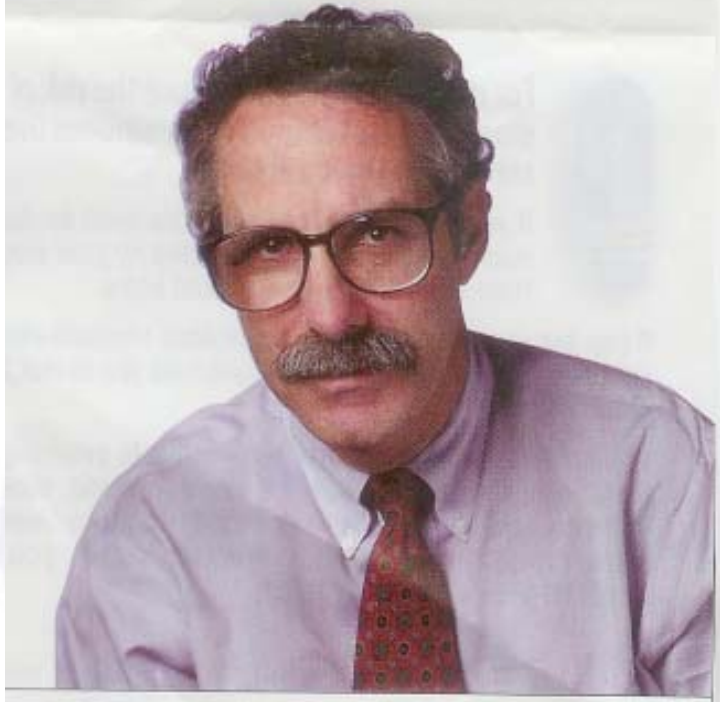
Energy supply is easy?

—ROBERT J. SAMUELSON



Newsweek

News. Trends. Voices.

"We Americans want it all: endless and secure energy supplies; low prices; no pollution; less global warming; no new power plants (or oil and gas drilling, either) near people or pristine places. This is a wonderful wish list, whose only shortcoming is the minor inconvenience of massive inconsistency."

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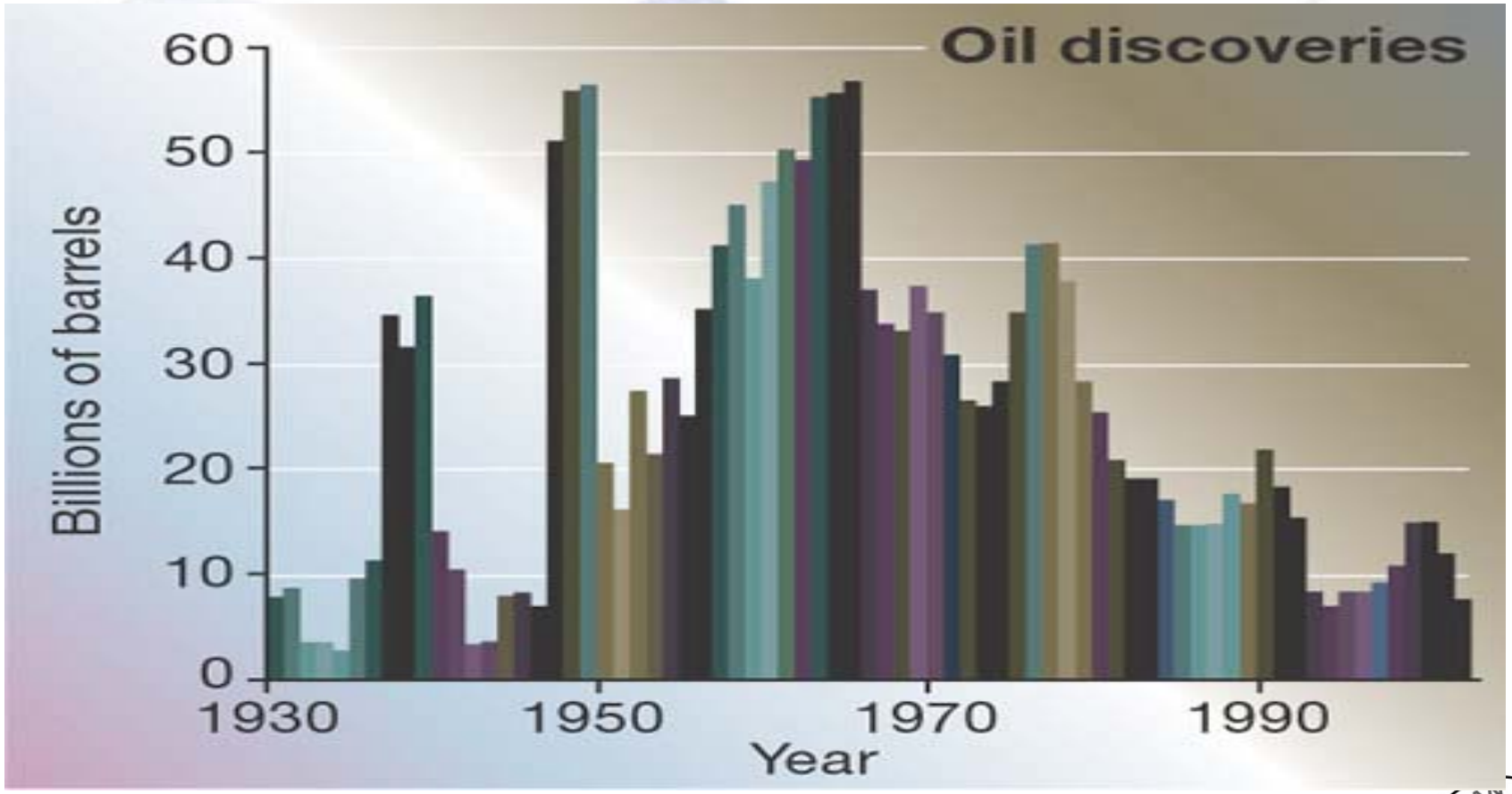
New oil discoveries are smaller, deplete quickly, more costly

(source: *Nature* 17 June 2004, p.694)



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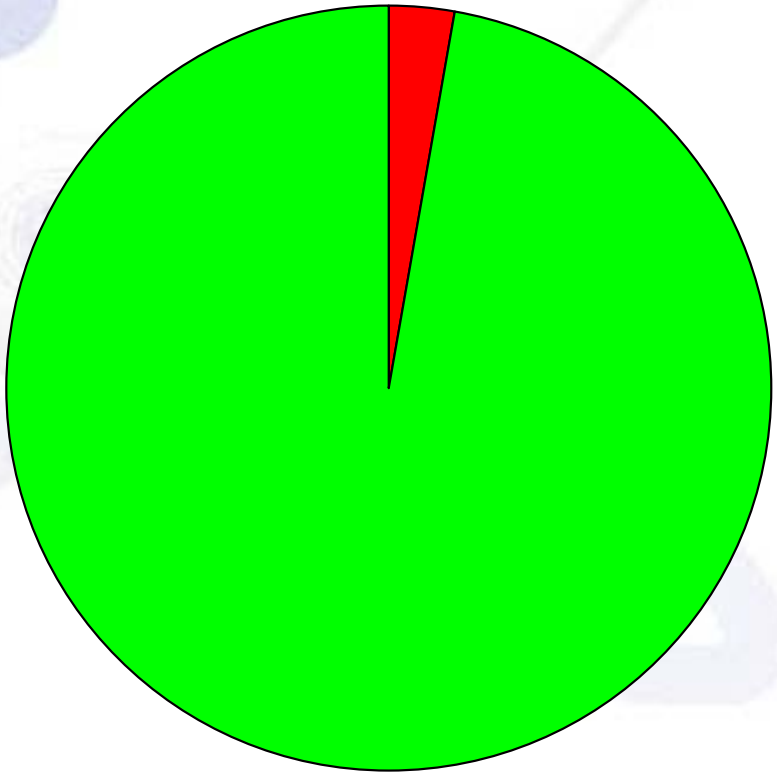
Most of the world's oil reserves (1,189 billion barrels*) are controlled by national oil companies, not major companies.

ExxonMobil
BP
Total
Chevron
Shell

} ~3%



***Year end 2004, BP Statistical Review**

Courtesy of David Greene, ORNL

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Most oil production in the "Golden Triangle" in the Middle East

From Simmons & Company, International

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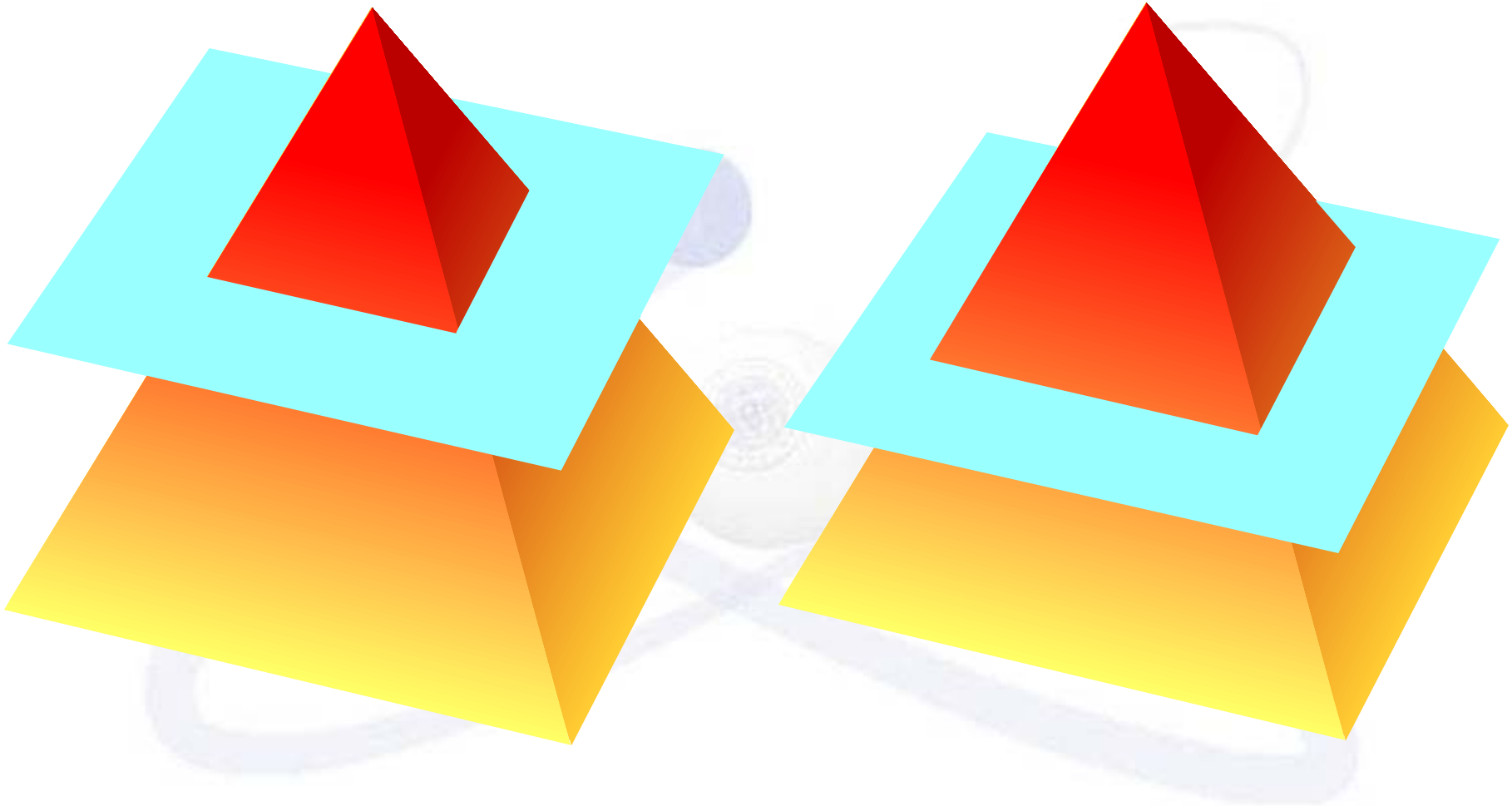
Resources farther down the pyramid seem to be more carbon intensive and their extraction more environmentally disruptive.

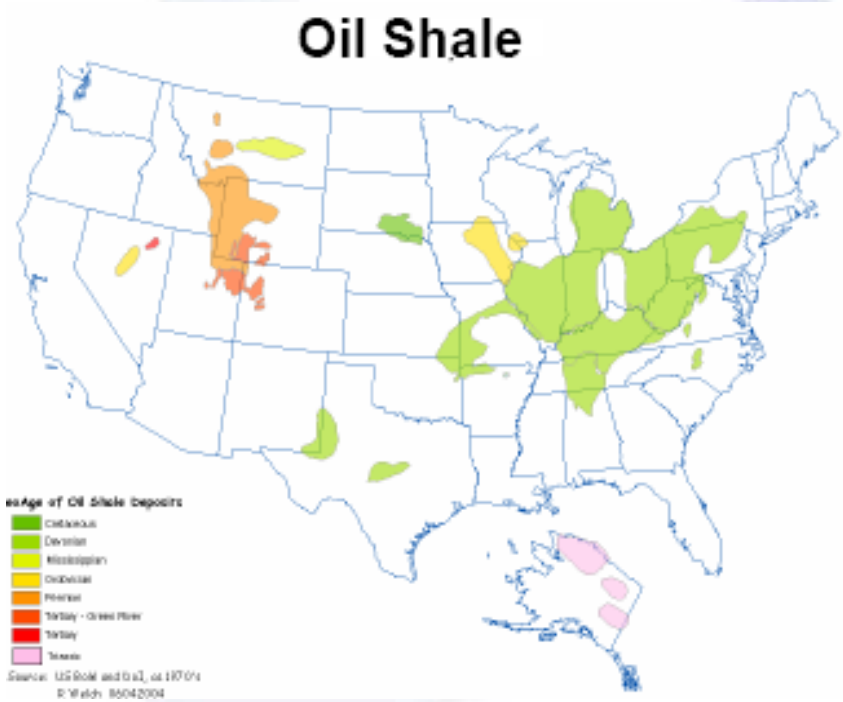


Courtesy of David Greene, ORNL

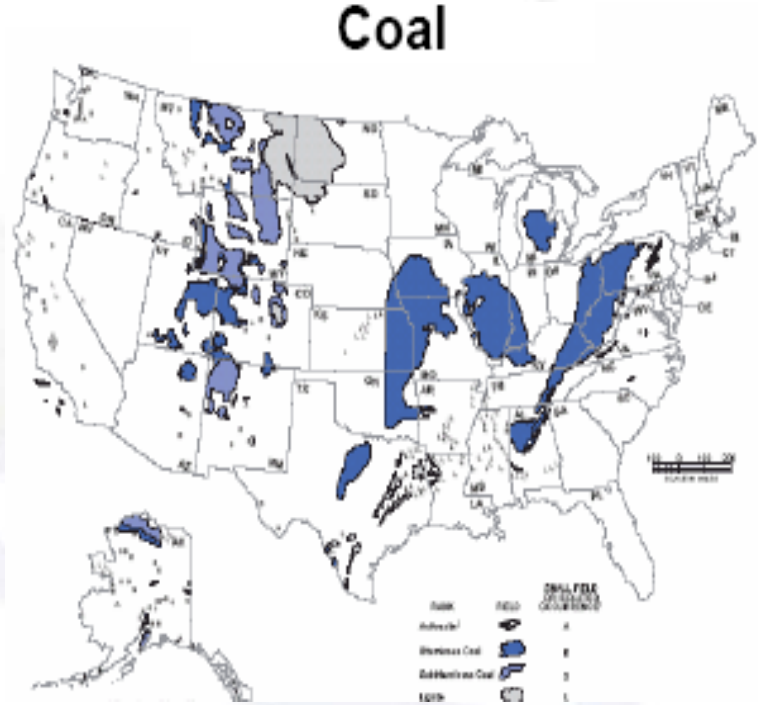
Successive assessments

From McCabe, 1998

Resources in United States



~2 Trillion BOE



~800 Billion BOE

BOE – Barrels of Oil Equivalent

Source: EIA, 2005

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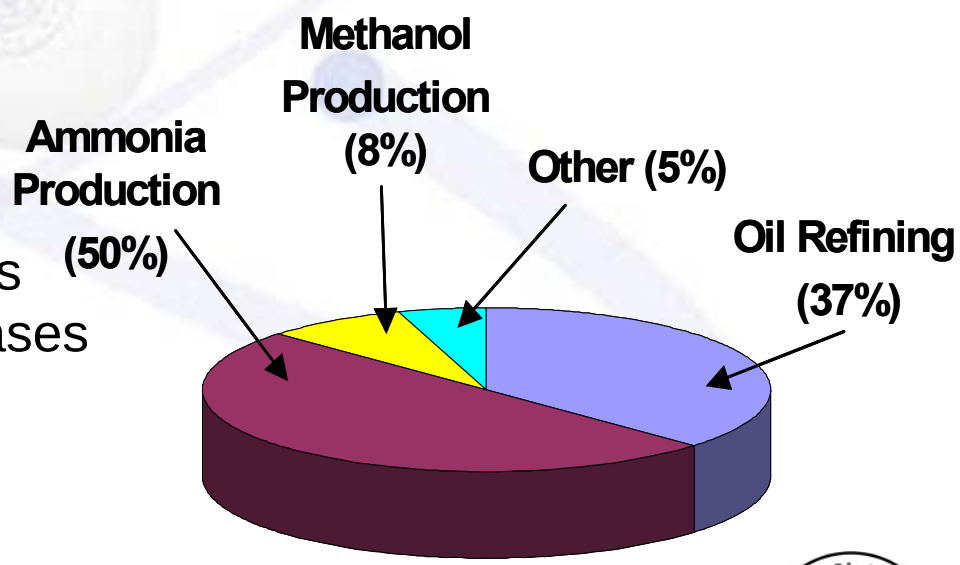
Current hydrogen use is significant

- Although hydrogen is the most abundant element in the universe, it does not naturally exist in its elemental form in large quantities or high concentrations on earth.
- The World consumption in 2002 was 50 million tons H_2/yr, produced primarily by steam reforming of methane
- We are now using more than 5% of North American natural gas for H_2 production which, with natural gas use for electricity production, is putting pressure on home heating costs
- The current H_2 production releases 320 million metric tons CO_2/yr



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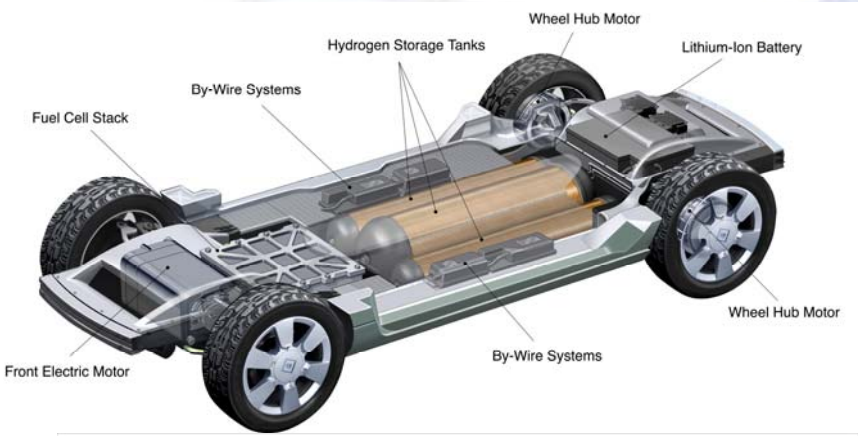
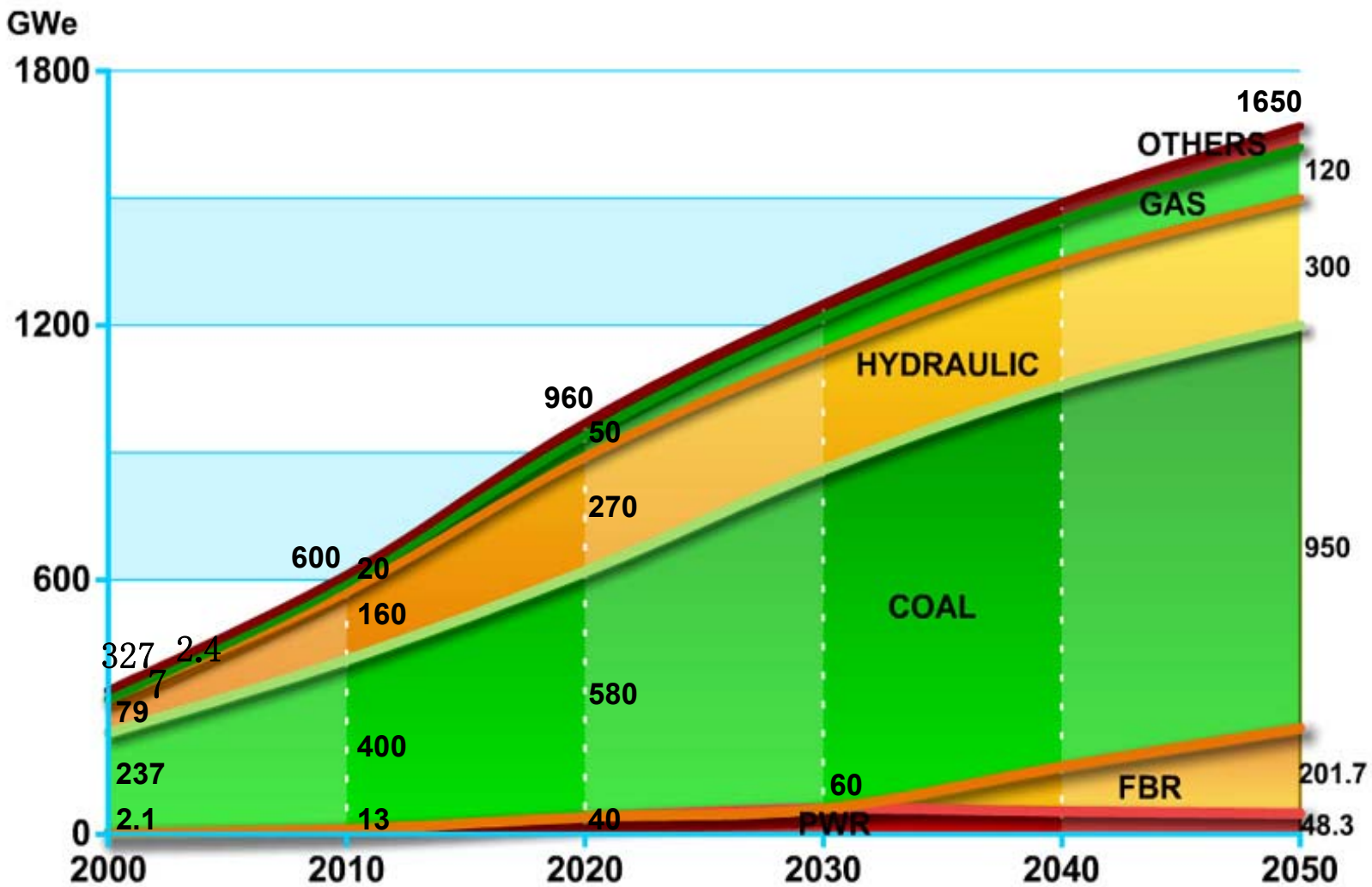
Eventually we will have viable fuel cells - hydrogen fuel & water out the tailpipes



China

XU MI, Oct. 2005

CHINA INSTITUTE OF ATOMIC ENERGY



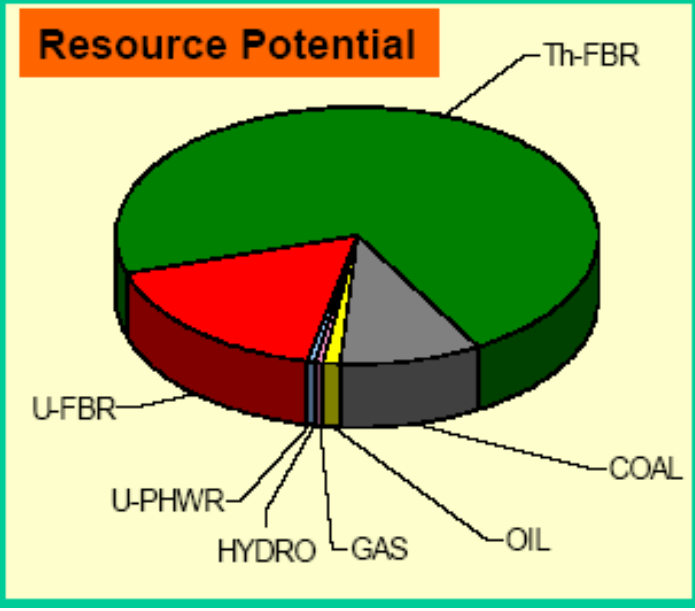
Electric Capacity Development Envisaged In China

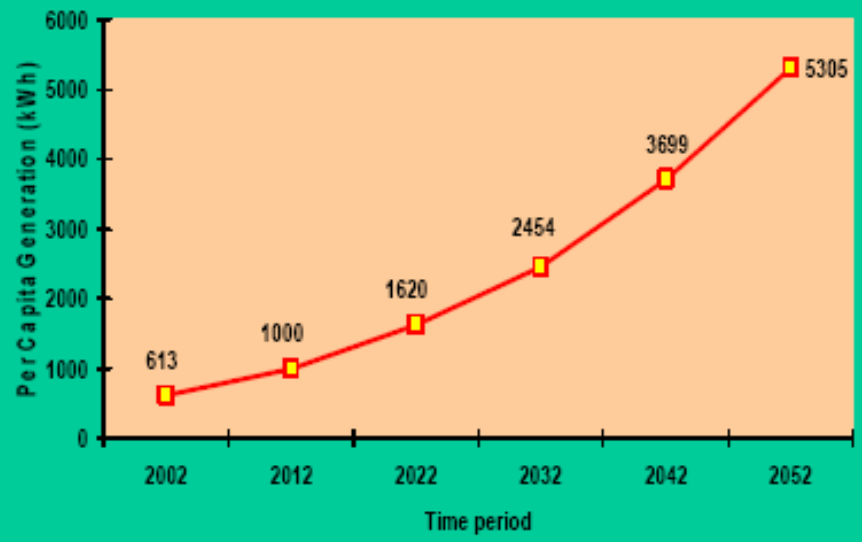
Indian Energy Growth Scenario

	2003-04	2052
➢ Electricity Generation (GWe)	112.0	~ 1344
➢ Nuclear Energy Share (GWe)	2.72	~ 275
➢ PHWR (GWe)	2.10	~ 0

➢ Faster Growth is needed to reach the target

➢ FBR with Closed Fuel Cycle is inevitable





Baldev Raj, GLOBAL 2005, October 2005

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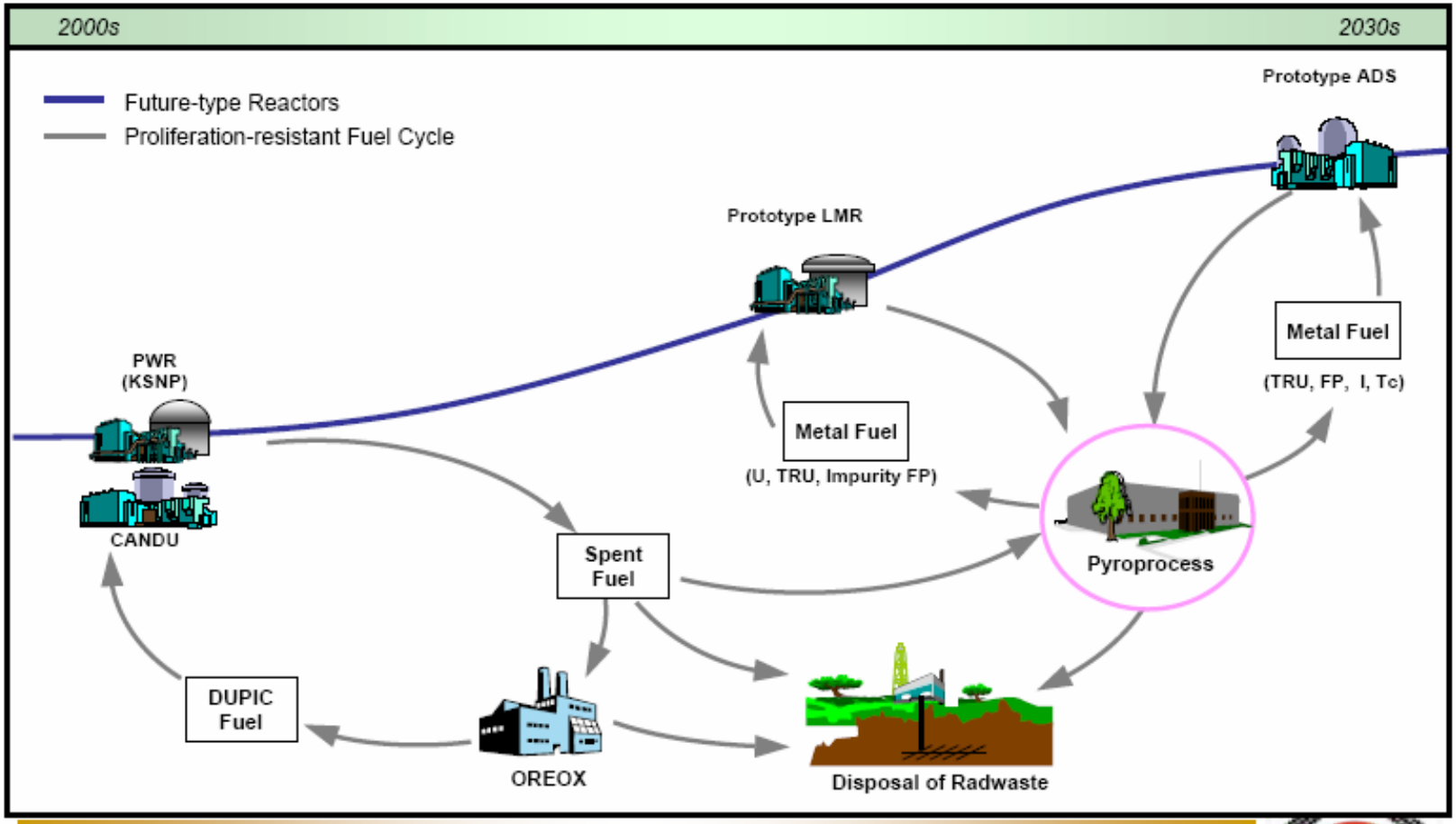
Prospect of Advanced Nuclear Fuel Cycle : KIEP-21

"K : Korea, I : Innovative, E : Environmentally friendly, P : Proliferation resistant"



GLOBAL 2005 International Conference, Tsukuba, Japan

Prof. Jun Kai Lee, October 2005
(Ph.D. Princeton 19XX)

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Let's talk about nuclear

Monday

Boston Consulting Group report says reprocessing is economically viable.

Tuesday

India-US nuclear pact overwhelmingly passed by House of Representatives

Wednesday

Amarillo Power announced intent to build 2 ABWRs in Texas

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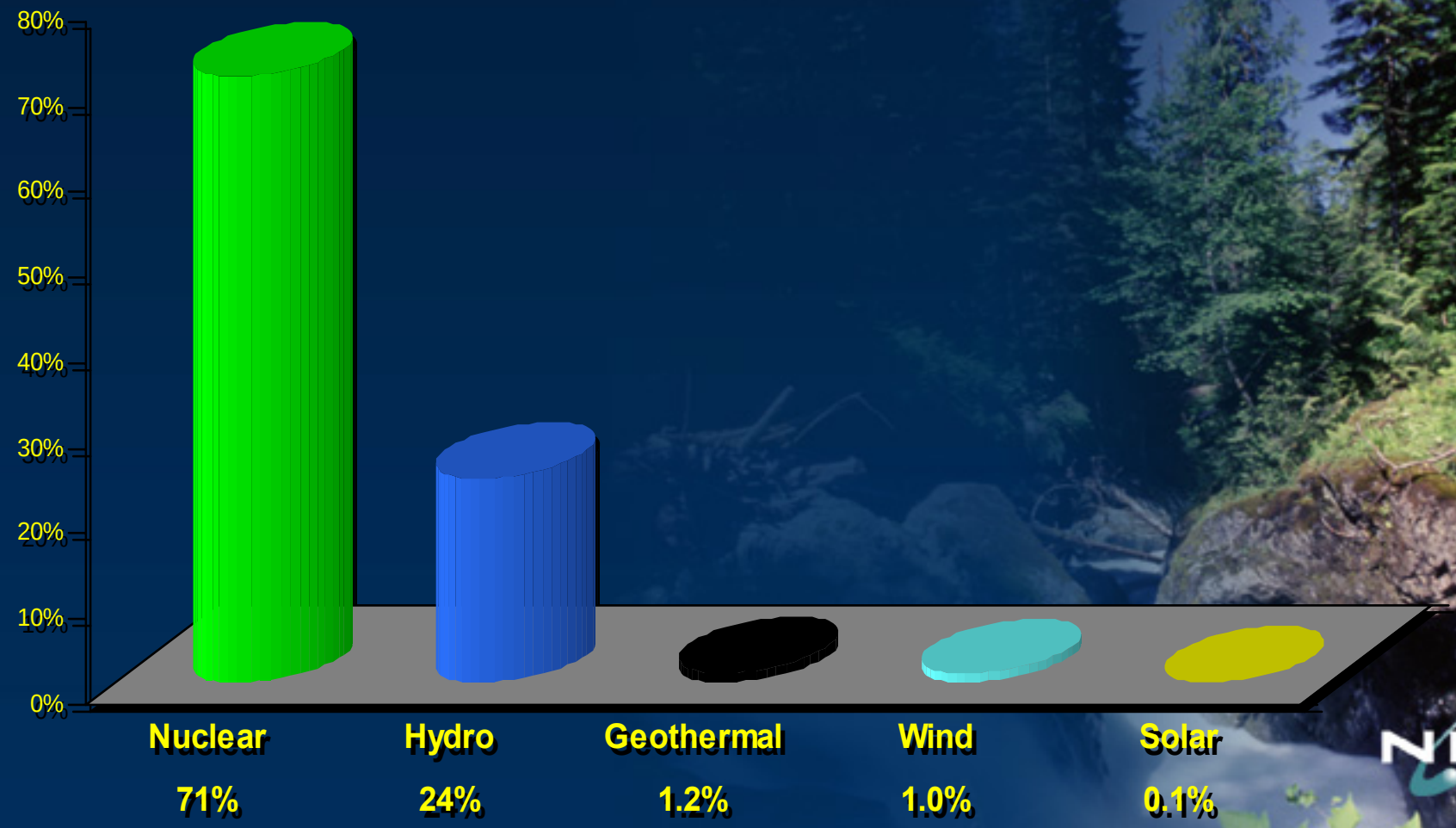
U.S. Emission-Free Electricity

(2003)



Source: U.S. Energy Information Administration

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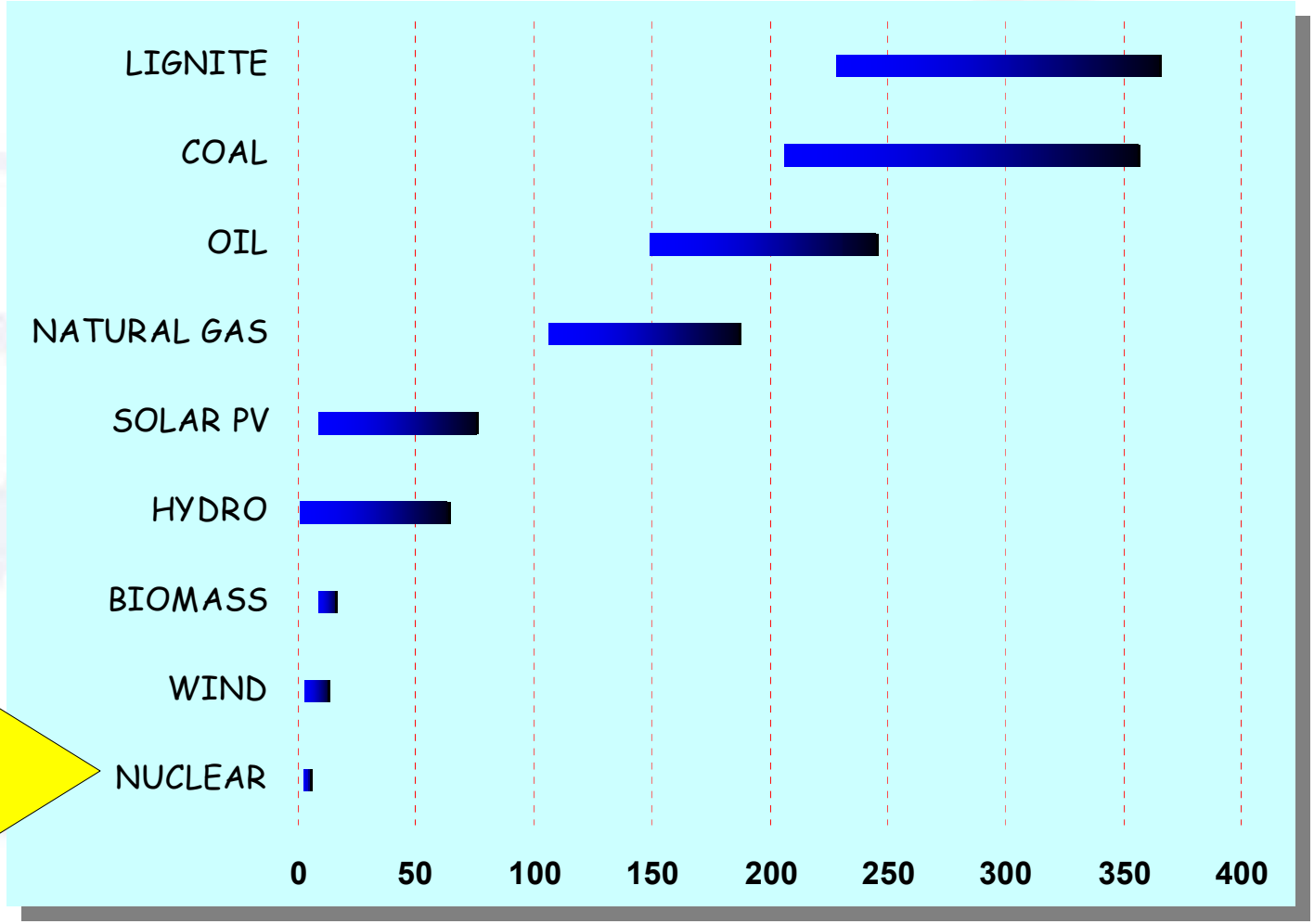
NEI

Greenhouse gas (GHG) emissions

GHG
gC_{eq}/kWh



low carbon ✔

Source: Sokolov, IAEA, 2005

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Evidence of a pending renaissance

- ✓ Enabling legislation
- ✓ Public announcements of pending nuclear plant orders
- ✓ Nuclear industry staffing
- ✓ Nuclear engineering enrollment
- ✓ Surge in favorable news stories
- ✓ Significant financial investment
- ✓ Shift in public policy to favor nuclear along with other environmentally friendly sources of power

- *It is a great year to be ANS president!*

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Performance improvements since President Carter's administration

Performance indicator	1979	Today
No. of commercial reactors	69	103
Electricity prod. (kilowatt-hours)	255 billion	789 billion
Fleet average capacity factor	56.3%	90.5%
Unplanned reactor shutdowns/7000 hr	7.3%	0
Industrial safety accident rate/200k-hr	2.1	0.25

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Conditions for nuclear to be a significant part of the 21st century energy mix

- Low carbon emission technology
- Affordable
- Expandable
- Sustainable
- Safe
- Accepted
- Doesn't leave a mess
- Consistent with national and international policy

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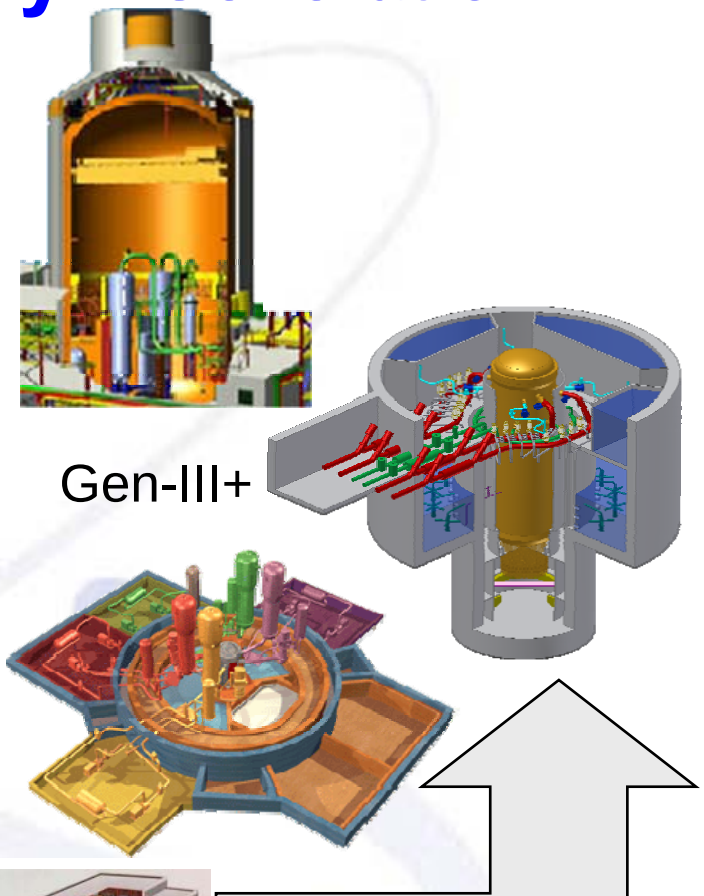
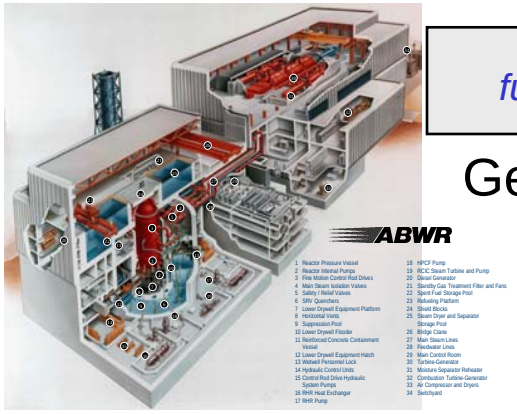
New designs available today—*Generation III+*

Advanced Light Water Reactors (ALWRs)

- Standardized designs based on modularization producing shorter construction schedules
- Passive or redundant systems to enhance safety
- Easier to protect from terrorist attacks



ABWR
Advanced Boiling Water Reactor



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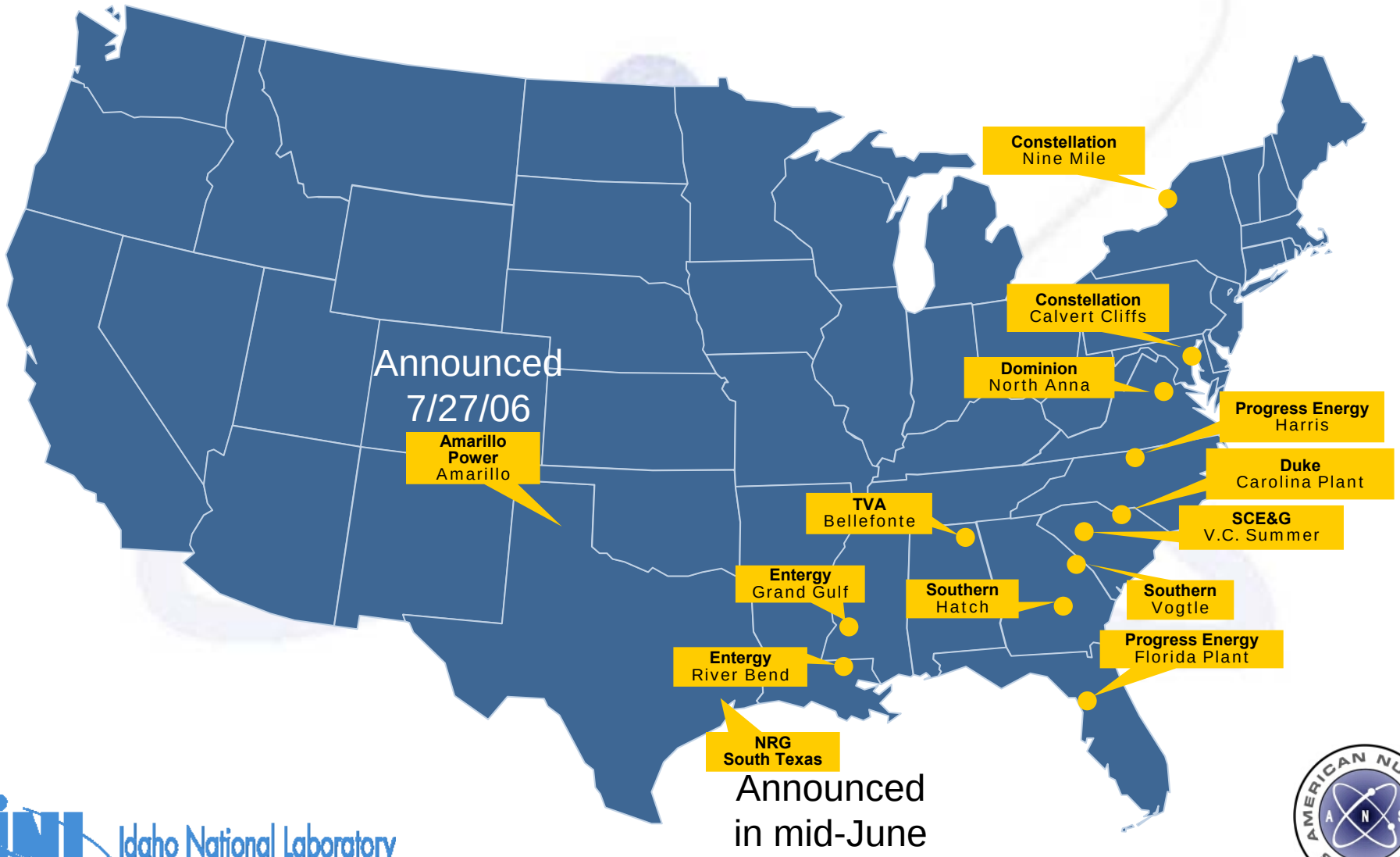
U.S. Nuclear Industry—First Movers



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U. S. NUCLEAR REGULATORY COMMISSION

Summary Estimate of New Nuclear Power Plants Based on the Design Centered Approach

(as of 7/2/06)

	COLs	Units
AP 1000	6	11
ESBWR	3	3
EPR	5	5
ABWR	2	4
Unspecified	3	3
	---	---
Total	19	26

Number of Reference COLs: 4
Number of Environmental Reviews: 19+

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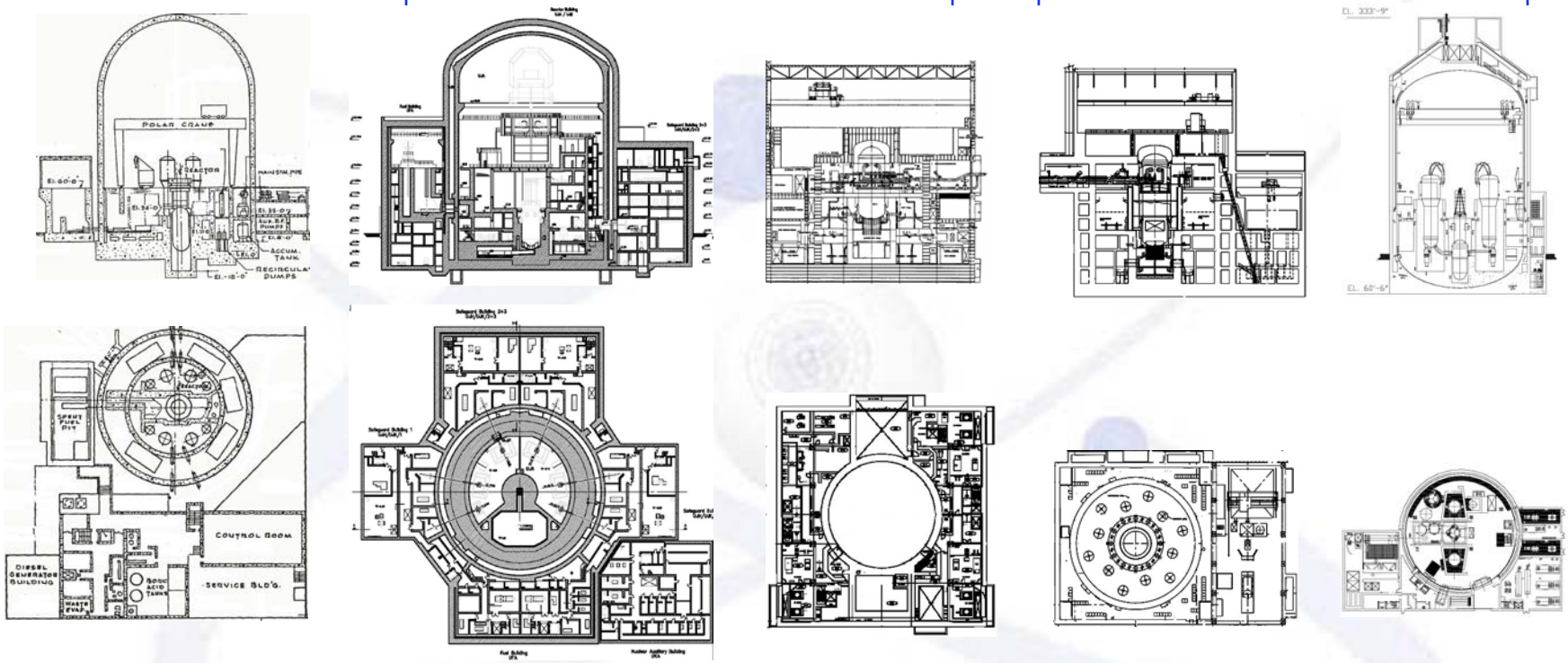
The new ALWR designs reverse the trend of increasing steel and concrete

Gen II | **Gen III - Active** | **Gen III+ - Passive**



1970's PWR	EPR	ABWR	ESBWR	AP-1000
1000 MWe	1600 MWe	1380 MWe	1550 MWe	1090MWe
40 MT_{steel}/MW	49 MT_{steel}/MW	51 MT_{steel}/MW	__ MT_{steel}/MW	42 MT_{steel}/MW

Scaled Comparison

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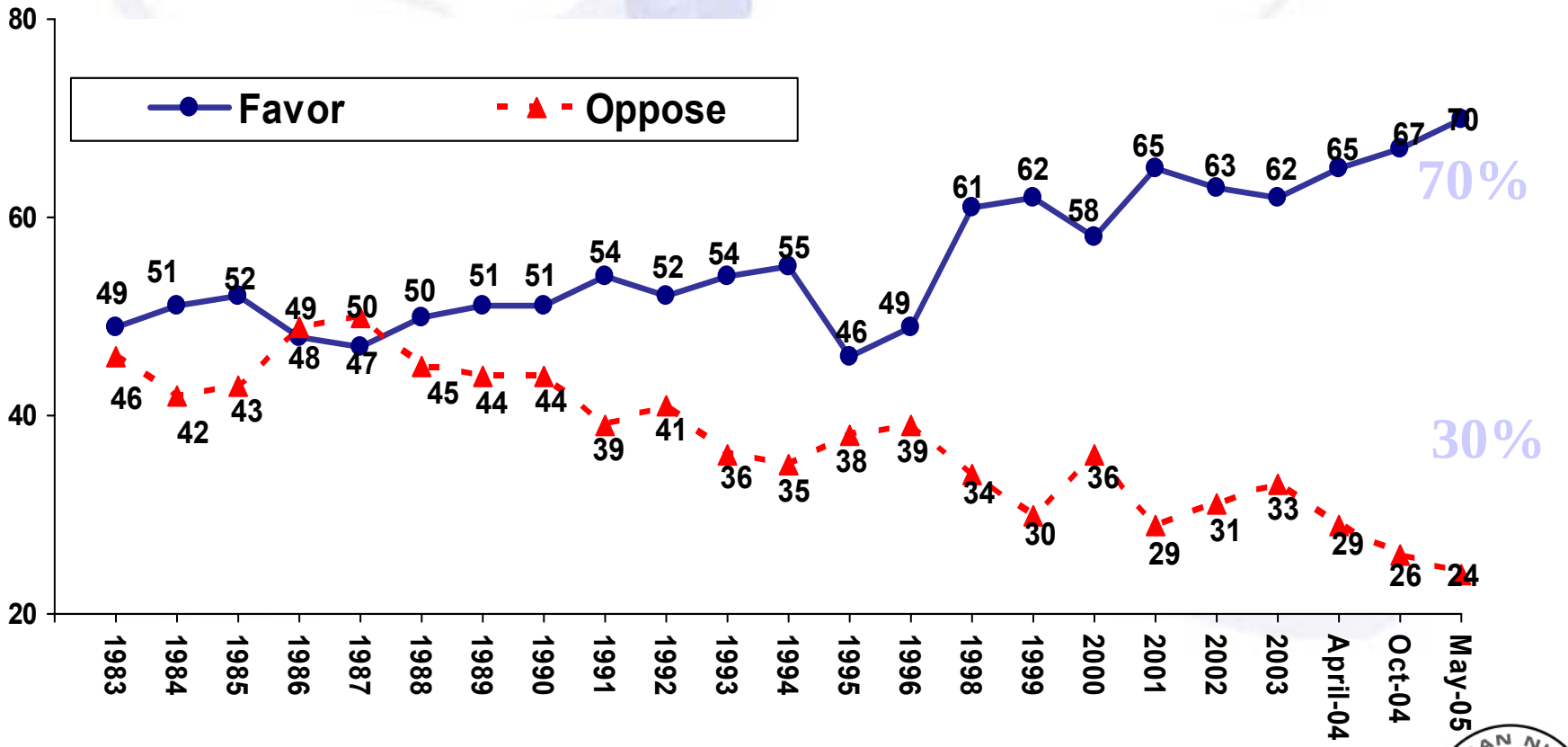
USA is decidedly pro-nuclear today



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Megatons to Megawatts

…atoms for peace.
2005 Nobel Peace Prize

- 1 out of 10 US light bulbs is powered by uranium from a former Soviet warhead
  - 6 trillion kW-hr
  - $12 billion cost
- Cost equivalent energy:
  - $600 billion in oil
  - $420 billion in gas
  - $43 billion in coal
- Energy equivalent:
  - 10 billion barrels of oil
  - 60 trillion cf natural gas
  - 3 billion tons of coal

International Policy ✔

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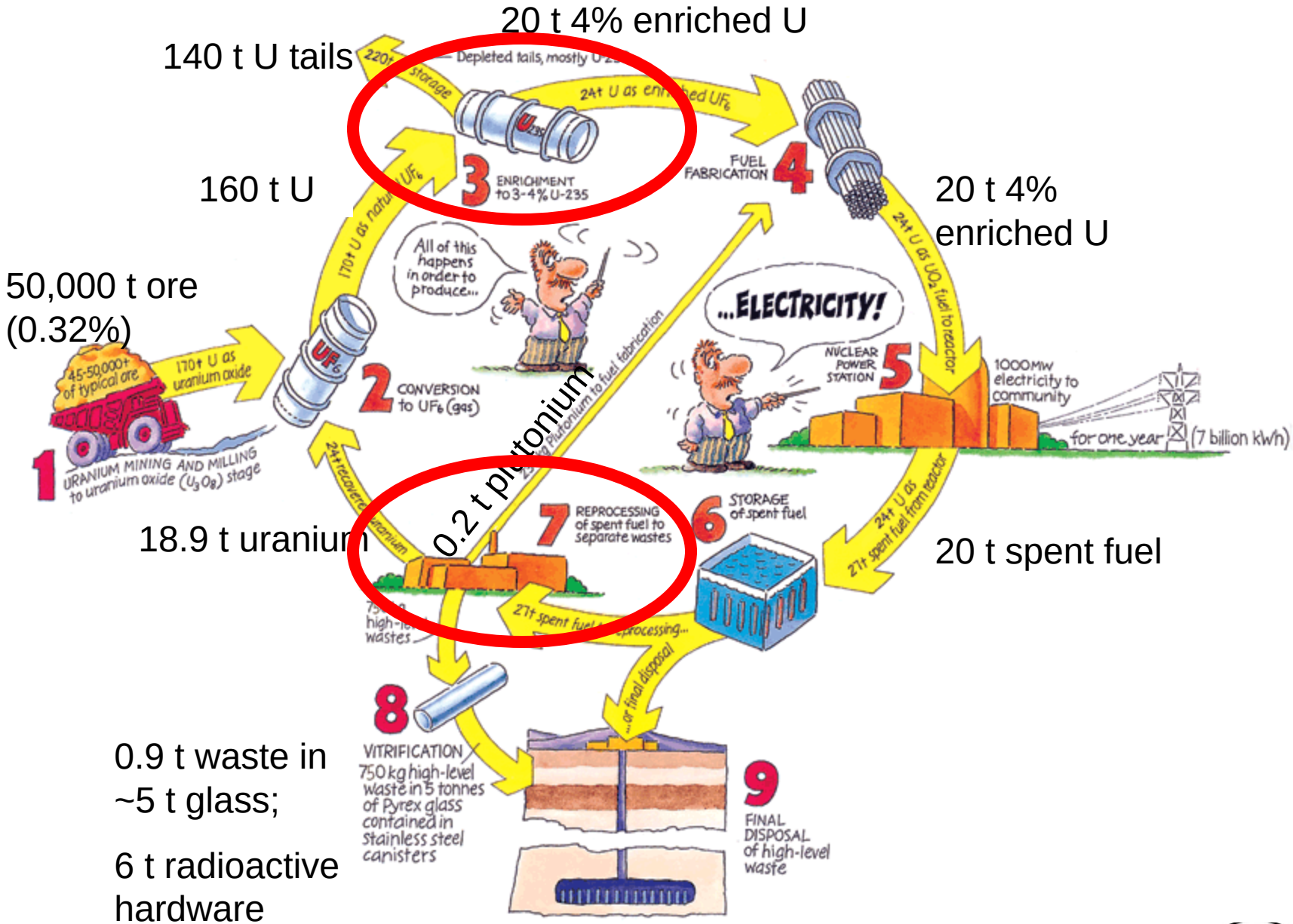

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Cost: a challenge to fuel cycle closure?

Cost Component	Units	OECD-NEA	MIT/Harvard
Ore	$/kg	20-30-40	30
Conversion	$/kg	3-5-7	8
Enrichment	$/kg SWU	50-80-110	100
UOX fabrication	$/kgIHM	200-250-300	275
SF storage/disposal	$/kgIHM	410-530-650	400
Reprocessing	$/kgIHM	700-800-900	1000
HLW storage/disposal	$/kgIHM	63-72-81	300
MOX fabrication	$/kgIHM	900-1100-1300	1500

IHM: initial heavy metal

Not according to the Boston Consulting Group

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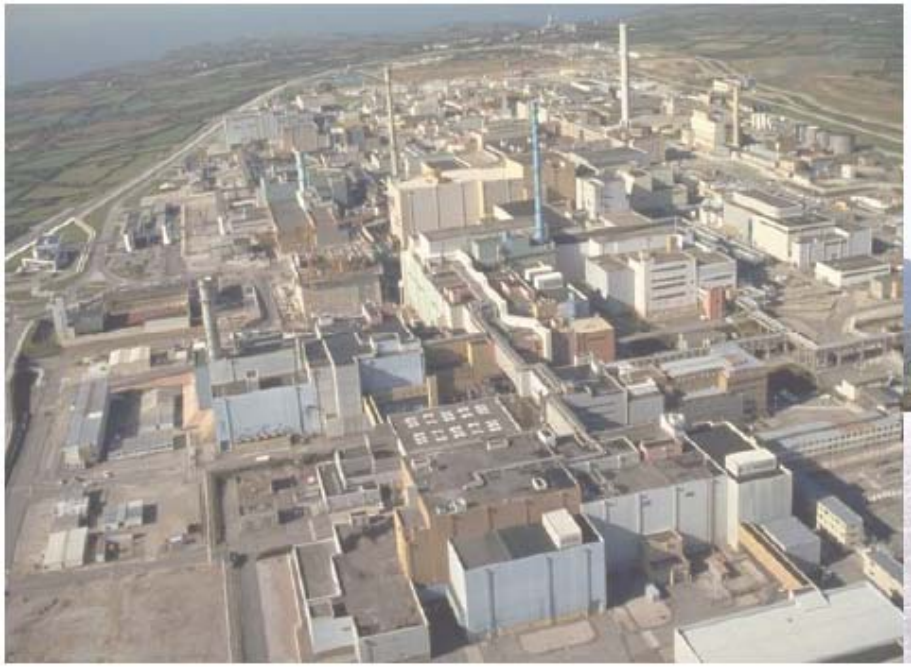
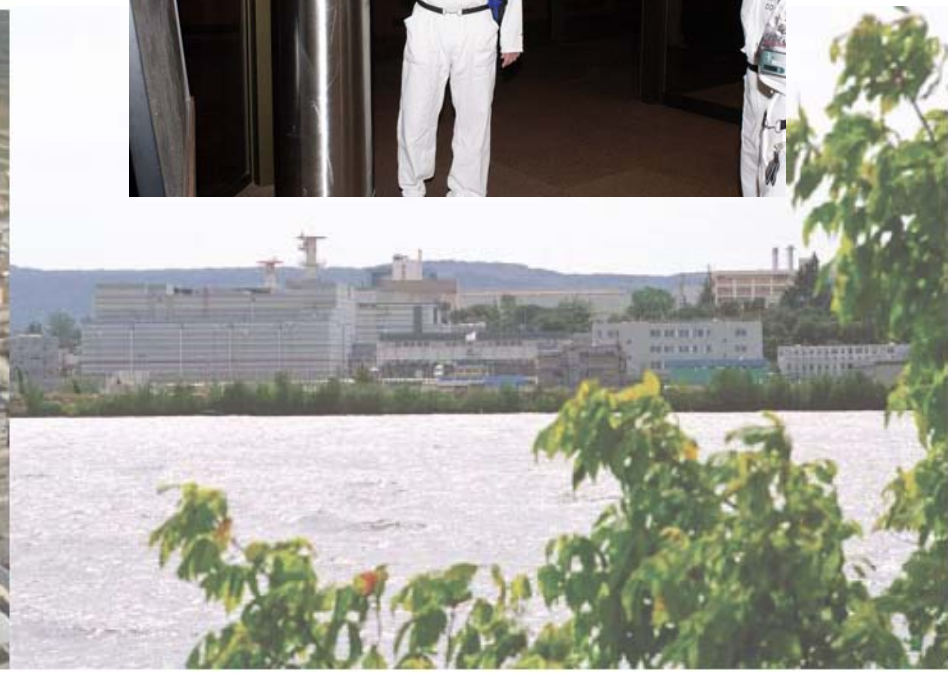
Current industrial recycle





La Hague

MELOX

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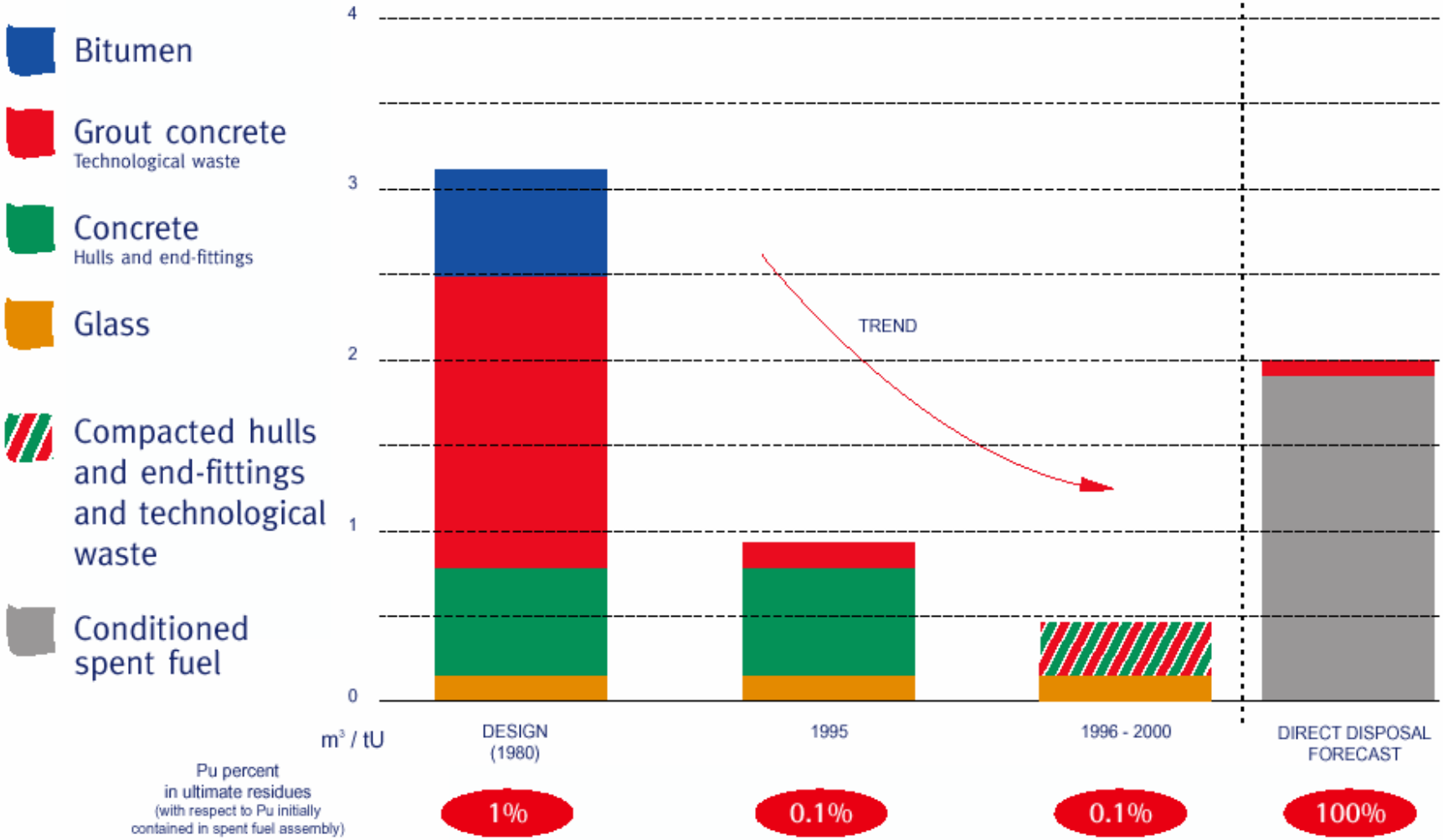
Waste volume has shrunk with *advancements*



Courtesy of COGEMA

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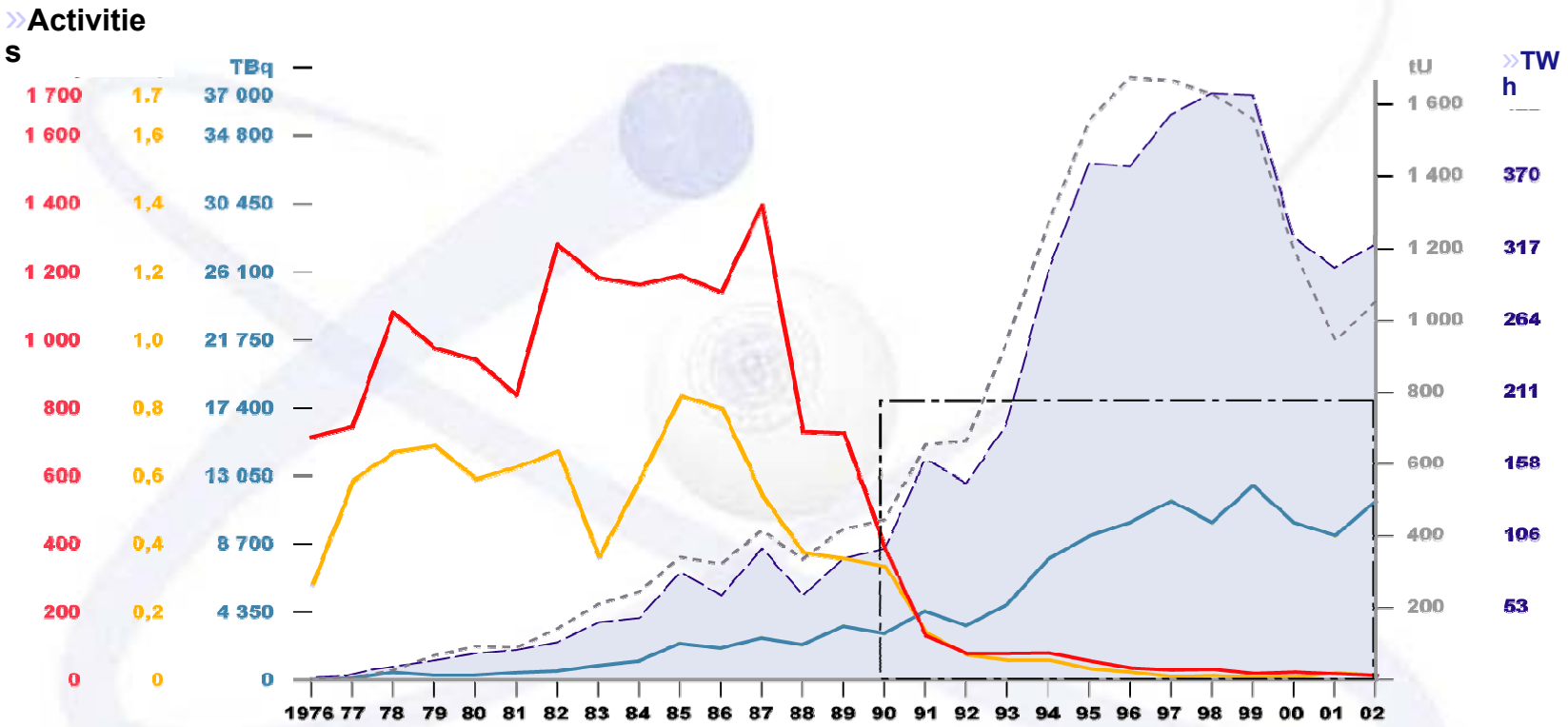
Discharges at La Hague 1976-2002



Courtesy of COGEMA

- Liquid discharges : β, γ activities (other than tritium)
- Liquid discharges : α radiation
- Liquid discharges : tritium
- tU : Tons of reprocessed spent fuel per year
- TWh : energy produced by the reprocessed fuel

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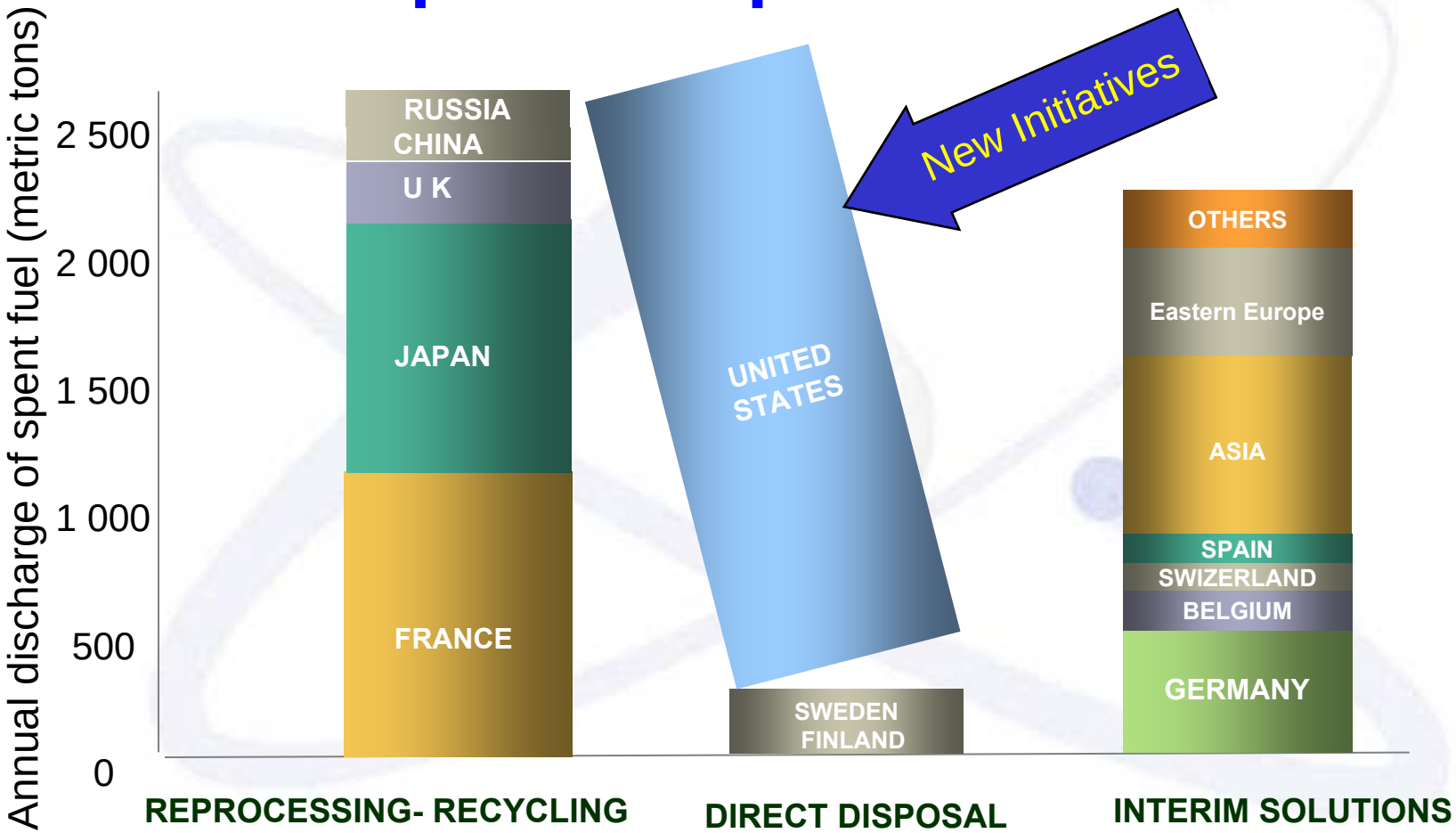
National spent fuel policies



Courtesy Areva

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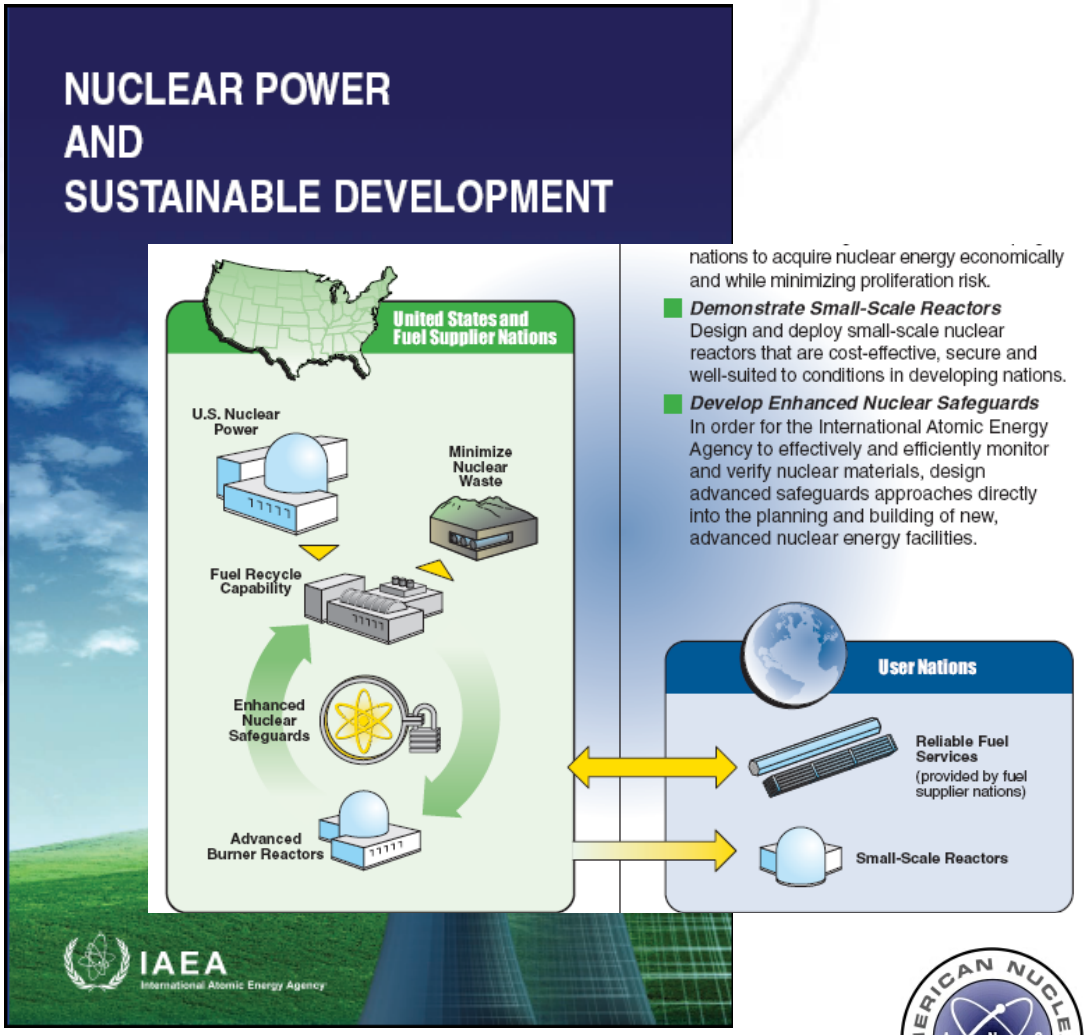
The Greening of Nuclear Energy



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Why nuclear is green; why it's not green enough

- Safe
- Potentially sustainable
- Minimal air emissions
- Readily expandable
- Minimal solid waste
- It's now a "cool" conversation topic
- Strong environmental endorsements
- Economically competitive

- Extractive industry
- Much remains to be proven
- Much remains to be implemented
- Lingering nonproliferation issues

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