2009 National Physics Teachers Workshop

Nuclear technology addressing worldwide energy demands

Idaho Falls

16 July 2009

Harold McFarlane

Deputy Associate Laboratory Director for Nuclear Science & Technology

Chairman, International Nuclear Energy Academy

& former high school physics student

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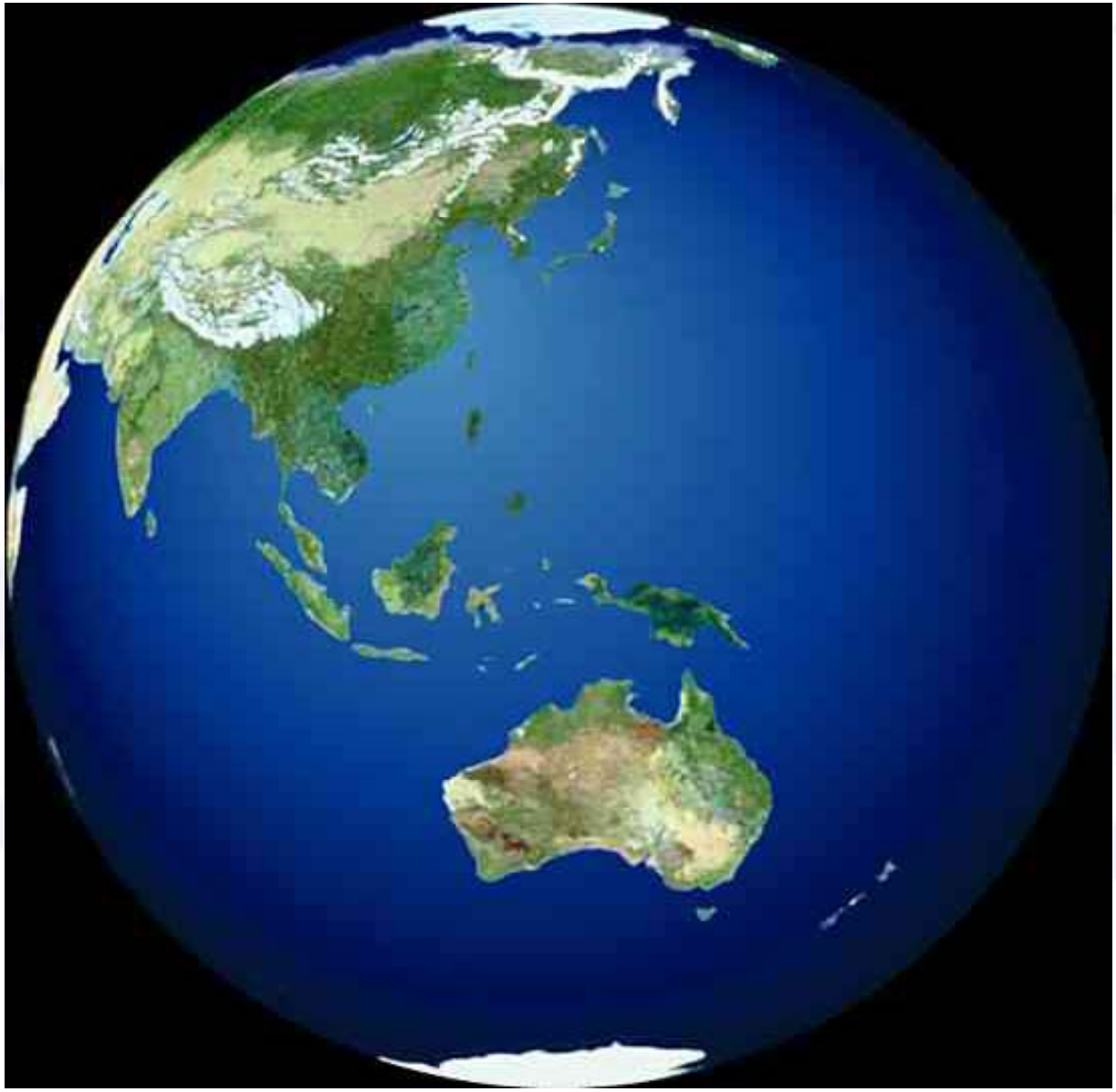

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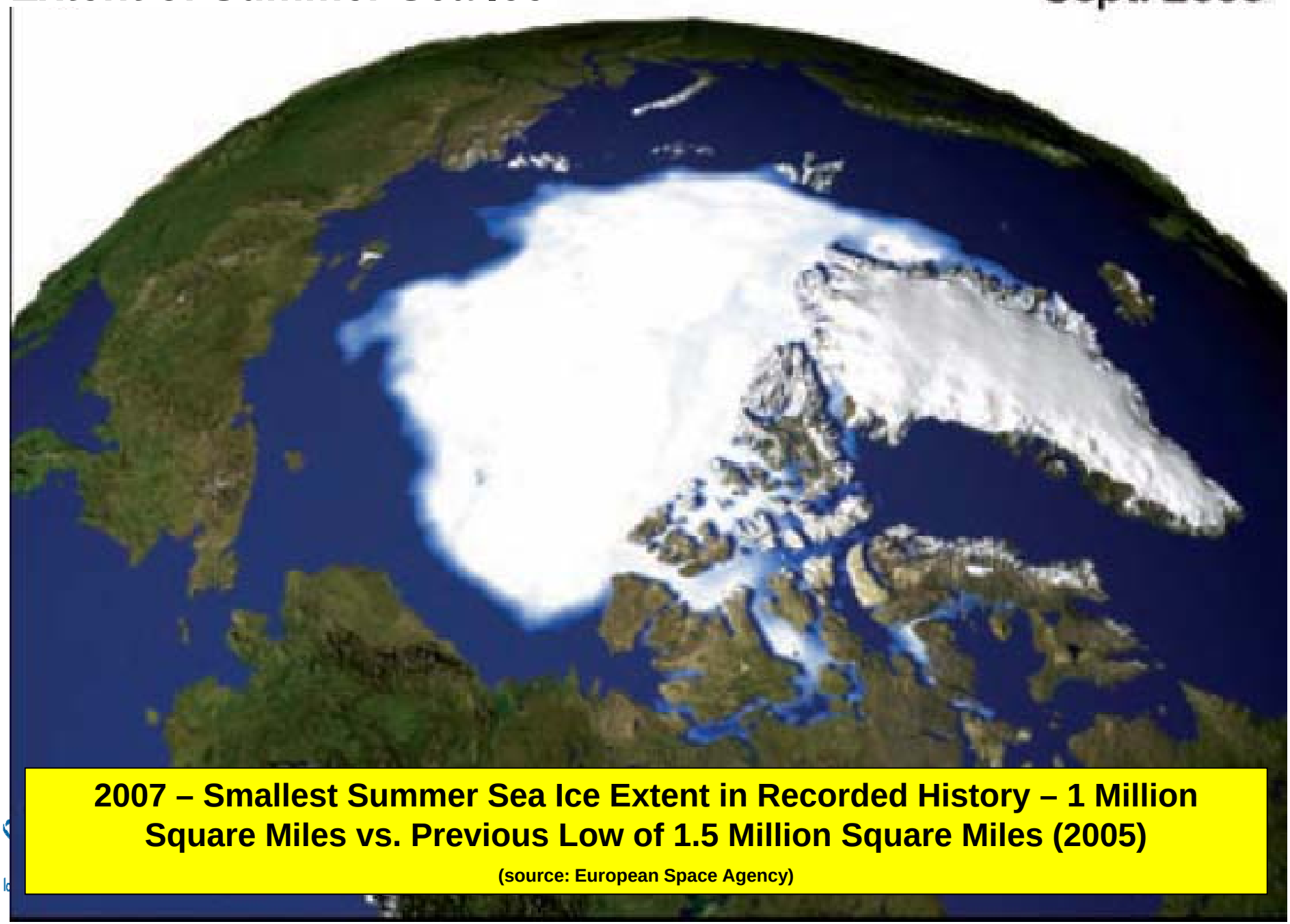
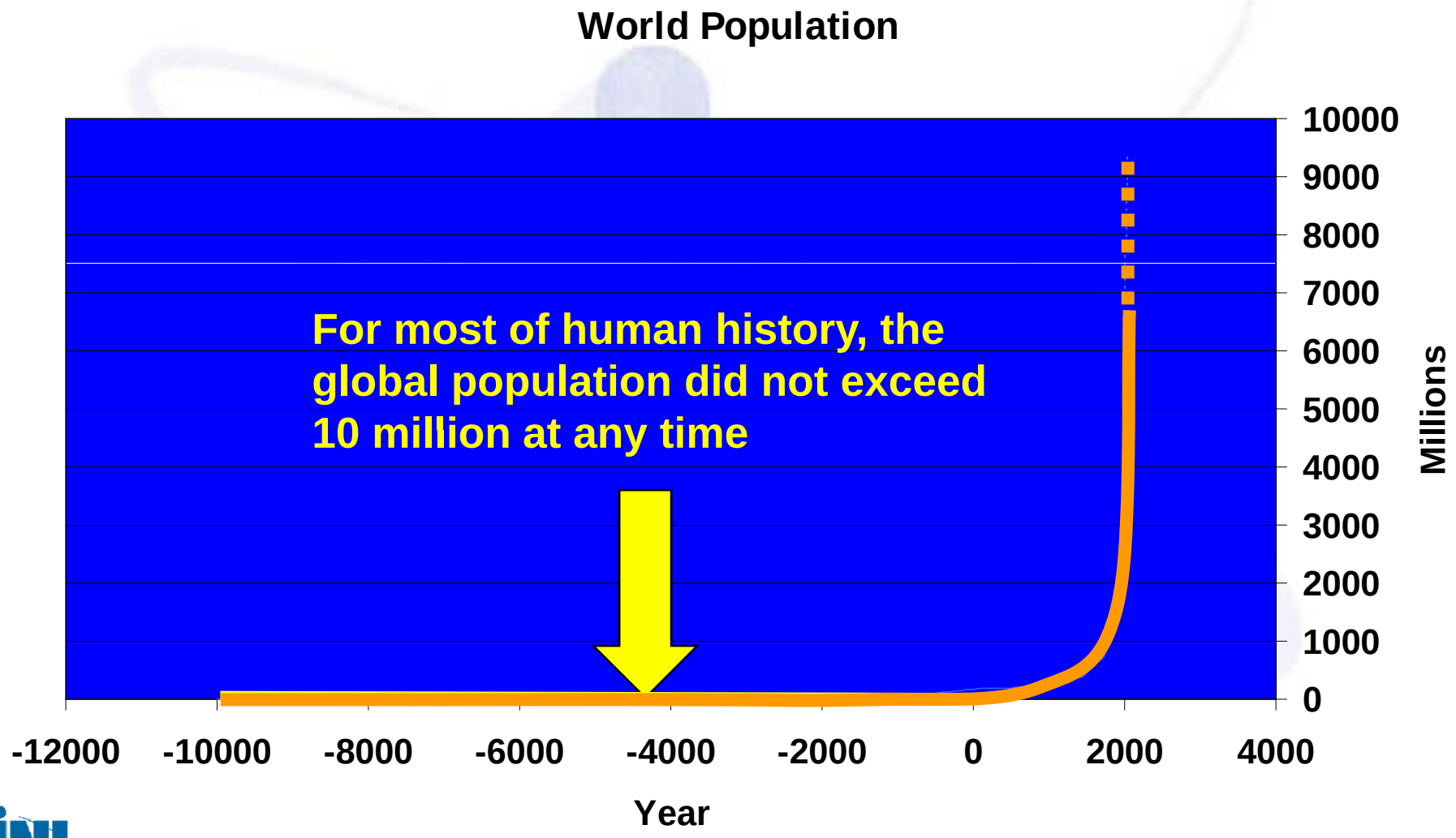
Extent of Summer Sea Ice



2007 – Smallest Summer Sea Ice Extent in Recorded History – 1 Million Square Miles vs. Previous Low of 1.5 Million Square Miles (2005)

(source: European Space Agency)

A brief review of the human population



Population 2000 years ago

The following manner of depicting the growth in population is due to John Ritch, World Nuclear Association

Population 1000 years ago

1800: Beginning of the industrial age

1927 Global Population

1960

1974

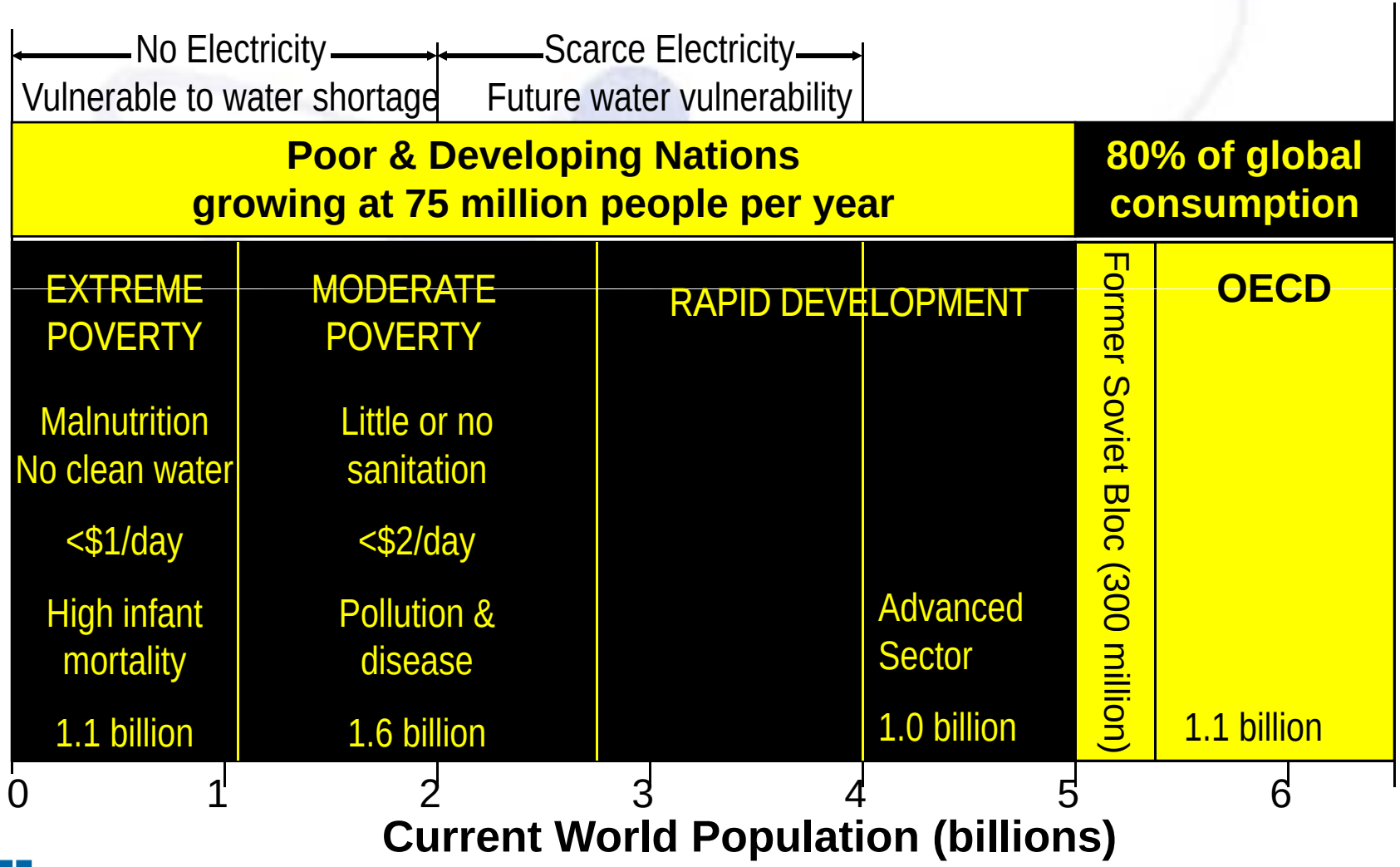
1987

1999

2050 Estimated Population

2100 estimated population

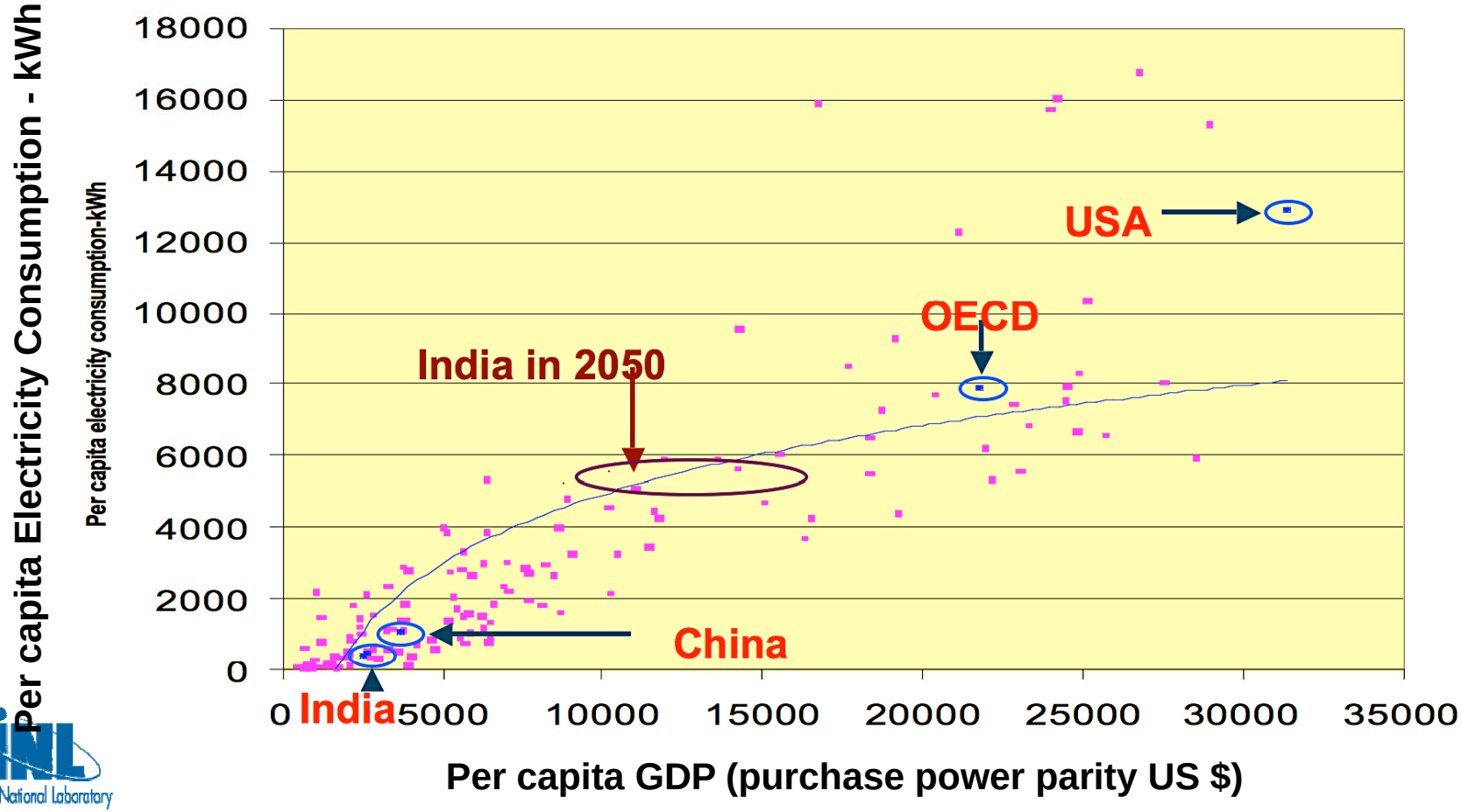
Global extremes of energy distribution



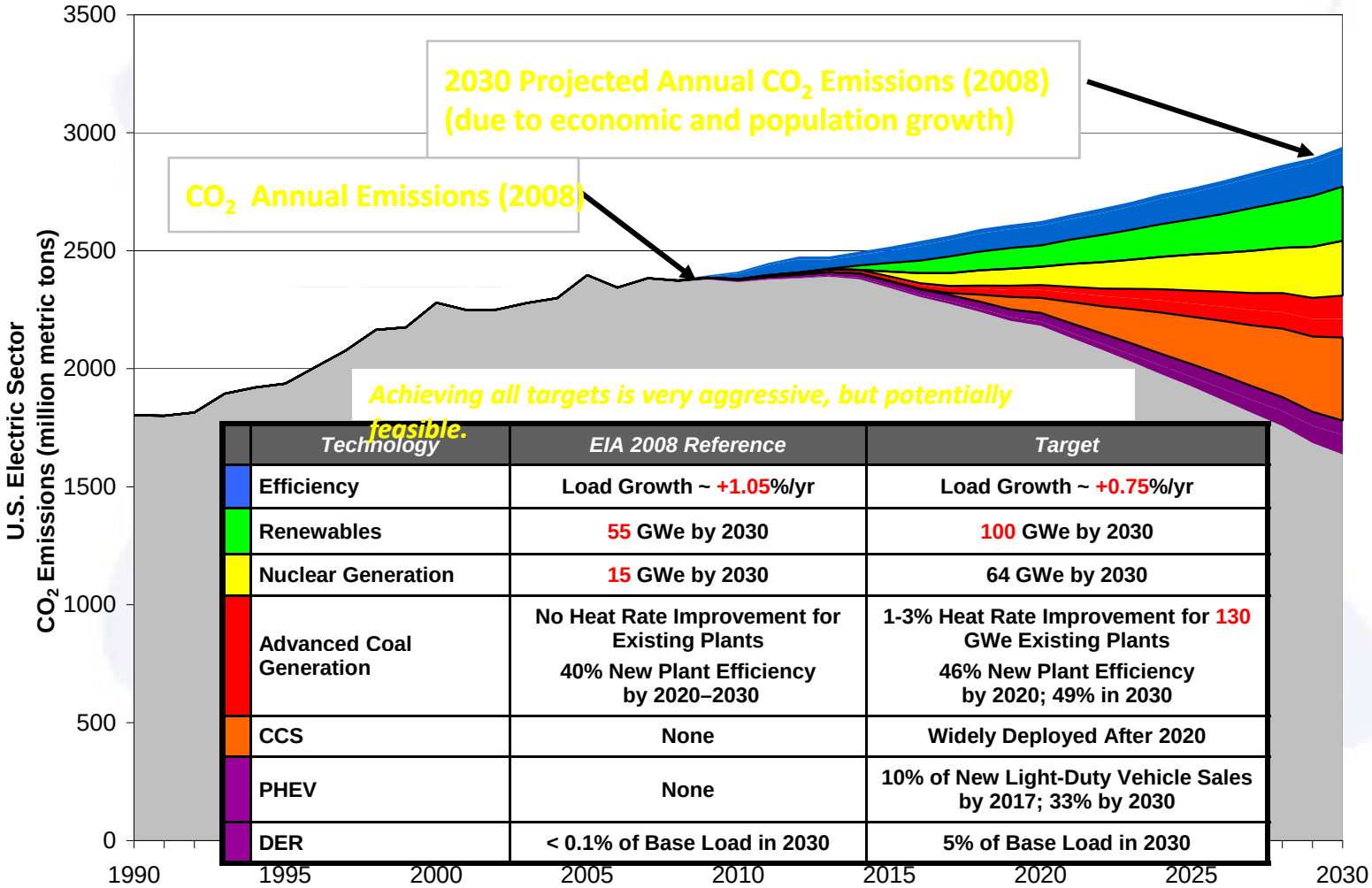
Source: John Ritch, WNA

Correlation Between Electricity Consumption & GDP

Per capita Electricity Consumption vs. Per capita GDP for various nations of the world



All technologies will be required, including nuclear energy

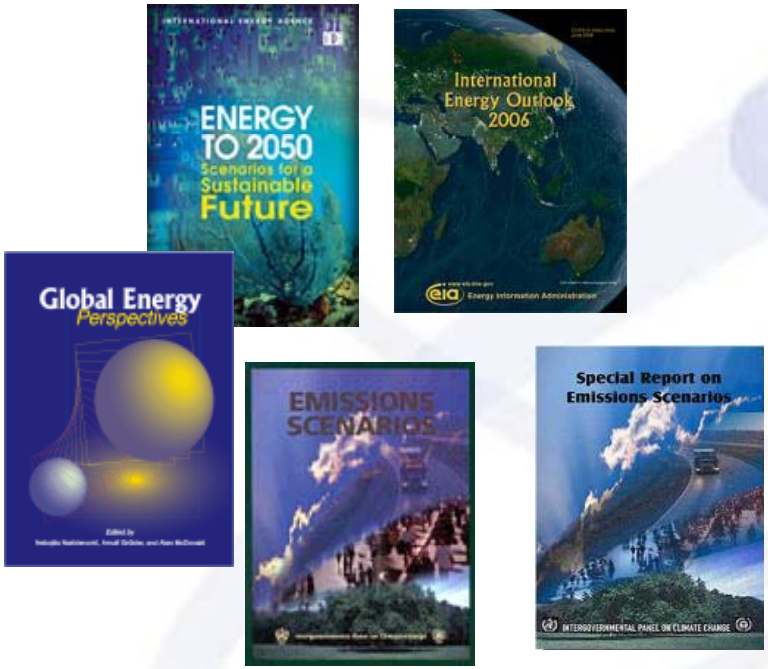


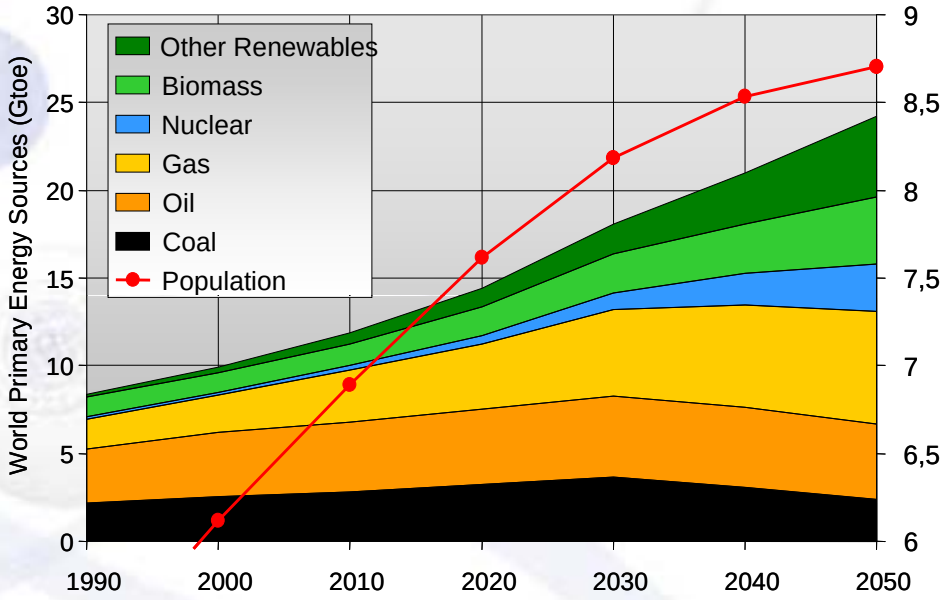
Achieving all targets is very aggressive, but potentially feasible.

Technology	EIA 2008 Reference	Target
Efficiency	Load Growth ~ +1.05%/yr	Load Growth ~ +0.75%/yr
Renewables	55 GWe by 2030	100 GWe by 2030
Nuclear Generation	15 GWe by 2030	64 GWe by 2030
Advanced Coal Generation	No Heat Rate Improvement for Existing Plants 40% New Plant Efficiency by 2020–2030	1-3% Heat Rate Improvement for 130 GWe Existing Plants 46% New Plant Efficiency by 2020; 49% in 2030
CCS	None	Widely Deployed After 2020
PHEV	None	10% of New Light-Duty Vehicle Sales by 2017; 33% by 2030
DER	< 0.1% of Base Load in 2030	5% of Base Load in 2030

Source: EIA Annual Energy Outlook, graph courtesy of Electric Power Research Institute

Energy Supply Will Increase to Meet Global Demand





Source IEA : Energy to 2050 - Scenarios for a Sustainable Future

The additional needs will mainly come from large developing Countries: China, India, Brazil…

Jacques Bouchard,
GLOBAL 2007

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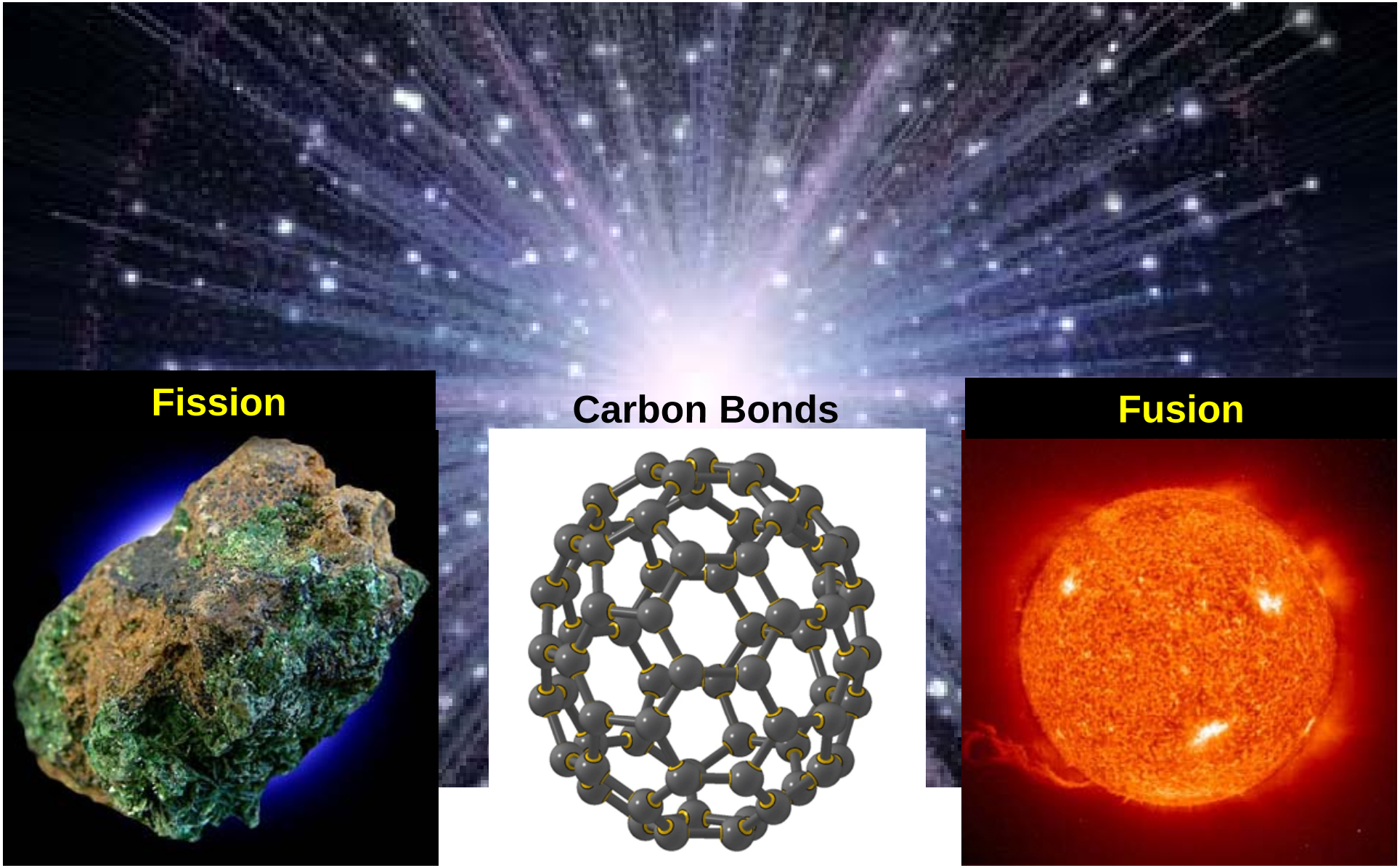
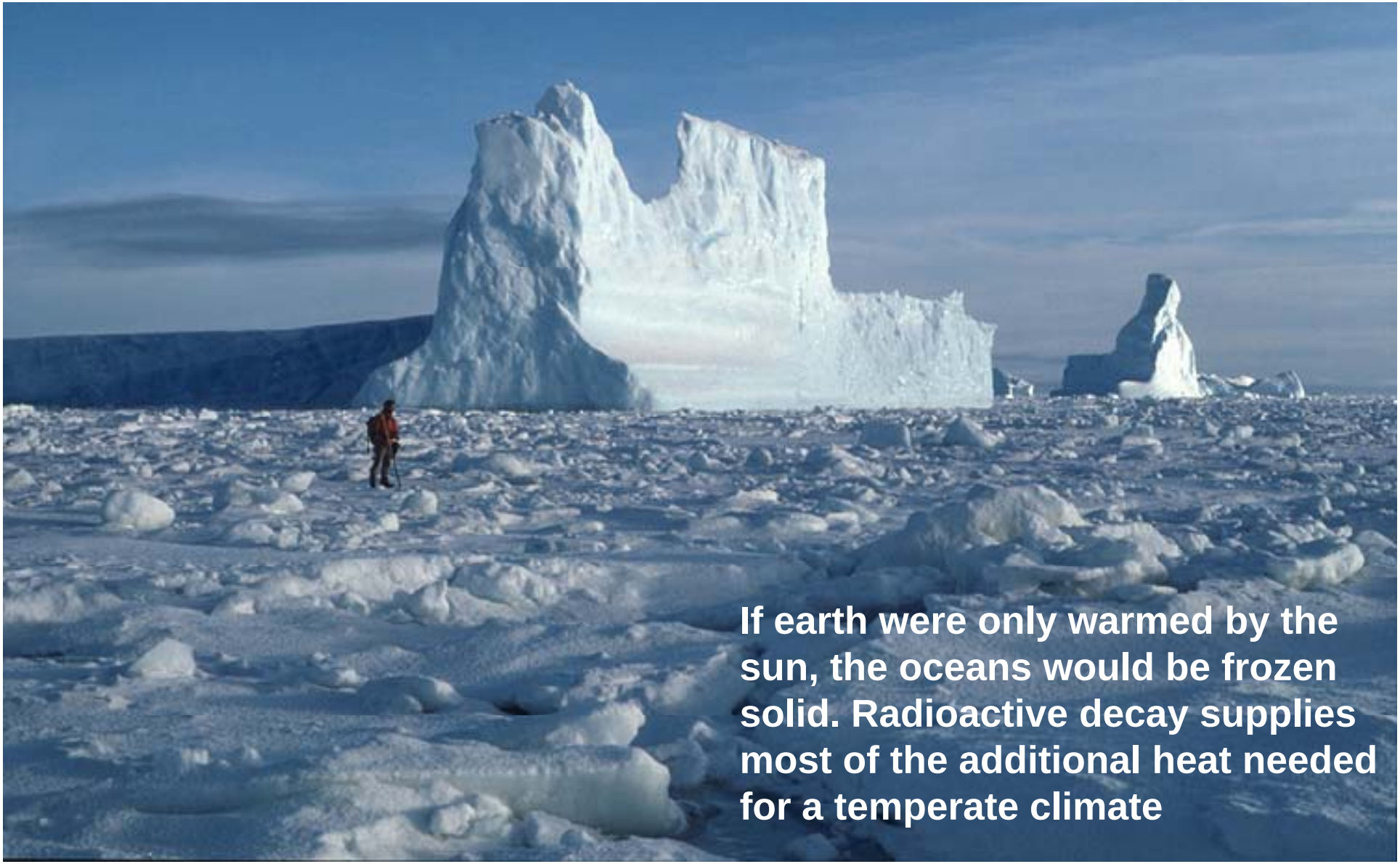
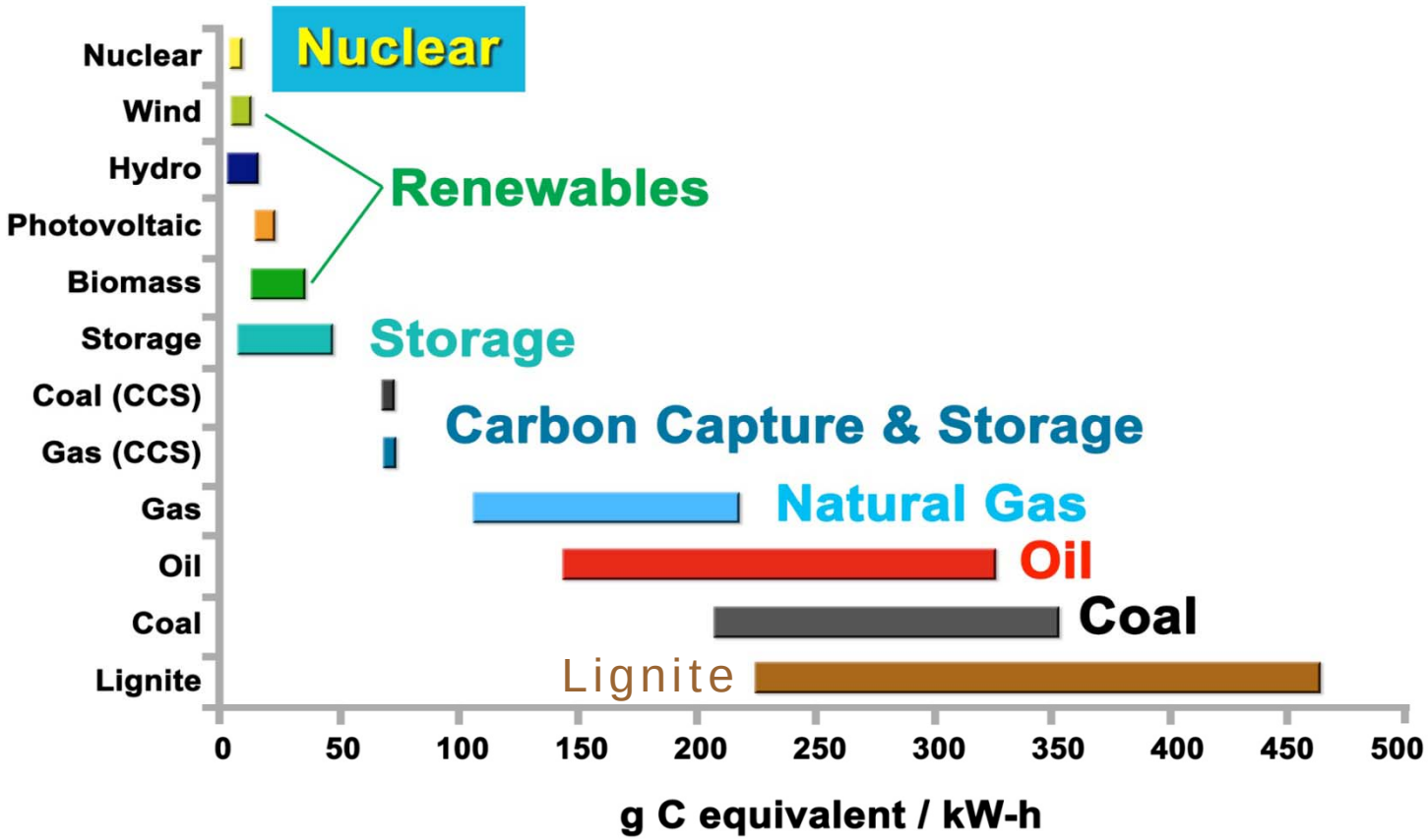
Energy: from the cosmos to electricity



Radiation enables life on earth



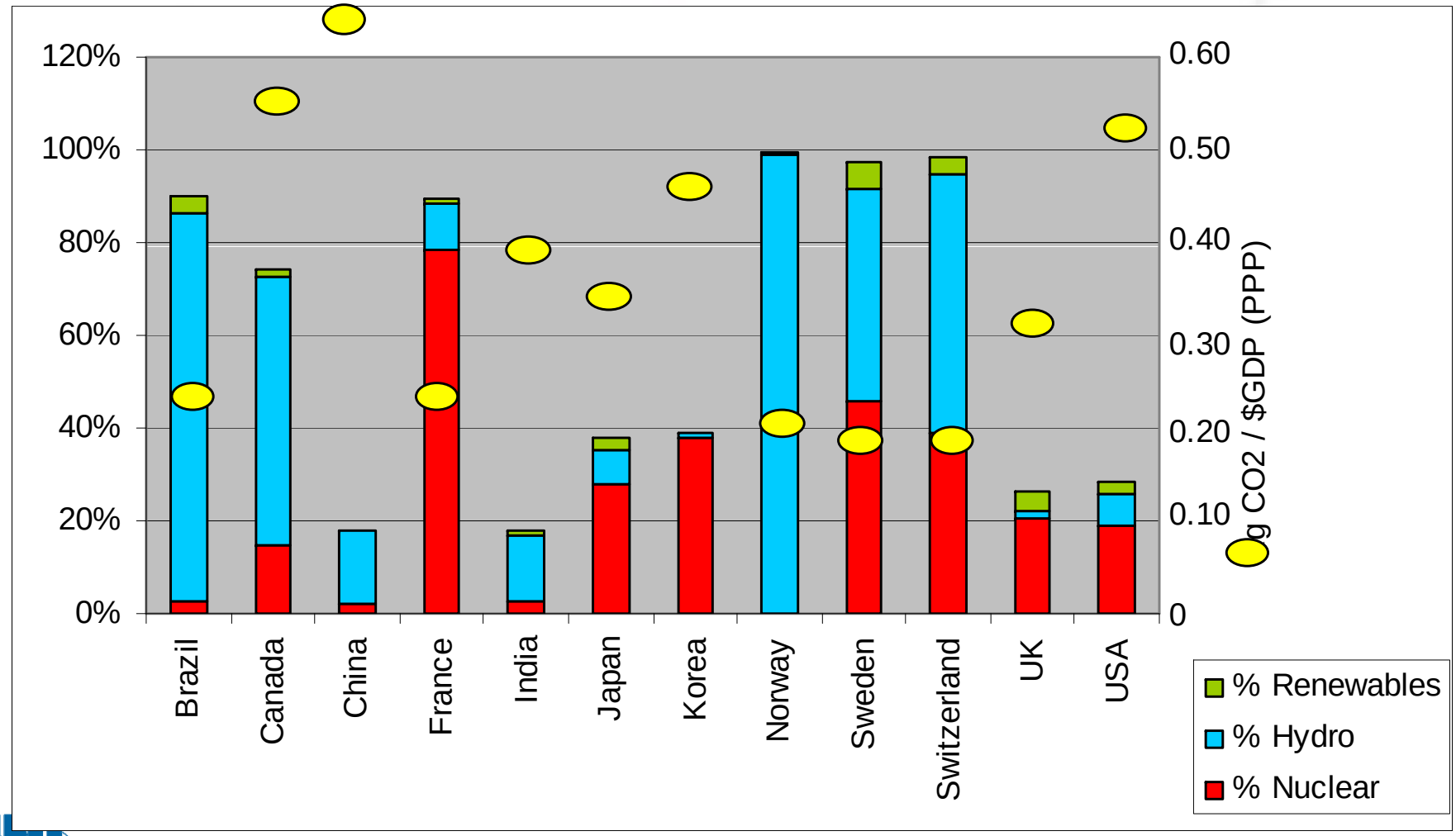
Life Cycle Greenhouse Gas Emissions



CO_2 emission rates for electricity generating alternatives (storage: batteries, pumped hydro, compressed air storage; CCS Carbon Capture and Storage) (Weisser 2007)

Source: IAEA 2006

Productivity and CO_2 intensity



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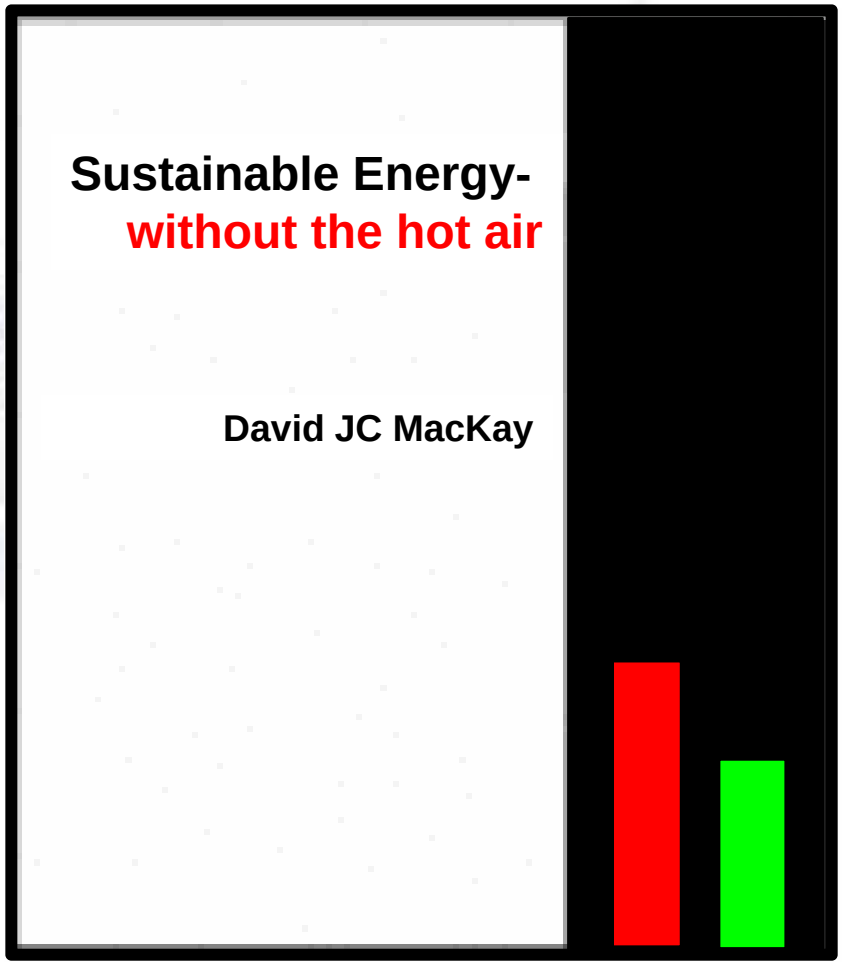
Technical basis for energy policy

- Highly recommended reading
- Very useful rule-of-thumb numbers
- No advocacy
- Free download or $0.99 on Kindle
- Looks at both supply and demand



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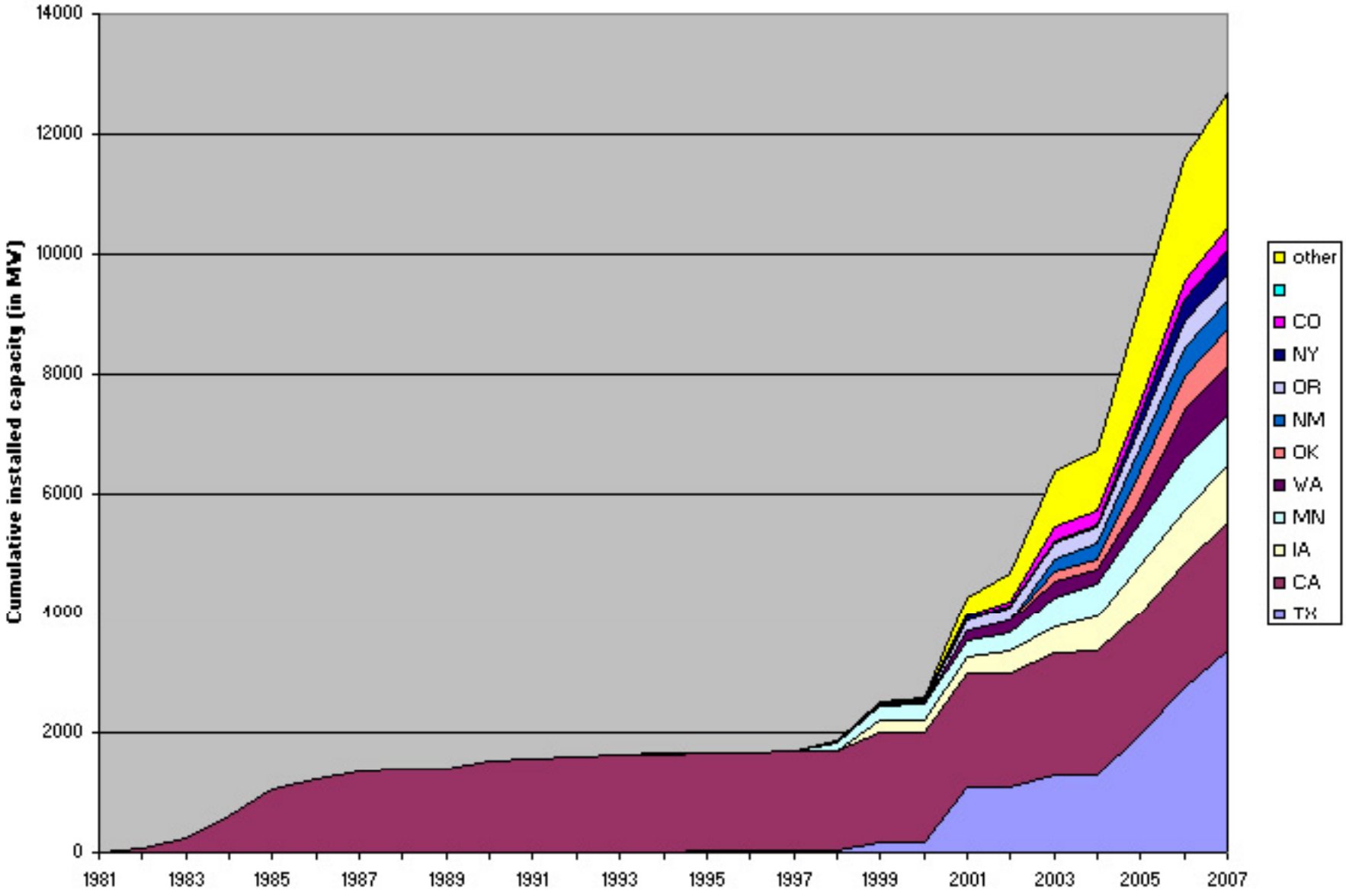
US Wind Energy Capacity



Most clean energy sources are intermittent

Texas Dodges Blackout After Drop In Wind Availability

Energy Daily Headline, 3/3/2008

- 2007 study of the daily behavior of wind by GE (maker of wind turbines) found that wind is anti-correlated with load.
- "If Texas has 15,000 megawatts of installed wind capacity, the grid could rely on having more than 75 percent of that capacity available for use only 10% of the year."

GE report based on data from the Electric Reliability Council of Texas

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Total output of Ireland's wind farms in 2007 from a capacity of 745 MW

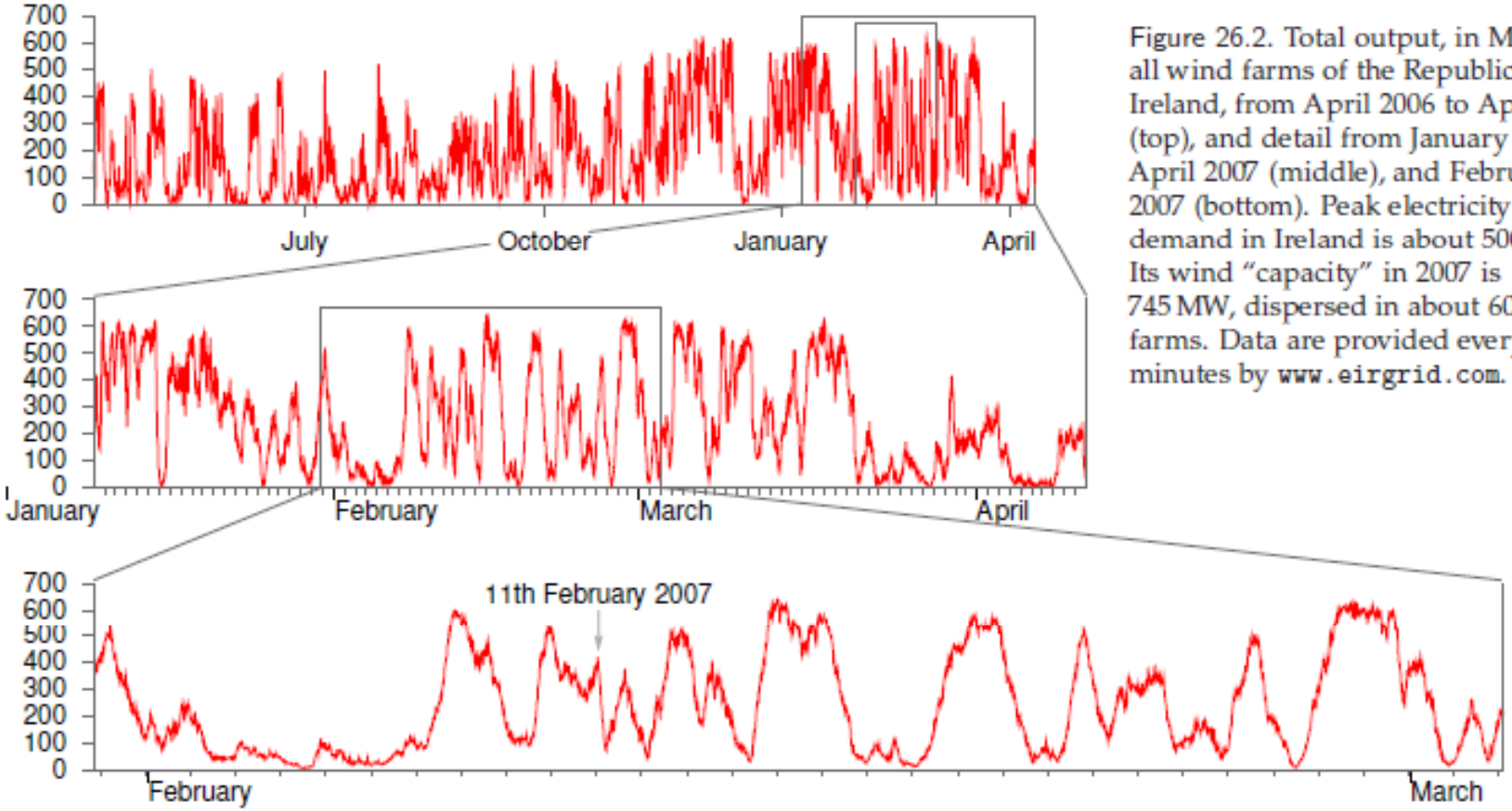

Figure 26.2. Total output, in MW, of all wind farms of the Republic of Ireland, from April 2006 to April 2007 (top), and detail from January 2007 to April 2007 (middle), and February 2007 (bottom). Peak electricity demand in Ireland is about 5000 MW. Its wind "capacity" in 2007 is 745 MW, dispersed in about 60 wind farms. Data are provided every 15 minutes by www.eirgrid.com.

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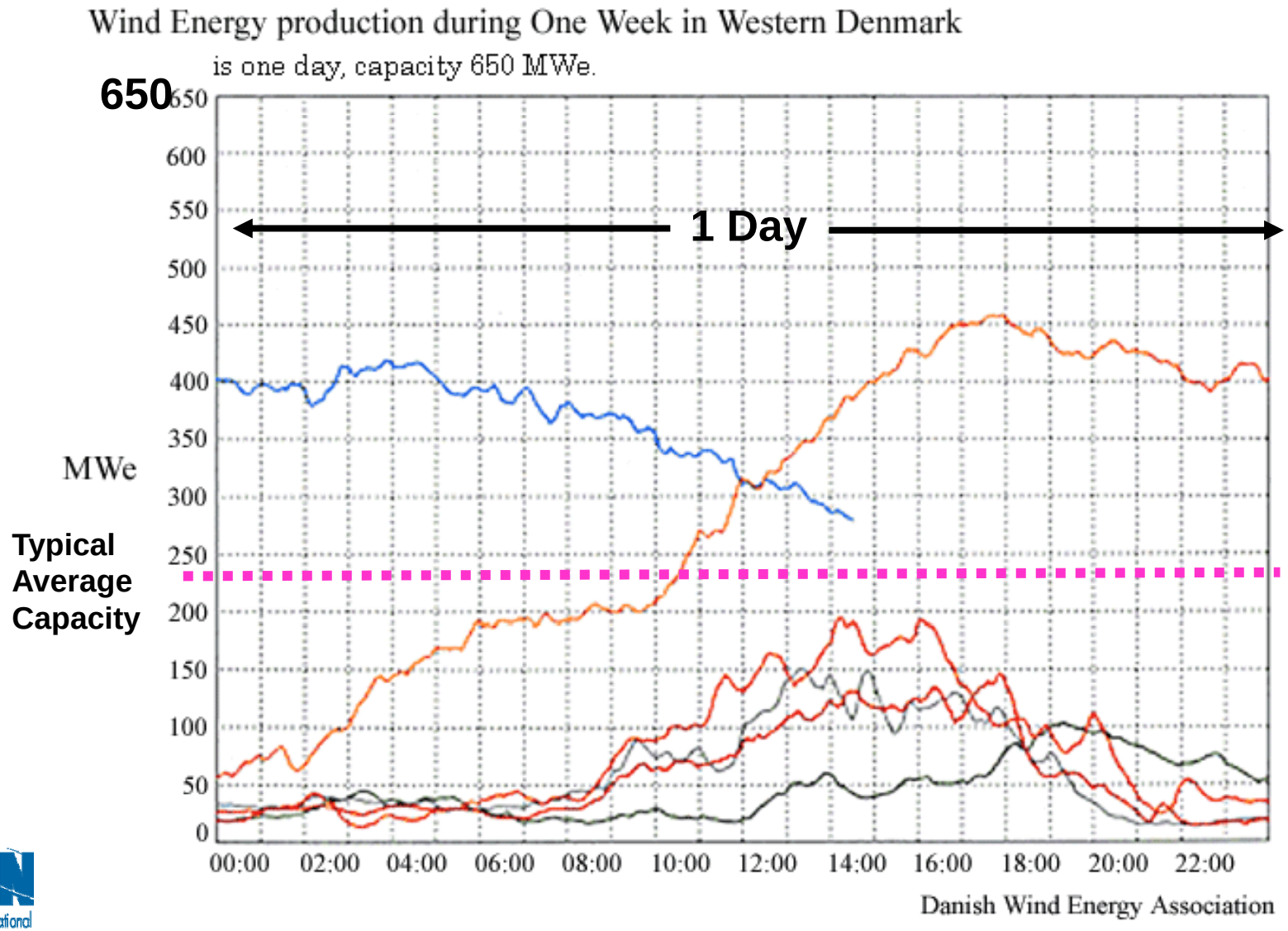
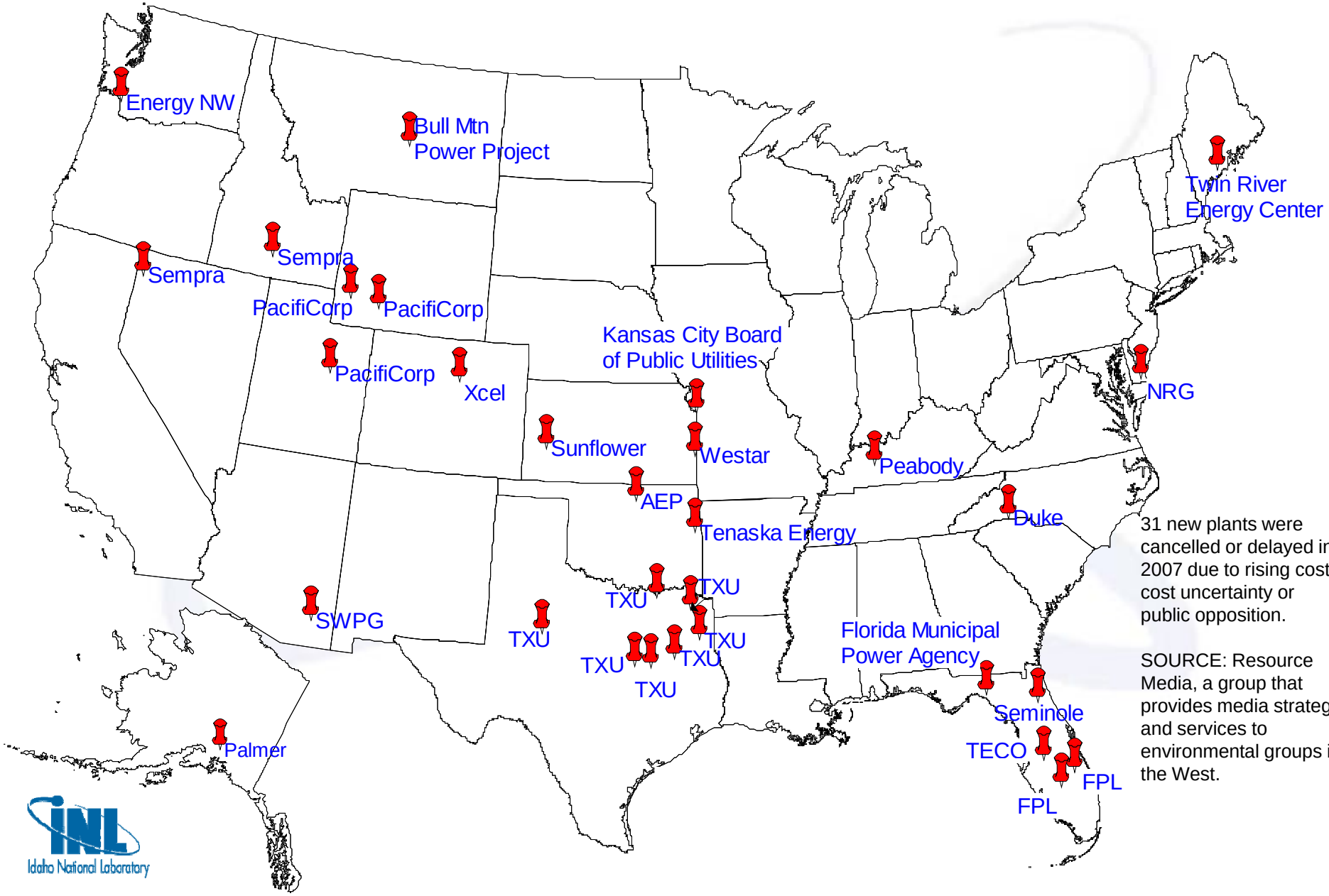
Grid stability is a major concern with a high percentage of variable generation



U.S Coal Fired Power Plants Cancelled or Delayed in 2007



31 new plants were cancelled or delayed in 2007 due to rising costs, cost uncertainty or public opposition.

SOURCE: Resource Media, a group that provides media strategy and services to environmental groups in the West.

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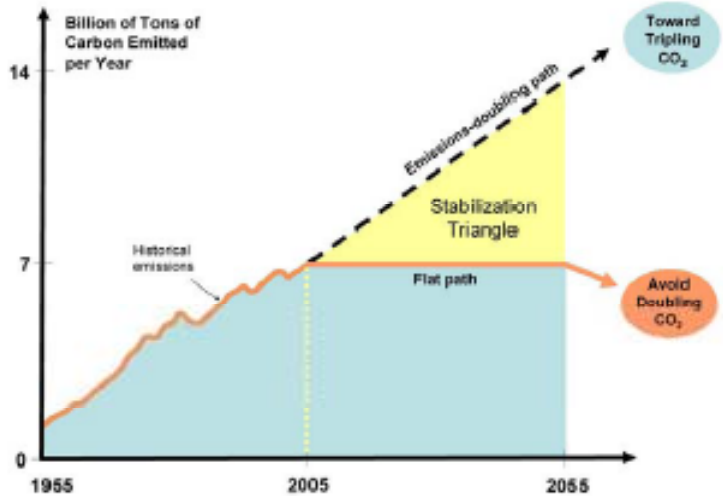
The Challenge for Nuclear Energy

- Carbon emissions need to be brought to a sustainable balance



Holding CO2 Emissions constant defines a 'triangle', or reduction goal

Achieving the goal would require 8 contributions of about 1 Gt/y in CO2 emissions each, through policy initiatives and/or technology deployment

- Nuclear energy can be part of the future, sustainable sources
- Contributing a 'nuclear wedge' would require tripling the number of nuclear plants worldwide, *to about 1000 plants*, for example
- Nuclear energy systems must continue their advances in order to unlock a potential on this scale

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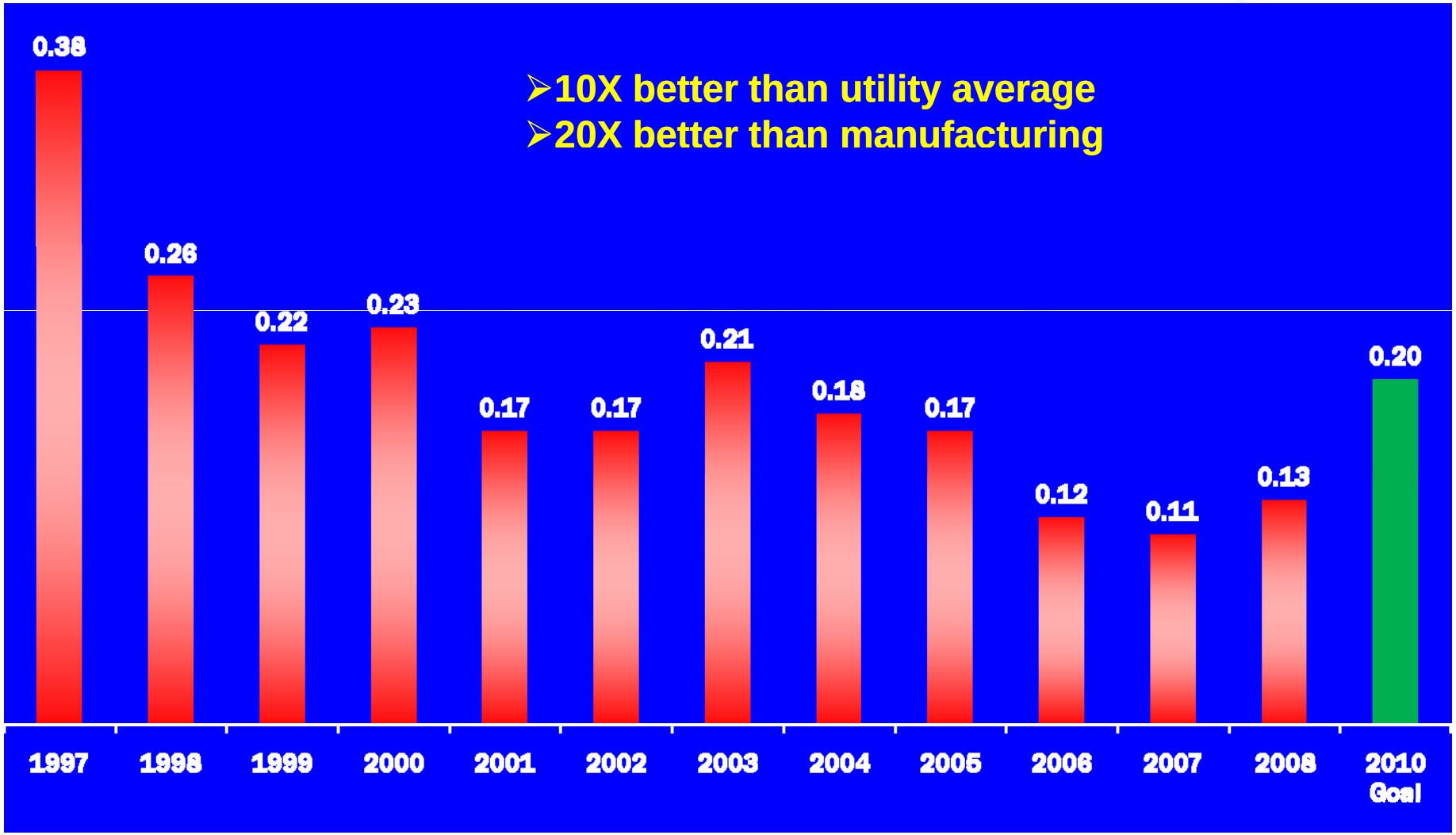
Nuclear power generation—safe workplace



ISAR = Number of accidents resulting in lost work, restricted work, or fatalities per 200,000 worker hours.
Note: Starting in 2008, data includes supplemental personnel.
Source: World Association of Nuclear Operators
Updated: 4/09

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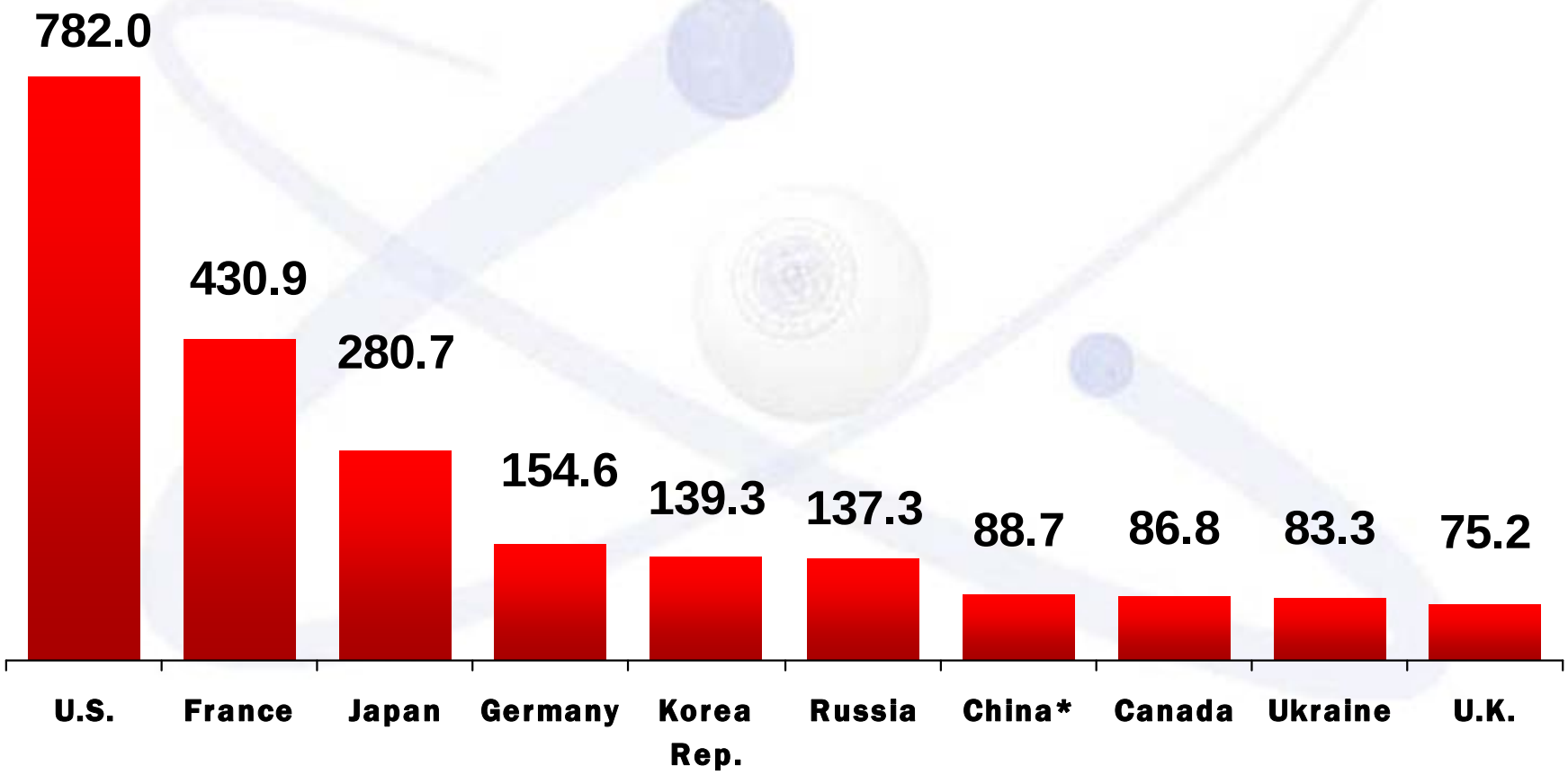
Top Nuclear Generating Countries
Billion kWh, 2005



** Includes Taiwan, China*

Source: International Atomic Energy Agency and Global Energy Decisions / Energy Information Administration

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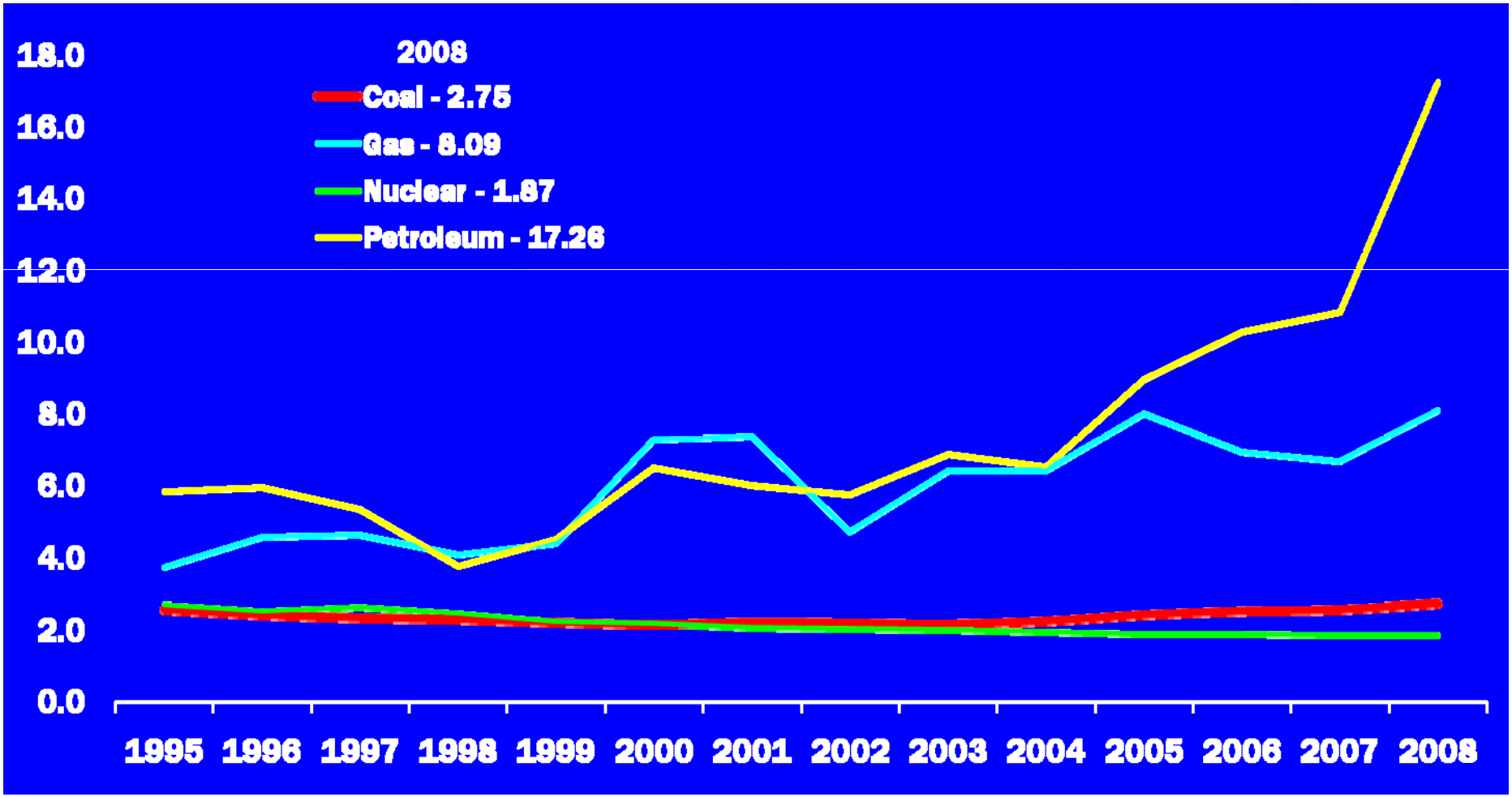
US electricity production cost, cents/kilowatt-hour



Production Costs = Operations and Maintenance Costs + Fuel Costs. Production costs do not include indirect costs and are based on FERC Form 1 filings submitted by regulated utilities. Production costs are modeled for utilities that are not regulated.

Source: Ventyx Velocity Suite
Updated: 5/09

US Nuclear by the numbers

10

- Percentage of US electricity capacity

20

- Percentage of US electricity production

75

- Percentage of US electricity emission free generation

700,000,000 tons of CO_2 emissions avoided annually by US nuclear energy production

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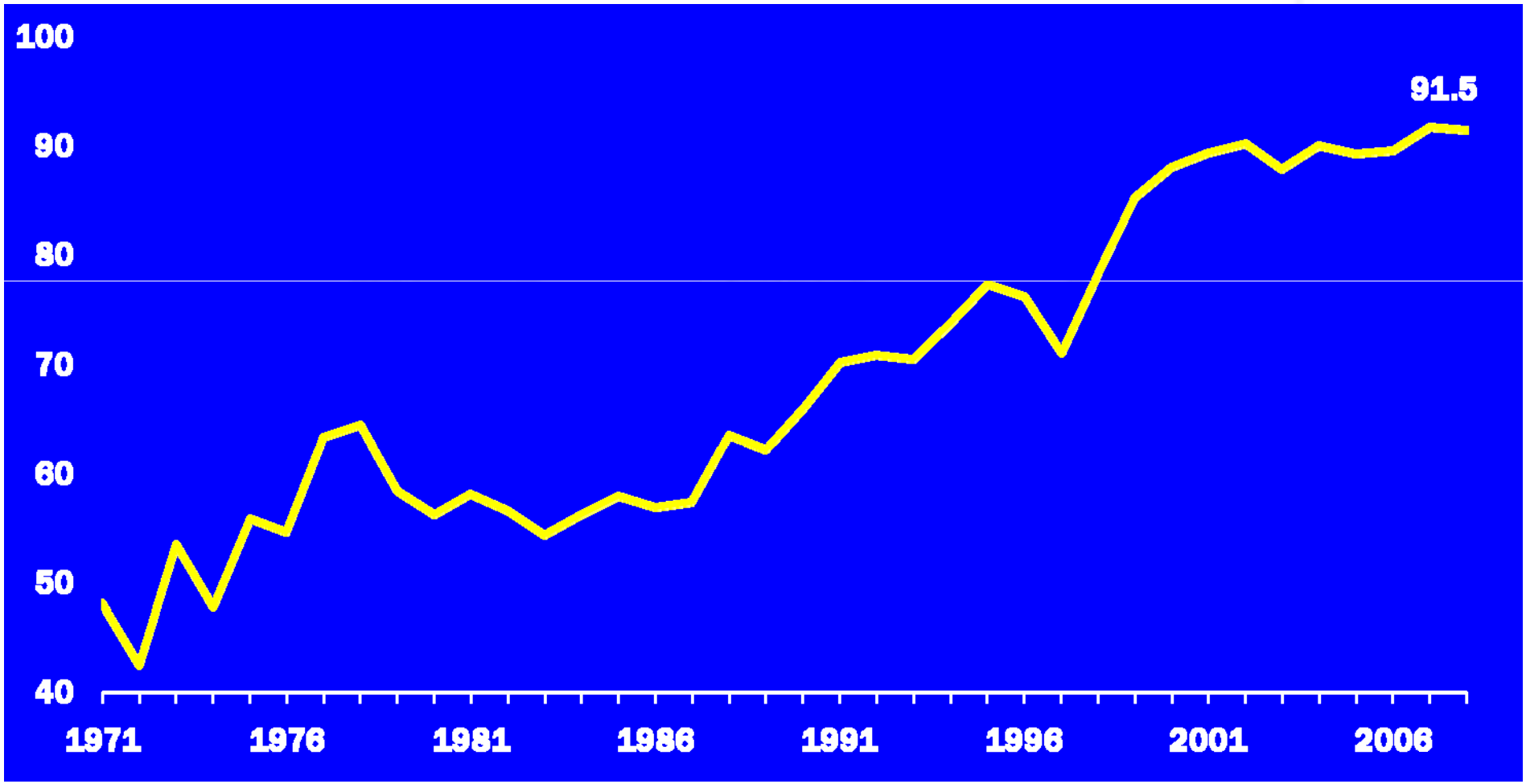
Nuclear capacity factors 1971-2008



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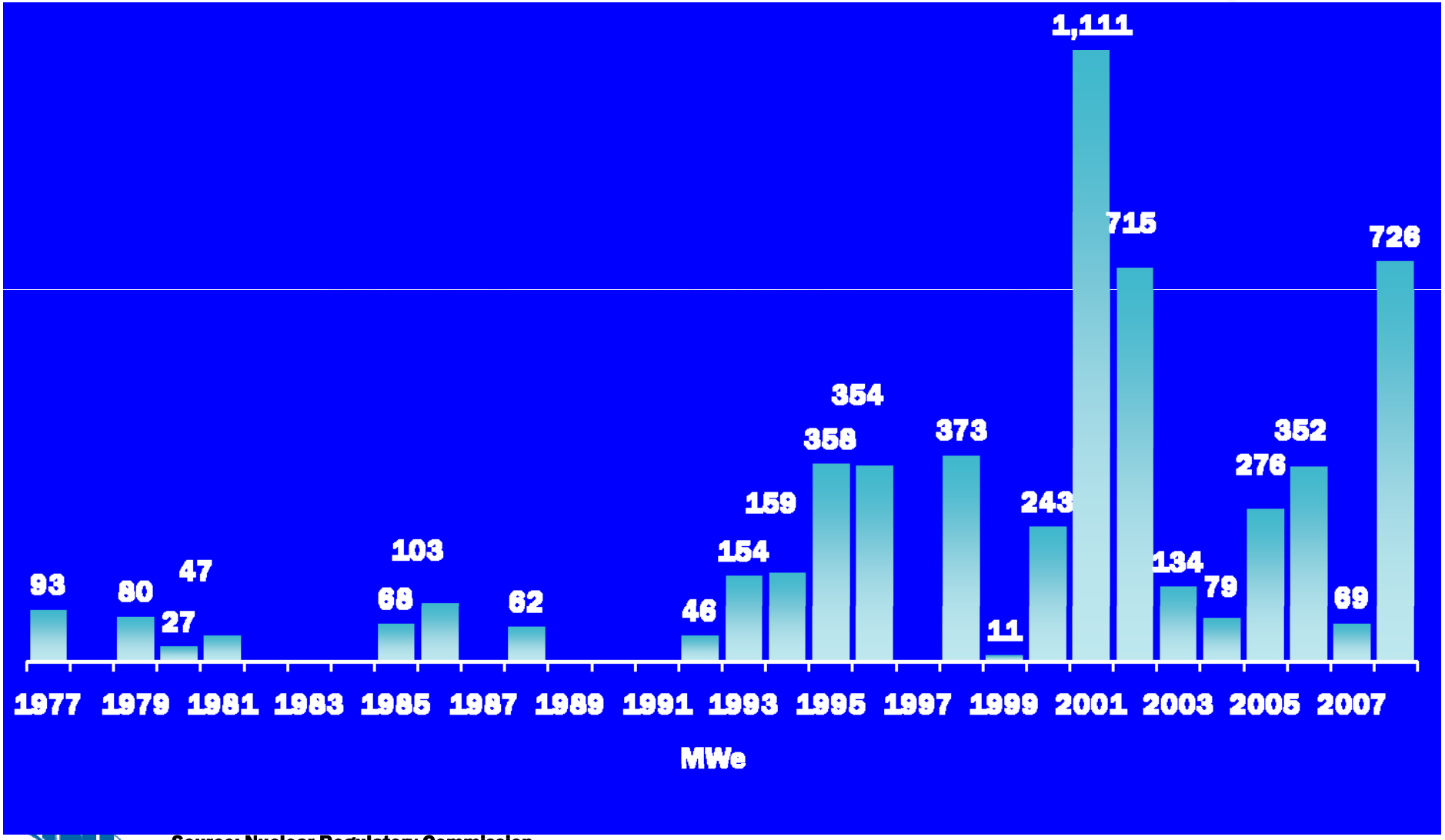
Source: Energy Information Administration

Updated: 4/09

US nuclear power uprates (MW/year)



Source: Nuclear Regulatory Commission
Updated: 11/08

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NRC has 17 applications for 26 new reactors

Expected New Nuclear Power Plant Applications Updated July 2, 2009						
Company*	Date of Application	Design	Date Accepted	Site Under Consideration	State	Existing Operating Plant
Calendar Year (CY) 2007 Applications						
NRG Energy (52-012/013)***	09/20/2007	ABWR	11/29/2007	South Texas Project (2 units)	TX	Y
NuStart Energy (52-014/015)***	10/30/2007	AP1000	01/18/2008	Bellefonte (2 units)	AL	N
UNISTAR (52-016)***	07/13/2007 (Envir.) 03/13/2008 (Safety)	EPR	01/25/2008 06/03/2008	Calvert Cliffs (1 unit)	MD	Y
Dominion (52-017)***	11/27/2007	ESBWR	01/28/2008	North Anna (1 unit)	VA	Y
Duke (52-018/019)***	12/13/2007	AP1000	02/25/2008	William Lee Nuclear Station (2 units)	SC	N
2007 TOTAL NUMBER OF APPLICATIONS = 5 TOTAL NUMBER OF UNITS = 8						
Calendar Year (CY) 2008 Applications						
Progress Energy (52-022/023)***	02/19/2008	AP1000	04/17/2008	Harris (2 units)	NC	Y
NuStart Energy (52-024)***	02/27/2008	ESBWR	04/17/2008	Grand Gulf (1 units)	MS	Y
Southern Nuclear Operating Co. (52-025/026)***	03/31/2008	AP1000	05/30/2008	Vogtle (2 units)	GA	Y
South Carolina Electric & Gas (52-027/028)***	03/31/2008	AP1000	07/31/2008	Summer (2 units)	SC	Y
Progress Energy (52-029/030) ***	07/30/2008	AP1000	10/06/2008	Levy County (2 units)	FL	N
Exelon (52-031/032)***	09/03/2008	ESWBR	10/30/2008	Victoria County (2 units)	TX	N
Detroit Edison (52-033)***	09/18/2008	ESBWR	11/25/2008	Fermi (1 unit)	MI	Y
Luminant Power (52-034/035)***	09/19/2008	USAPWR	12/2/2008	Comanche Peak (2 units)	TX	Y
Entergy (52-036)***	09/25/2008	ESBWR	12/4/2008	River Bend (1 unit)	LA	Y
AmerenUE (52-037)***	07/24/2008	EPR	12/12/2008	Callaway (1 unit)	MO	Y
UNISTAR (52-038)***	09/30/2008	EPR	12/12/2008	Nine Mile Point (1 unit)	NY	Y
PPL Generation (52-039)***	10/10/2008	EPR	12/19/2008	Bell Bend (1 unit)	PA	Y
2008 TOTAL NUMBER OF APPLICATIONS = 12 TOTAL NUMBER OF UNITS = 18						
Calendar Year (CY) 2009 Applications						
Florida Power and Light (763)	6/30/2009	AP1000		Turkey Point (2 units)	FL	Y
Amarillo Power (752)		EPR		Vicinity of Amarillo (2 units)	TX	UNK
Alternate Energy Holdings (765)		EPR		Hammett (1 unit)	ID	N
2009 TOTAL NUMBER OF APPLICATIONS = 3 TOTAL NUMBER OF UNITS = 5						
Calendar Year (CY) 2010 Applications						
Blue Castle Project		TBD		Utah	UT	N
Unannounced		TBD		TBD	TBD	UNK
2010 TOTAL NUMBER OF APPLICATIONS = 2 TOTAL NUMBER OF UNITS = 2						
Calendar Year (CY) 2011 Applications						
No Letters of Intent have been received from applicants expressing their plans to submit new COL applications in CY 2011.						
2007 – 2011 Total Number of Applications = 22 Total Number of Units = 33						

*Project Numbers/Docket Numbers **Yellow – Acceptance Review Ongoing ***Blue – Accepted/Docketed

Nuclear Regulatory Commission Web Site updated

2 July 2009

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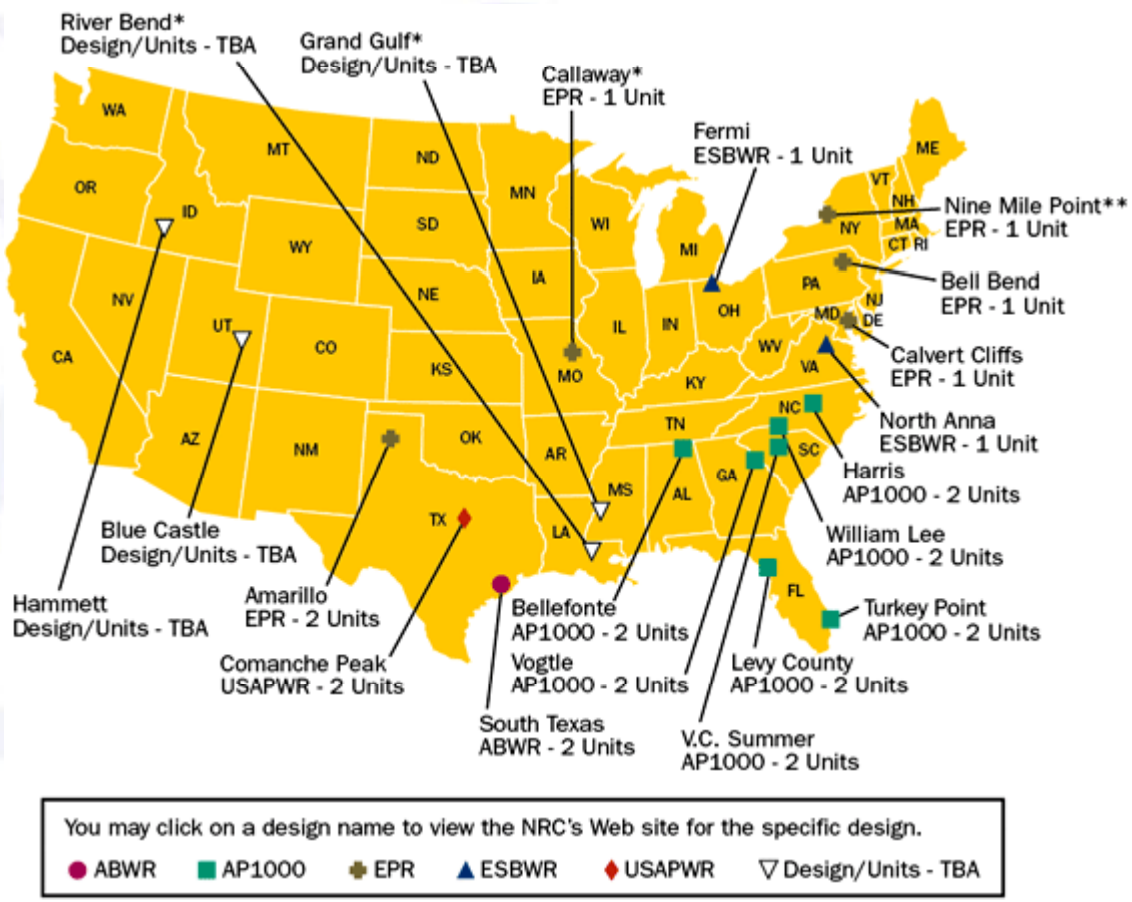
Proposed locations for new reactor plants



You may click on a design name to view the NRC's Web site for the specific design.

● ABWR ■ AP1000 ✚ EPR ▲ ESBWR ♦ USAPWR ▽ Design/Units - TBA

*Review Suspended
**Review Partially Suspended

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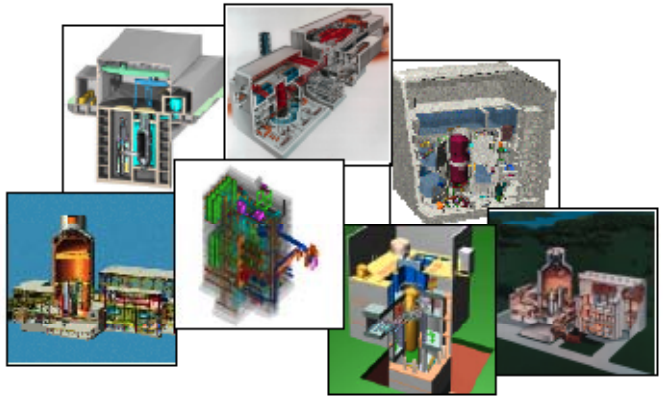
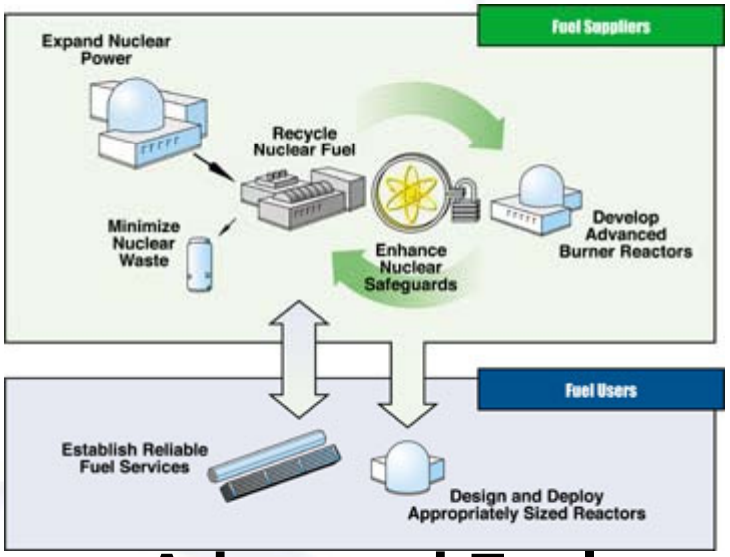
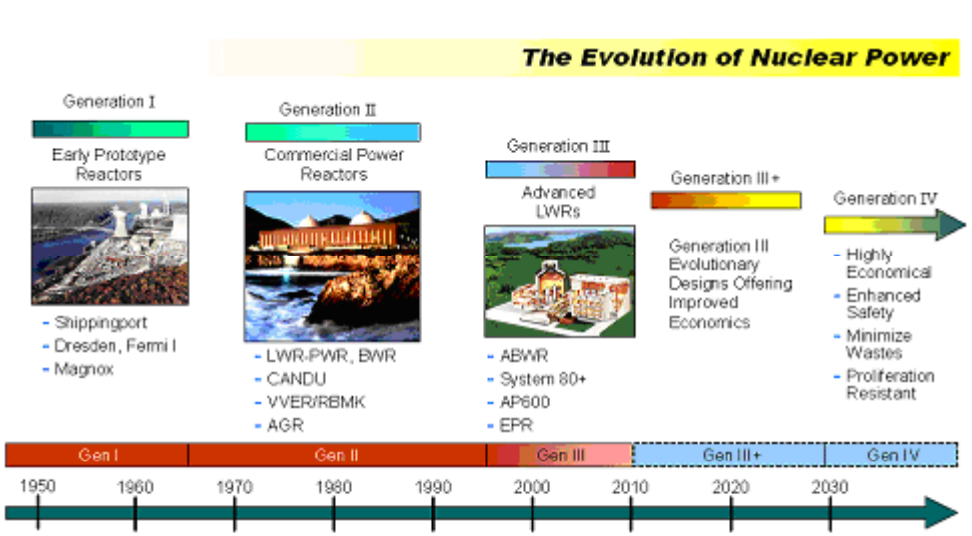
DOE programs to advance nuclear energy



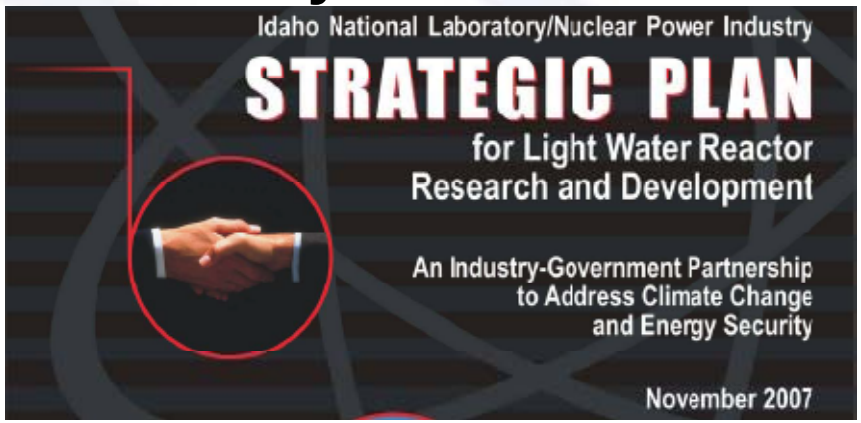
NP-2010



Advanced Fuel Cycle Initiative



Generation-IV



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Generations of Nuclear Energy

Generation I

Early Prototypes

- Shippingport
- Dresden
- Magnox

Generation II

Commercial Power

- PWRs
- BWRs
- CANDU

Generation III

Advanced LWRs

- CANDU 6
- System 80+
- AP600

Generation III+

Evolutionary Designs

- ABWR
- ACR1000
- AP1000
- APWR
- EPR
- ESBWR

Generation IV

Revolutionary Designs

- Safe
- Sustainable
- Economical
- Proliferation Resistant and Physically Secure

1950 1960 1970 1980 1990 2000 2010 2020 2030

Gen I | Gen II | Gen III | Gen III+ | Gen IV

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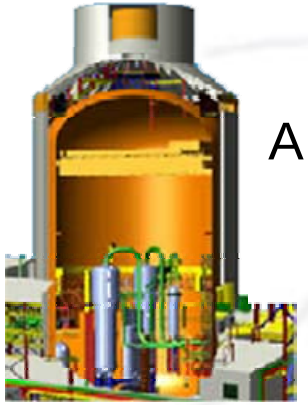
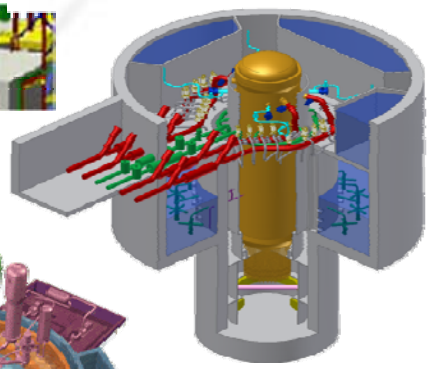
Designs competing for US market: *Generation III*

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

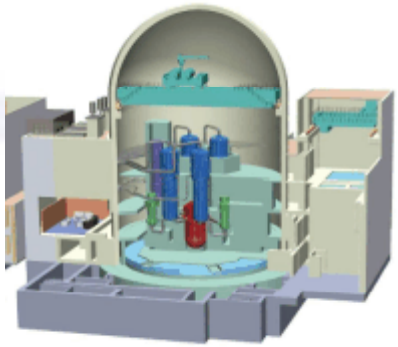


AP-1000

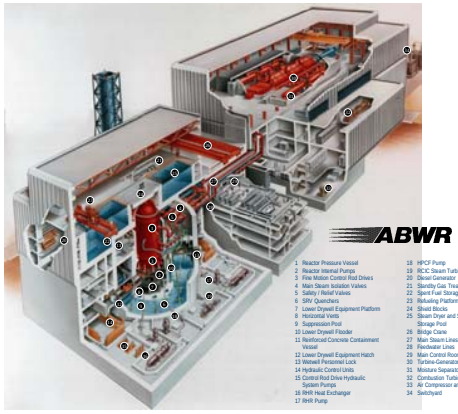


ESBWR

EPR



US APWR



ABWR

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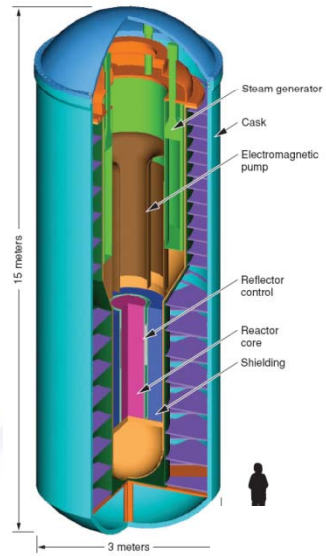
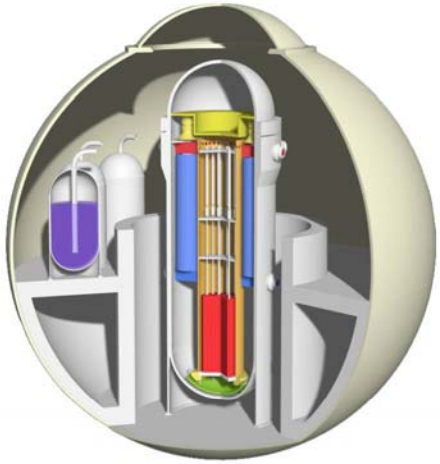
Integrated LWR SMR Vendors

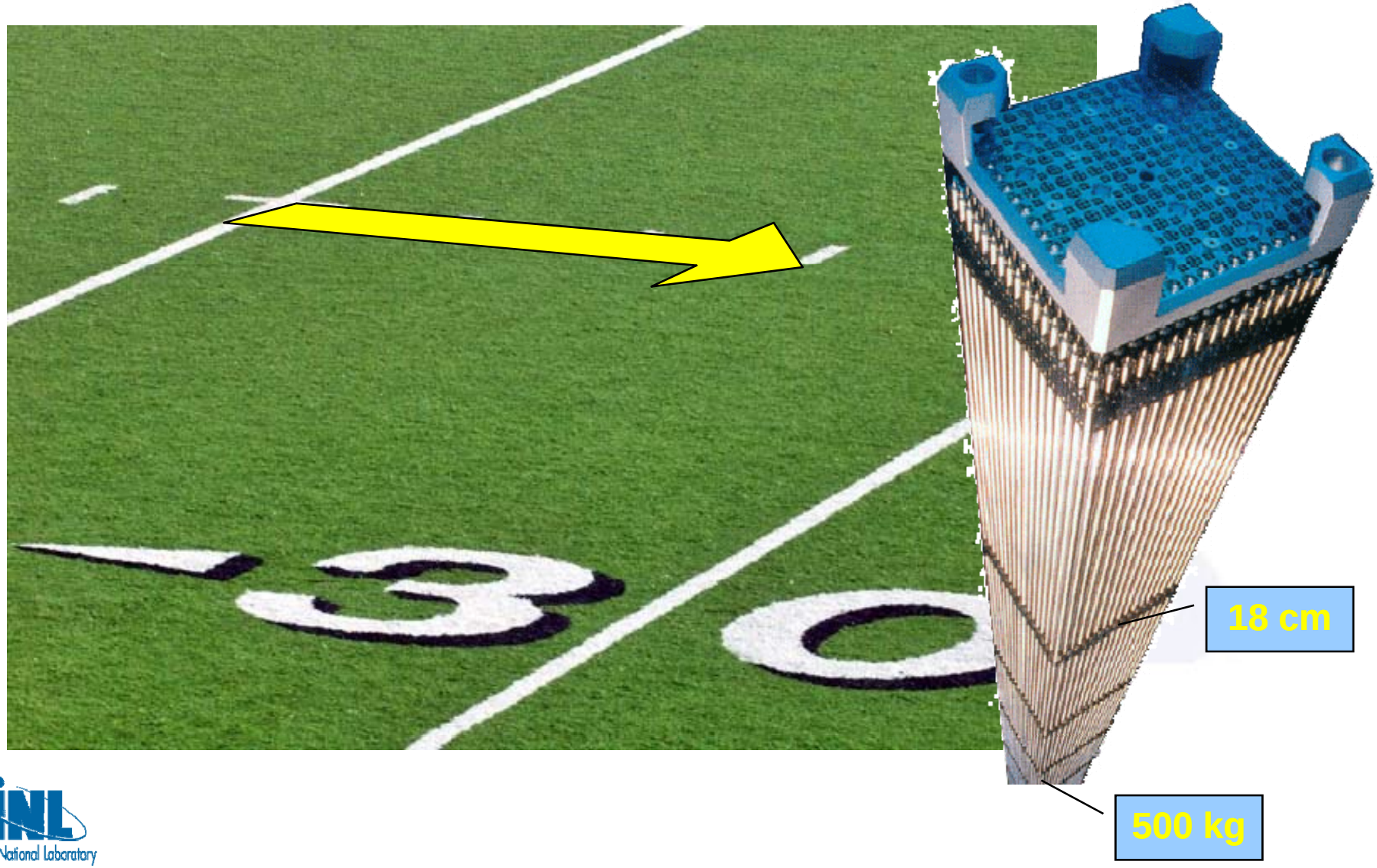
- Babcock & Wilcox
  - mPower
  - 125 MW*e*
- NuScale Power, Inc.
  - NuScale
  - 45 MW*e*
- Westinghouse International
  - International Reactor Innovative and Secure (IRIS)
  - 335 MW*e*





Source, R. Black, DOE 2009 ANS Conference

How many soccer fields needed to stack all that nuclear waste? 50,000 tons of used fuel; 2000 t/a



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DOE has submitted a license application for a nuclear repository at Yucca Mountain, Nevada

However, its future is in doubt. A blue ribbon panel will examine the high level waste issue in the US

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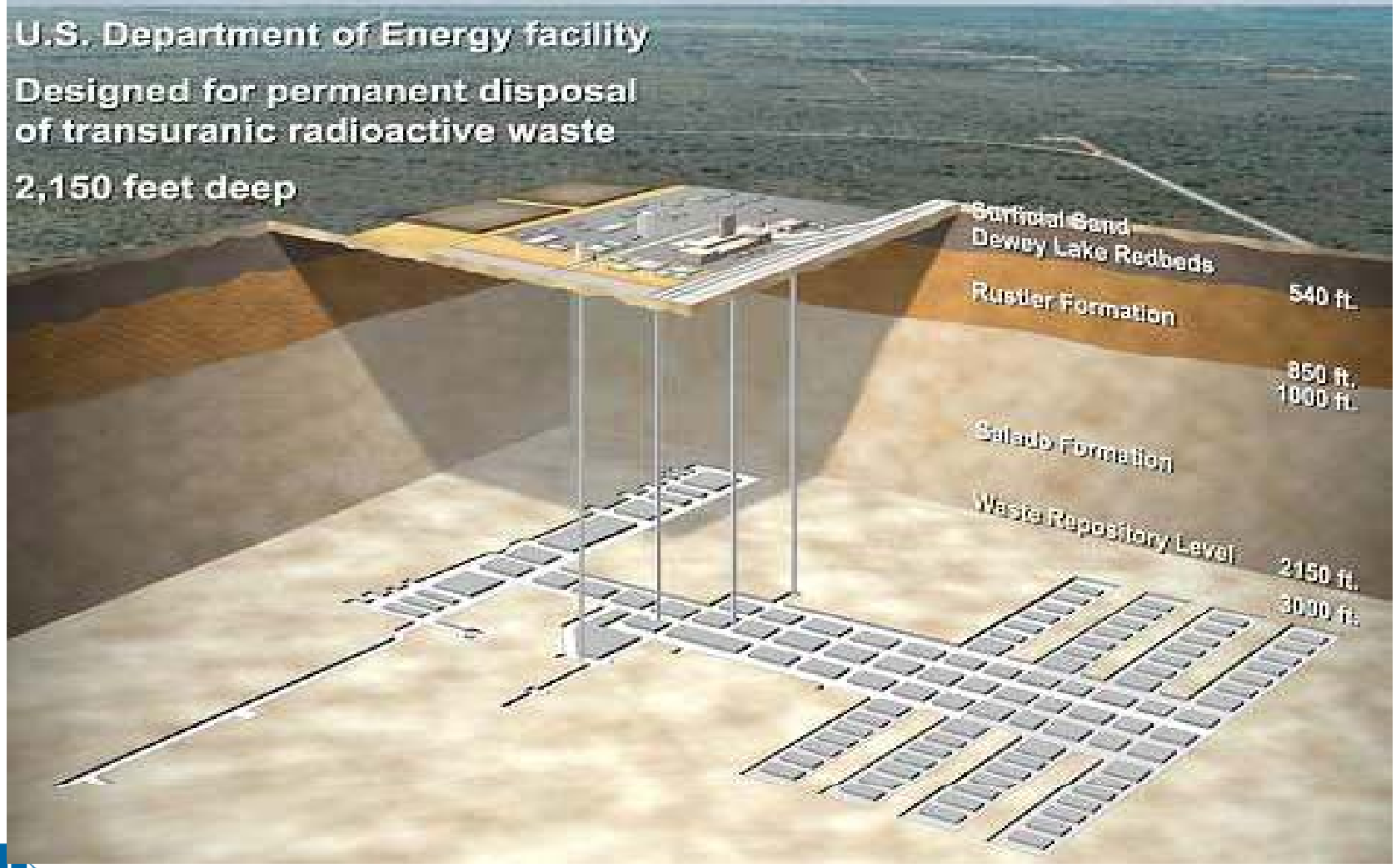
Waste Isolation Pilot Plant



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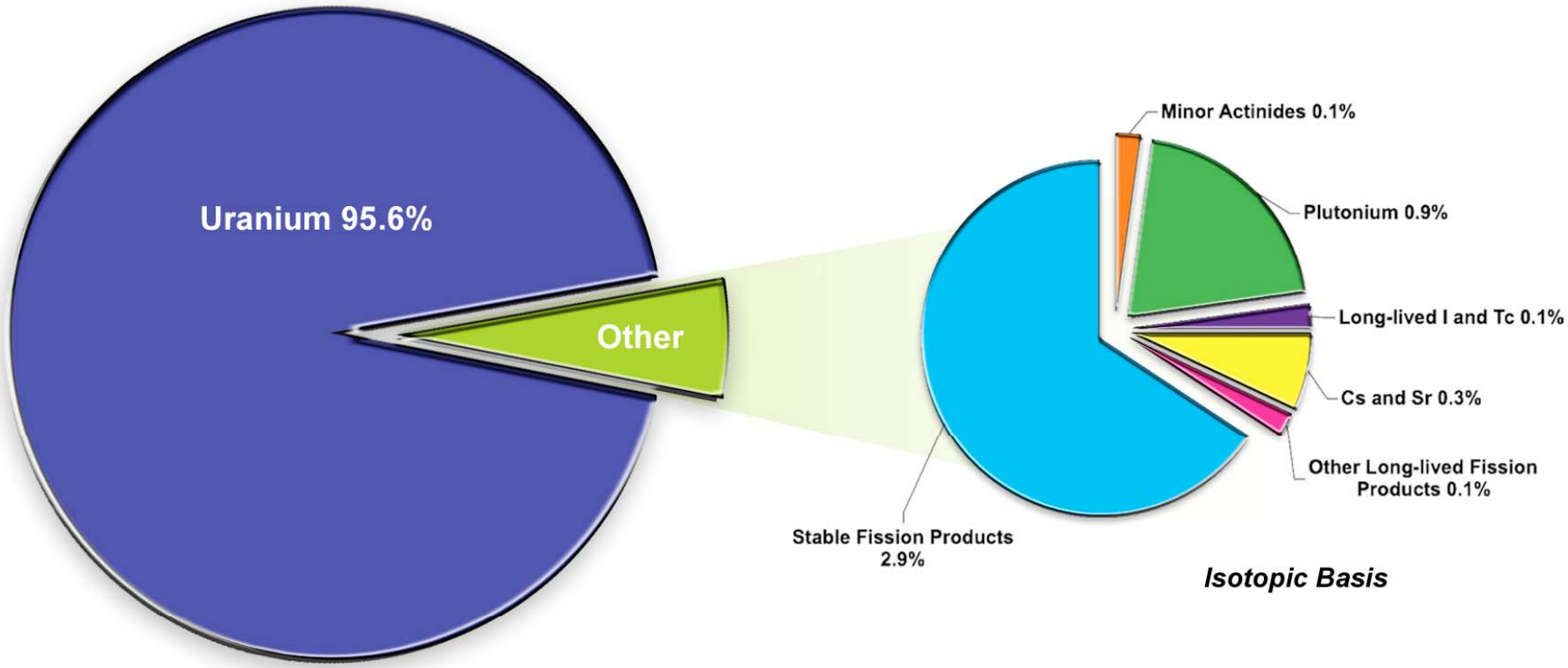
Composition of used nuclear fuel



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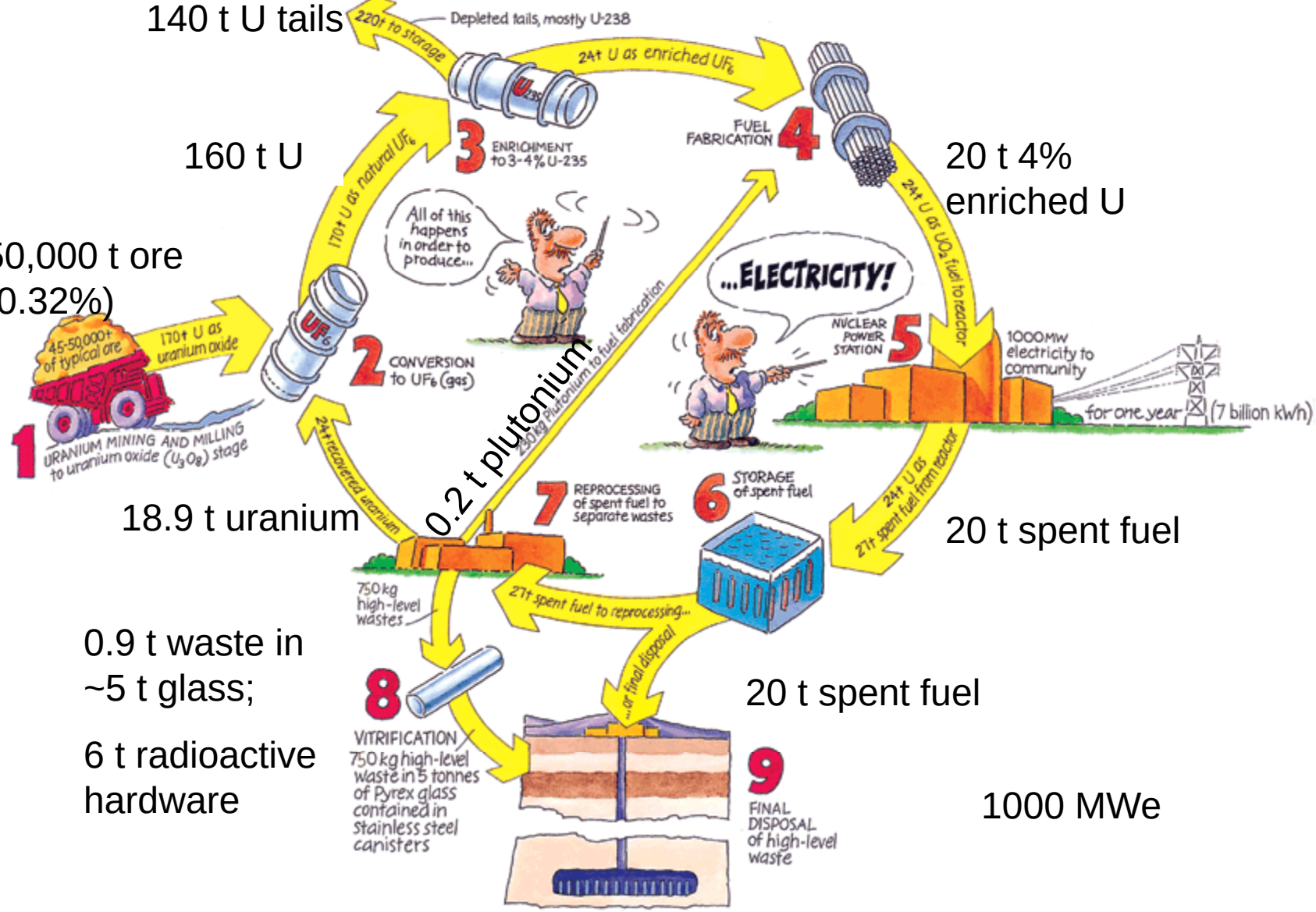
20 t 4% enriched U

140 t U tails

160 t U

20 t 4% enriched U

50,000 t ore (0.32%)



0.2 t plutonium

18.9 t uranium

20 t spent fuel

0.9 t waste in ~5 t glass;

6 t radioactive hardware

20 t spent fuel

1000 MWe

Modified from WNA

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Nuclear Power and Global Security

- Megatons to megawatts
  - 325 tonnes of Russian military grade uranium downblended to make nuclear fuel
  - Equivalent of 13,000 nuclear warheads
  - 40-50% of US nuclear electric generation
  - To be completed in 2013
  - 500 tonnes; 20,000 warheads

- International regime has worked; must continually evolve

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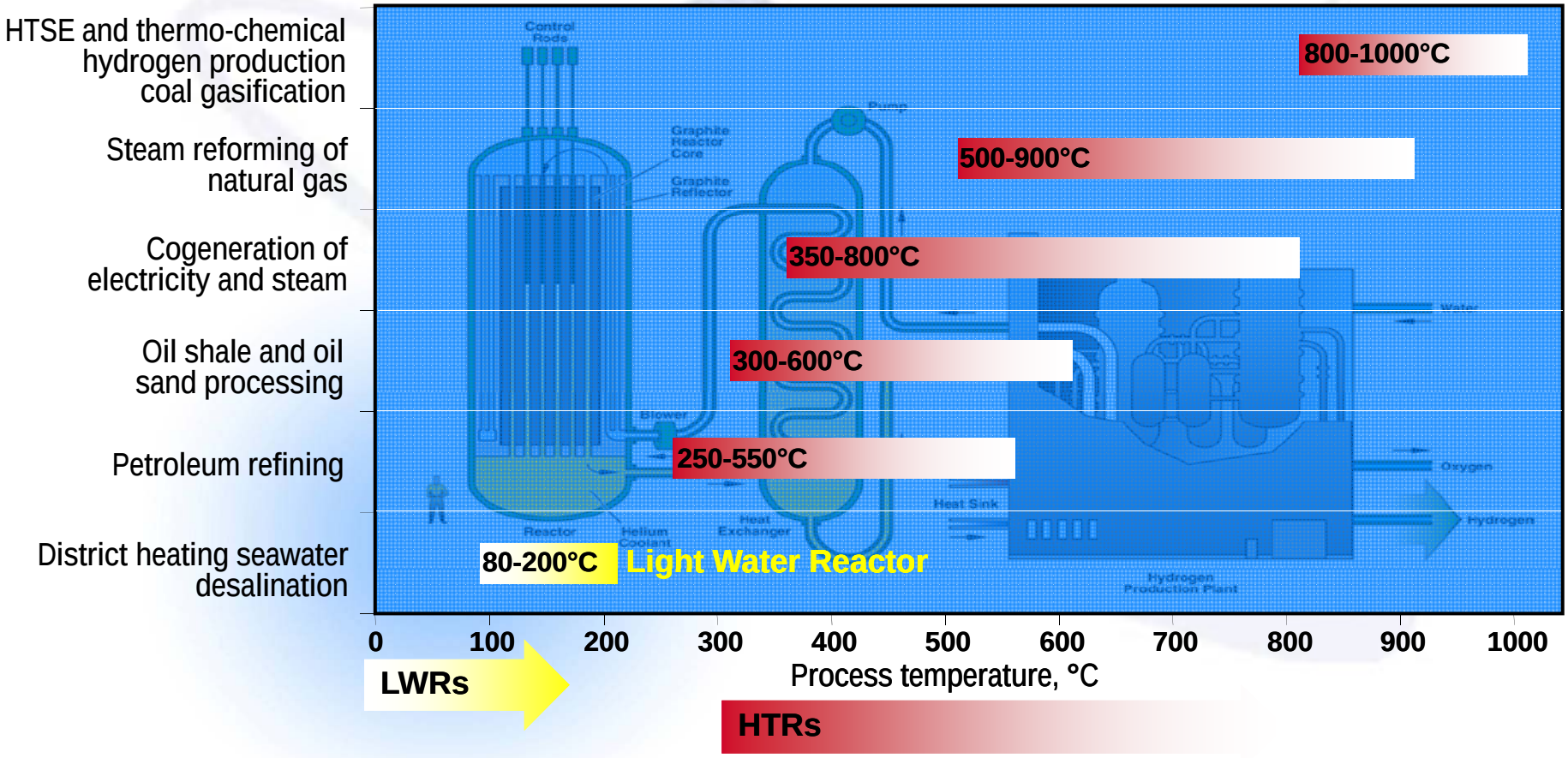
Efficiency gains could be possible in the future with high temperature reactors



There is a role for existing LWRs, advanced LWRs, and small reactors…

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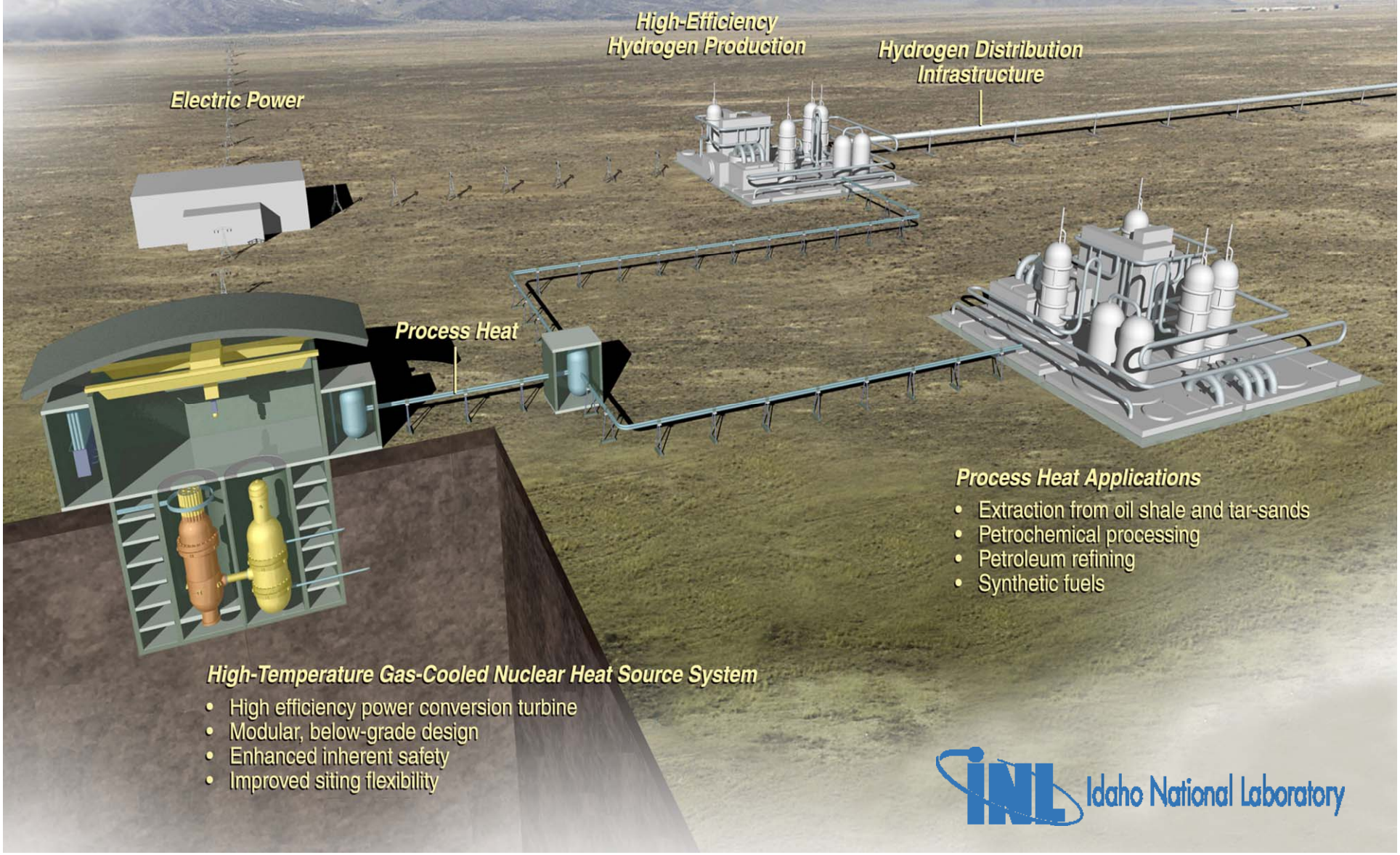
The Next Generation Nuclear Plant (NGNP)
— Process Heat, Hydrogen, and Electricity



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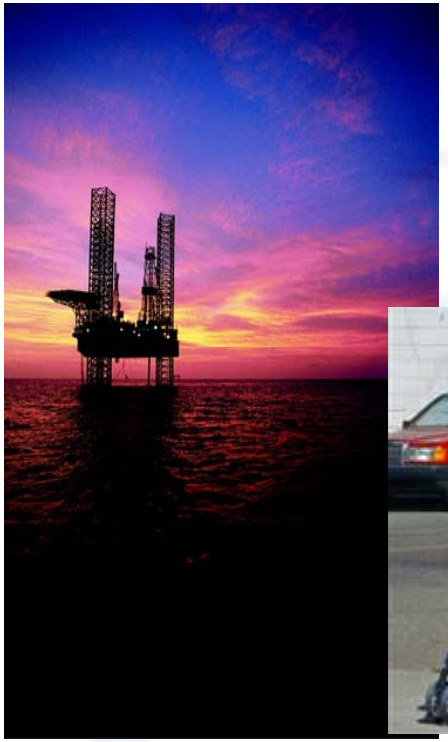
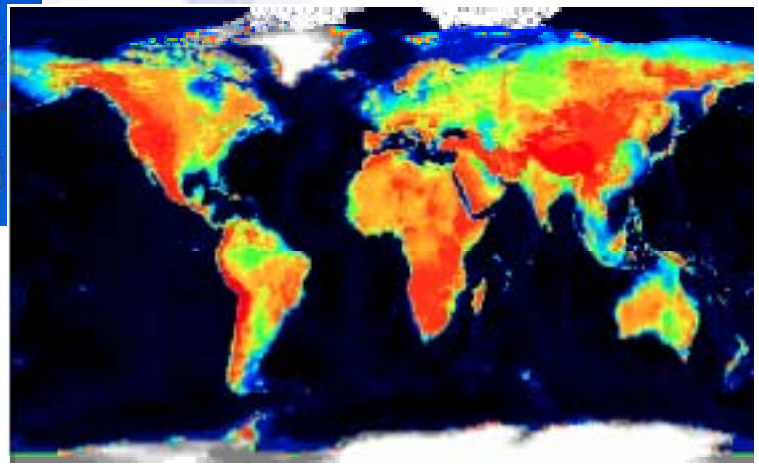
USA's wakeup call

Our growing concerns



Energy security

Price volatility



Climate Change

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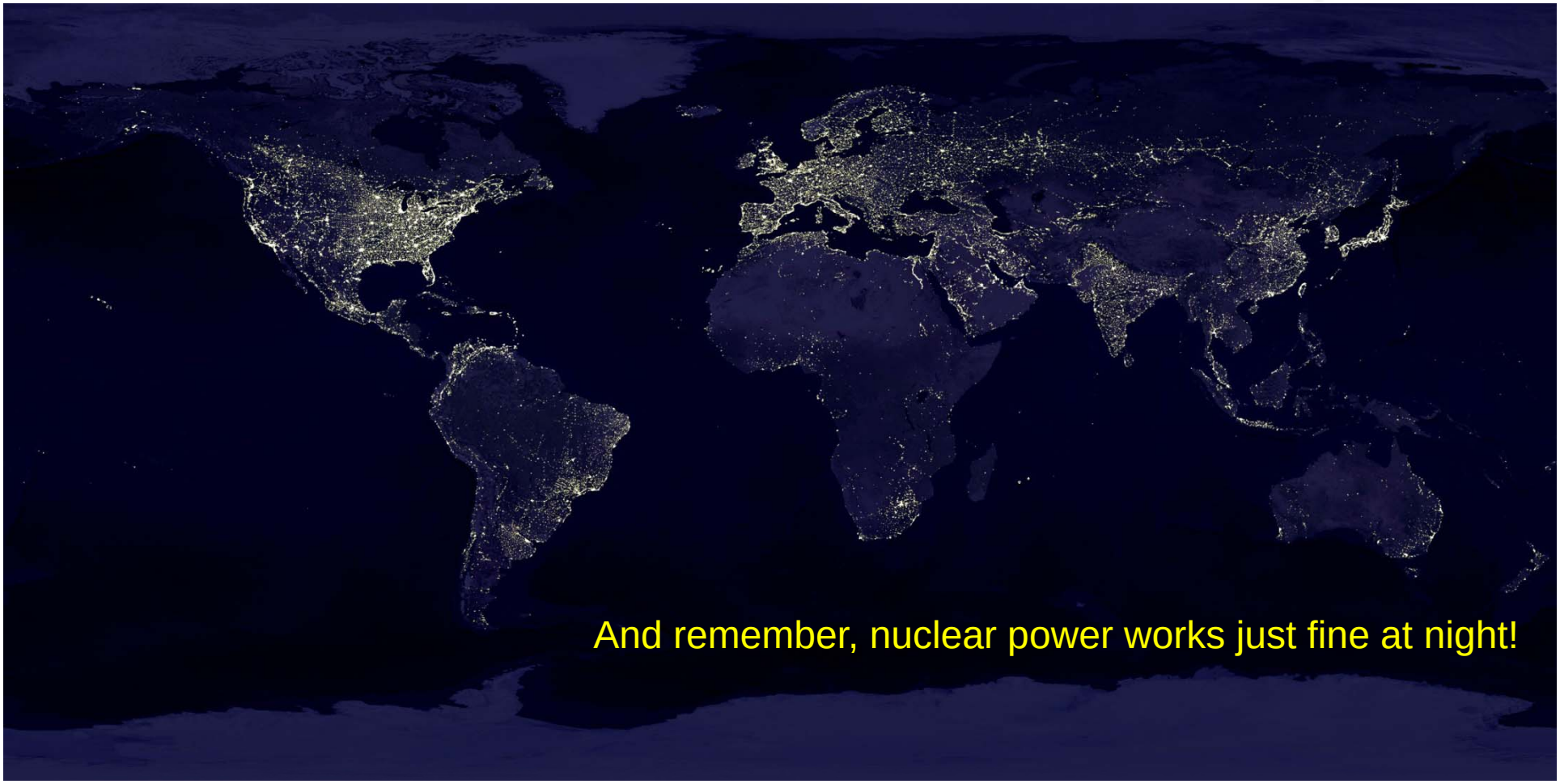
Thank you for your participation



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