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Global Nuclear Energy Perspectives

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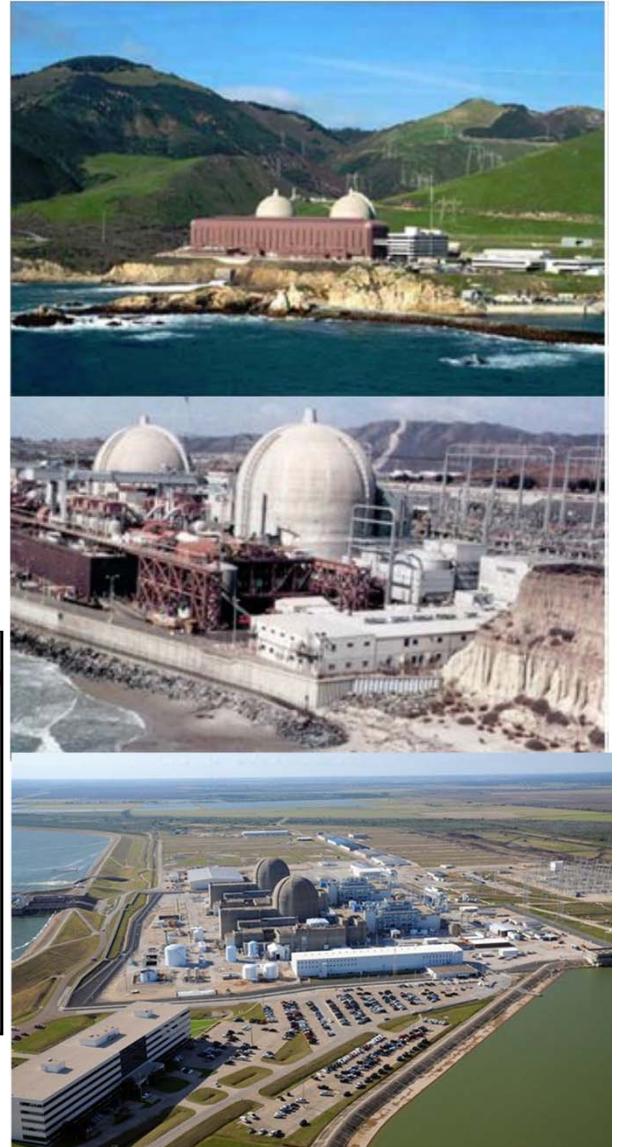
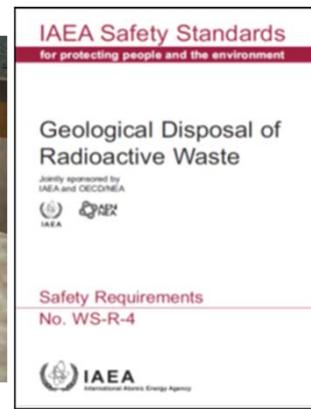
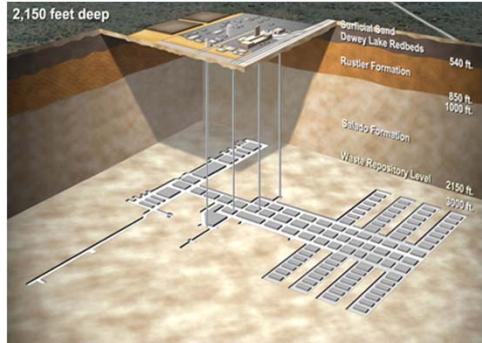
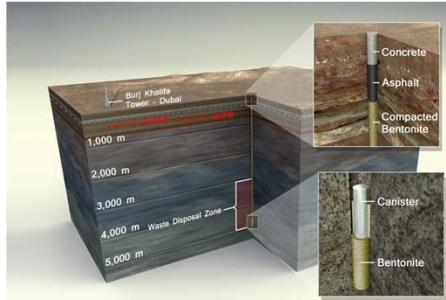
34th International Geological Congress 2012
Brisbane, Australia
August 9, 2012



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Discussion Topics

- Pre-Fukushima Industry Review
 - The Rise, Fall and Rise of Nuclear Energy
- Post-Fukushima Outlook
- Concluding Remarks
 - Geologic Implications



Birth of the Nuclear Energy Industry

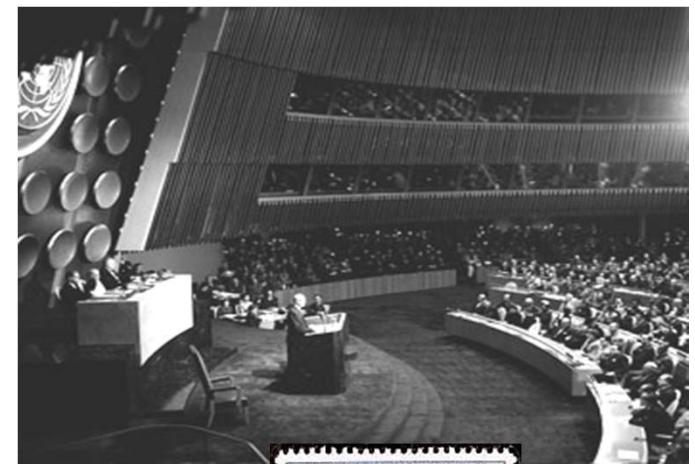
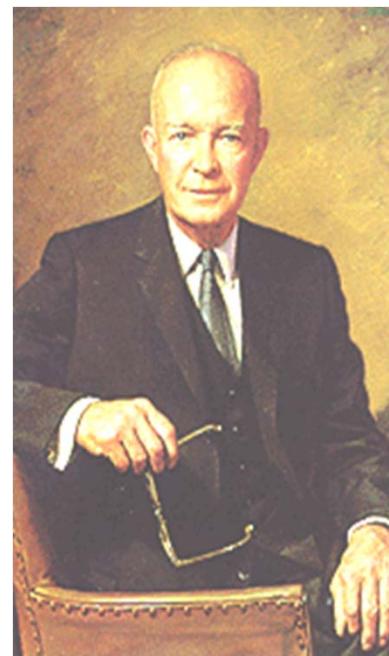
Atoms for Peace - 1953



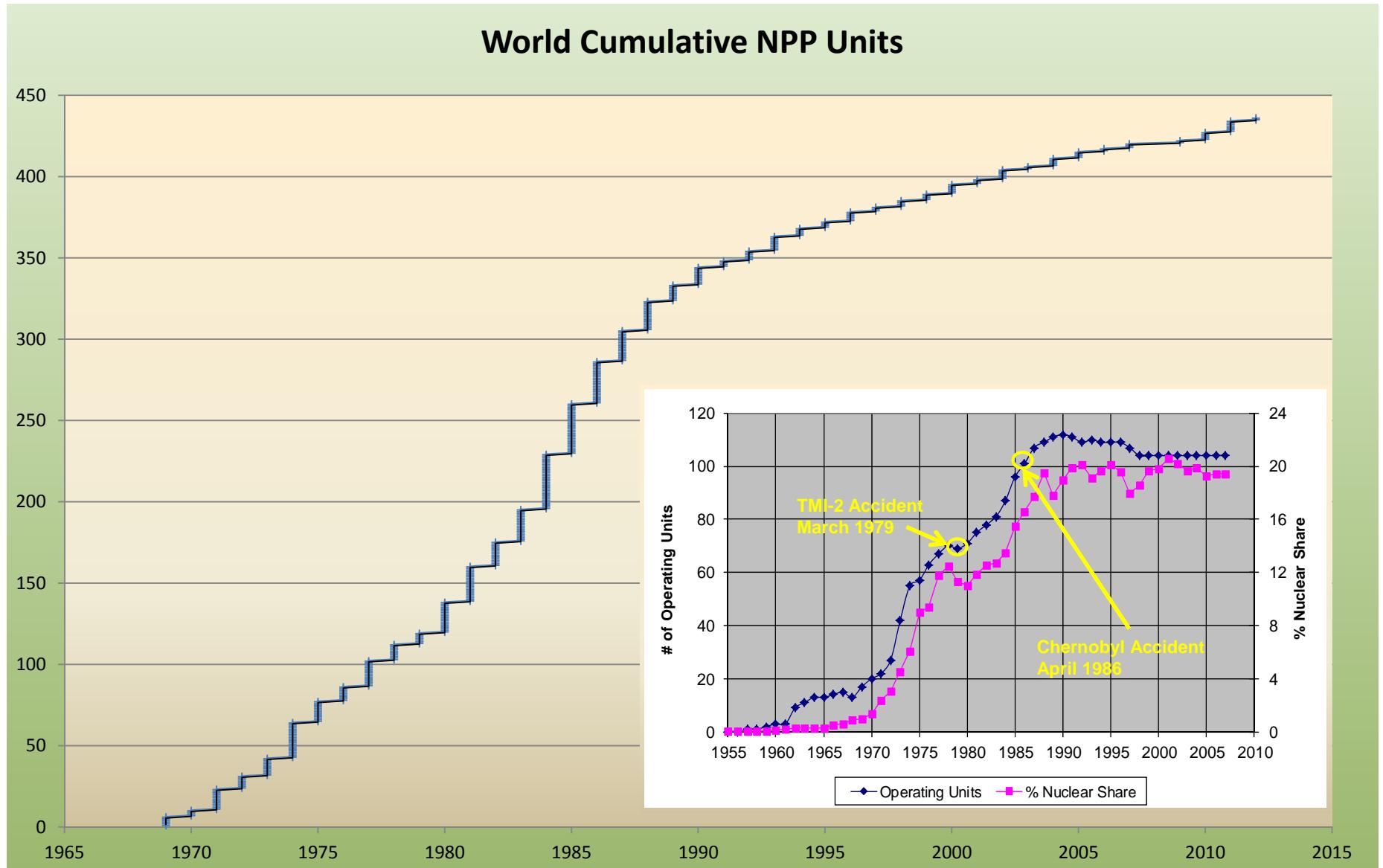
- Serve the peaceful pursuits of mankind, provide abundant electrical energy in power starved areas of the world
- Encourage world-wide investigations with the most effective peacetime uses of fissionable material
- Create international controls to prevent proliferation (IAEA)



Shippingport Atomic Power Station, Pennsylvania, the first full-scale nuclear power generating station in the US began operating in 1957.

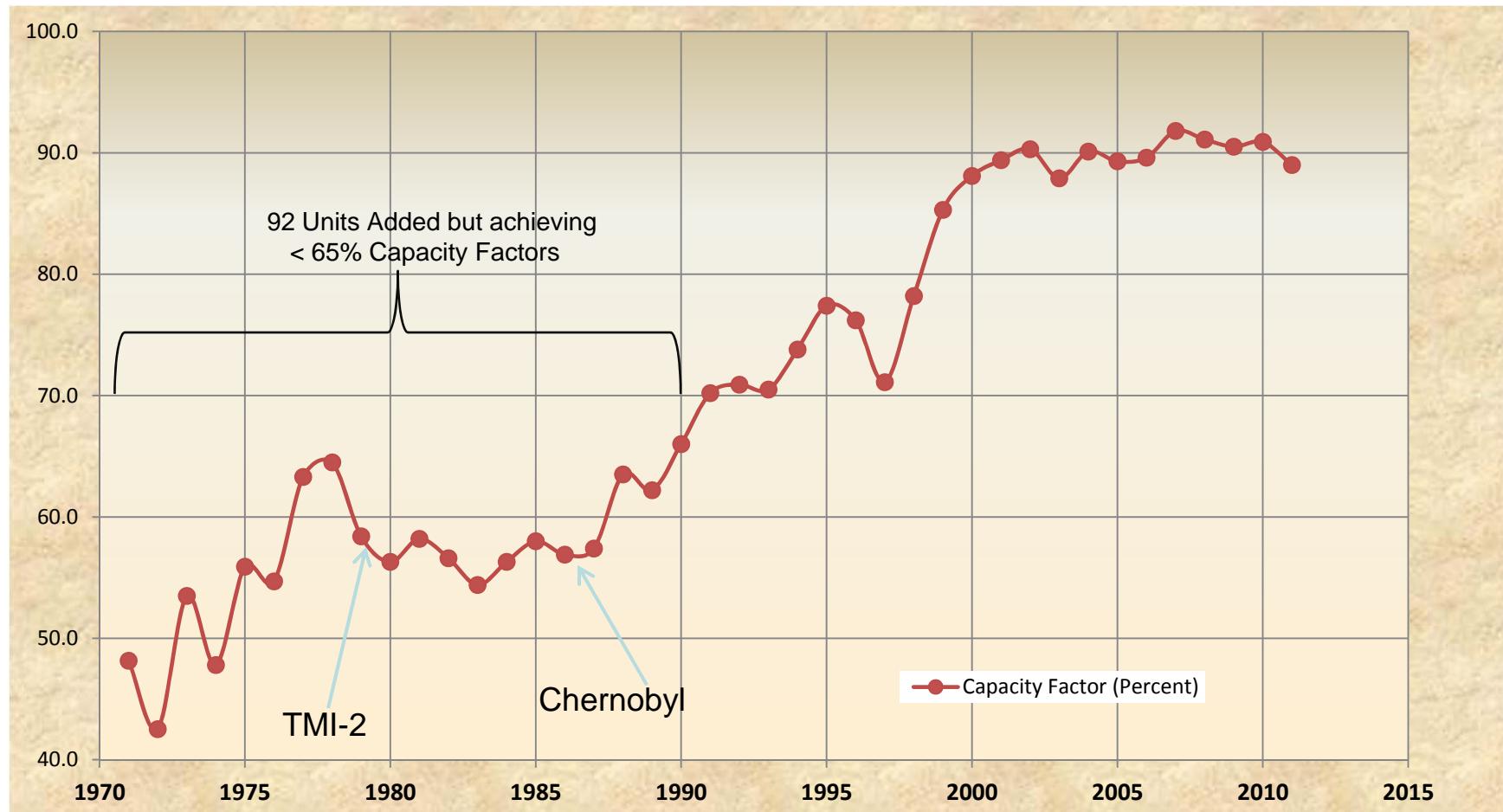


The Rise...



The Fall...

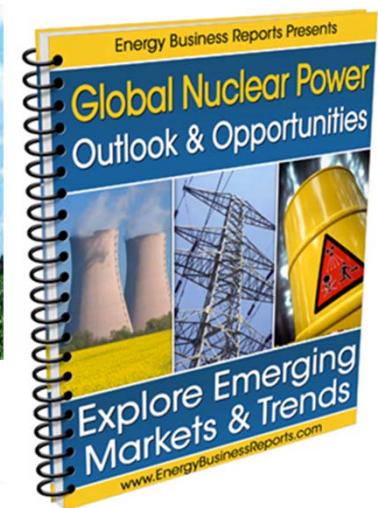
U.S. Nuclear Plant Capacity Factors



...capacity factors (efficiency) didn't keep pace.

Still, we now have 104 plants, making ~100GW low-carbon energy with a capacity factor of 90%

The Rise of a Nuclear Renaissance

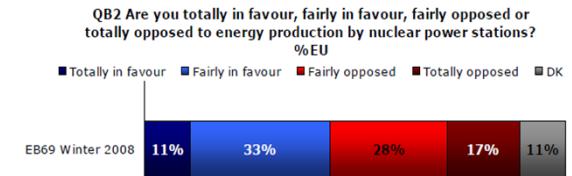


NuScale notified the NRC in January 2008 of its intent to begin the Pre-Application Review process for the preparation of the Design Certification request and the combined Construction & Operating License application.

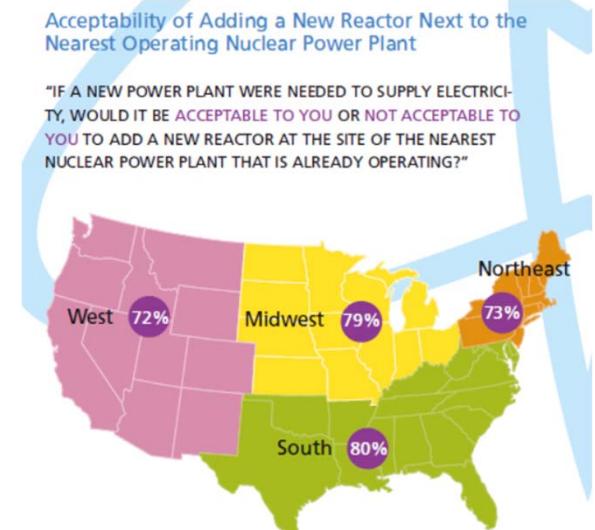
Factors Favoring a Global Nuclear Renaissance

Starting ~2001

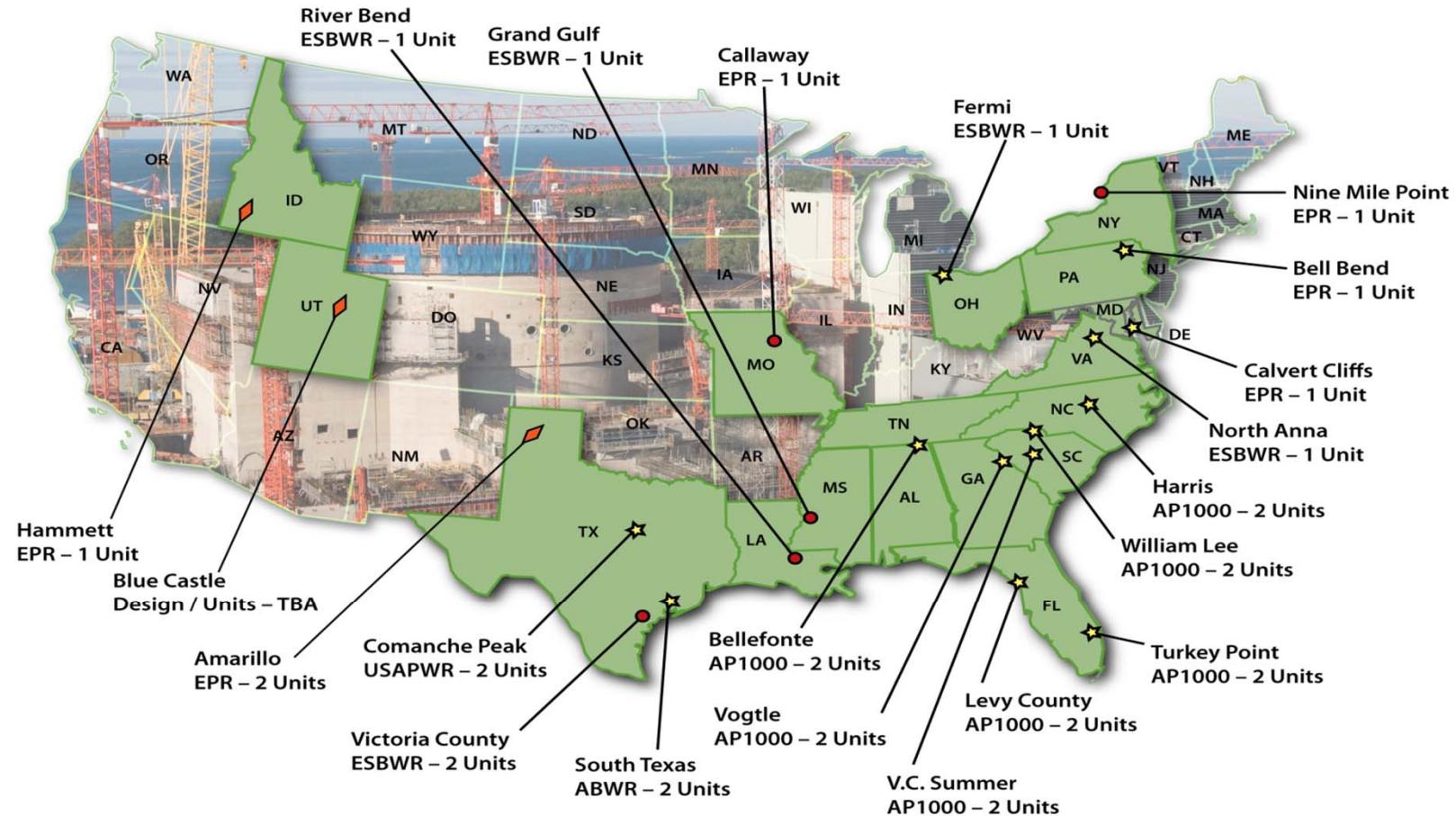
- **Economics** of high-capacity factor plants (analogous to a Saudi oil well)
 - South Texas Project has the lowest production cost reported by nuclear power plants nationwide, at 1.356 cents per kilowatt-hour in 2006.
 - Improved construction management practice and experience
- GHG and **climate change** concerns, potential for Carbon Tax Credits
 - Overturning of state moratoriums on new build for construction jobs and clean energy objectives
- NRC COL Implemented 10 CFR 52 **streamlined licensing** (vs. two step process under 10 CFR 50)
 - By issuing a Combined Construction and Operating license (COL), the NRC authorizes the licensee to construct and operate a nuclear power plant at a specific site, valid for 40 years.
- U.S. Federal Loan Guarantees and similar **Federal Government Support** programs in other nations
 - \$18.5B under Bush 2005 EPAct, Obama ↑ to \$54B and made first awards
 - 2005 Renewal of the Price Anderson Nuclear Industries Indemnity Act
 - 1.8 cent/kWh production tax credit
- Increase in overall **energy demand** while **reducing strategic importance of fossil fuels and foreign oil**
 - Tempered by global recession
 - Desires for energy security
- Improved **Public and Political Support**
 - PUC approving 'Construction Work In Progress' enabling utilities to recover costs before first power.



Eurobarometer on Radioactive Waste published in June 2008, indicated there were almost as many citizens in favor of nuclear energy (44%) as against it (45%). Likely tied to concerns with climate change and supply security issues.



Investor Confidence Yields Plans for New Build

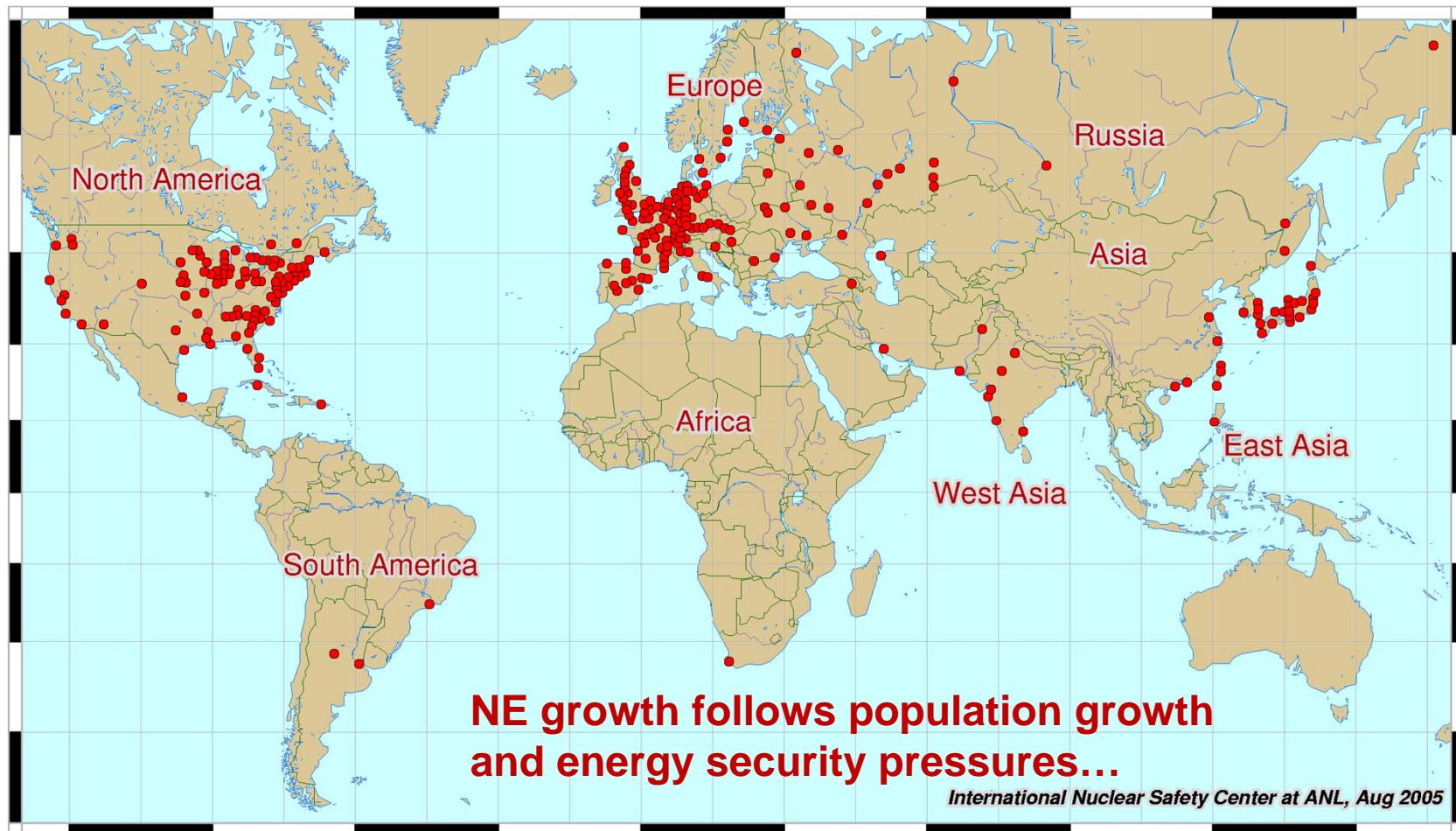


Construction and Operating License (COL) Status

★ Under Nuclear Regulatory Review (NRC) ♦ Planned Future Submittal ● NRC Review Suspended

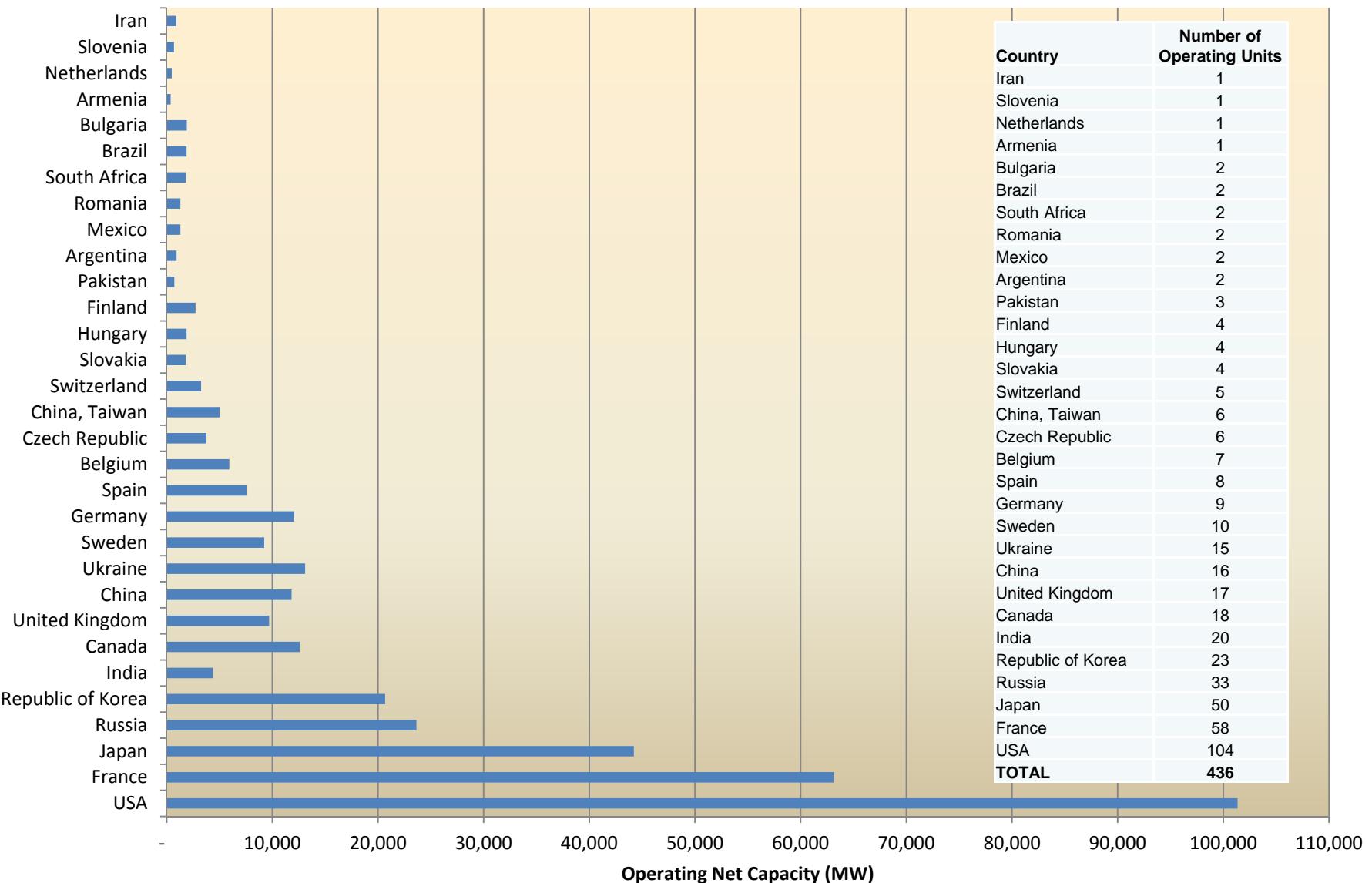
Between 2007 and 2009, NRC accepted and docketed a total of 17 applications for 26 new units (approximately 31 GW new, a 30% increase in nuclear).

World NPP Locations



- As of July 2012, there were 435 nuclear reactors operating in 30 countries, with a total capacity of 370 GWe
- The **United States, France and Japan** have > half of the world's nuclear generating capacity, 16 countries relied on nuclear energy to generate over 25% of their electricity.
- 61 plants with an installed capacity of 45 GWe are under construction in 14 countries

World NPP Numbers



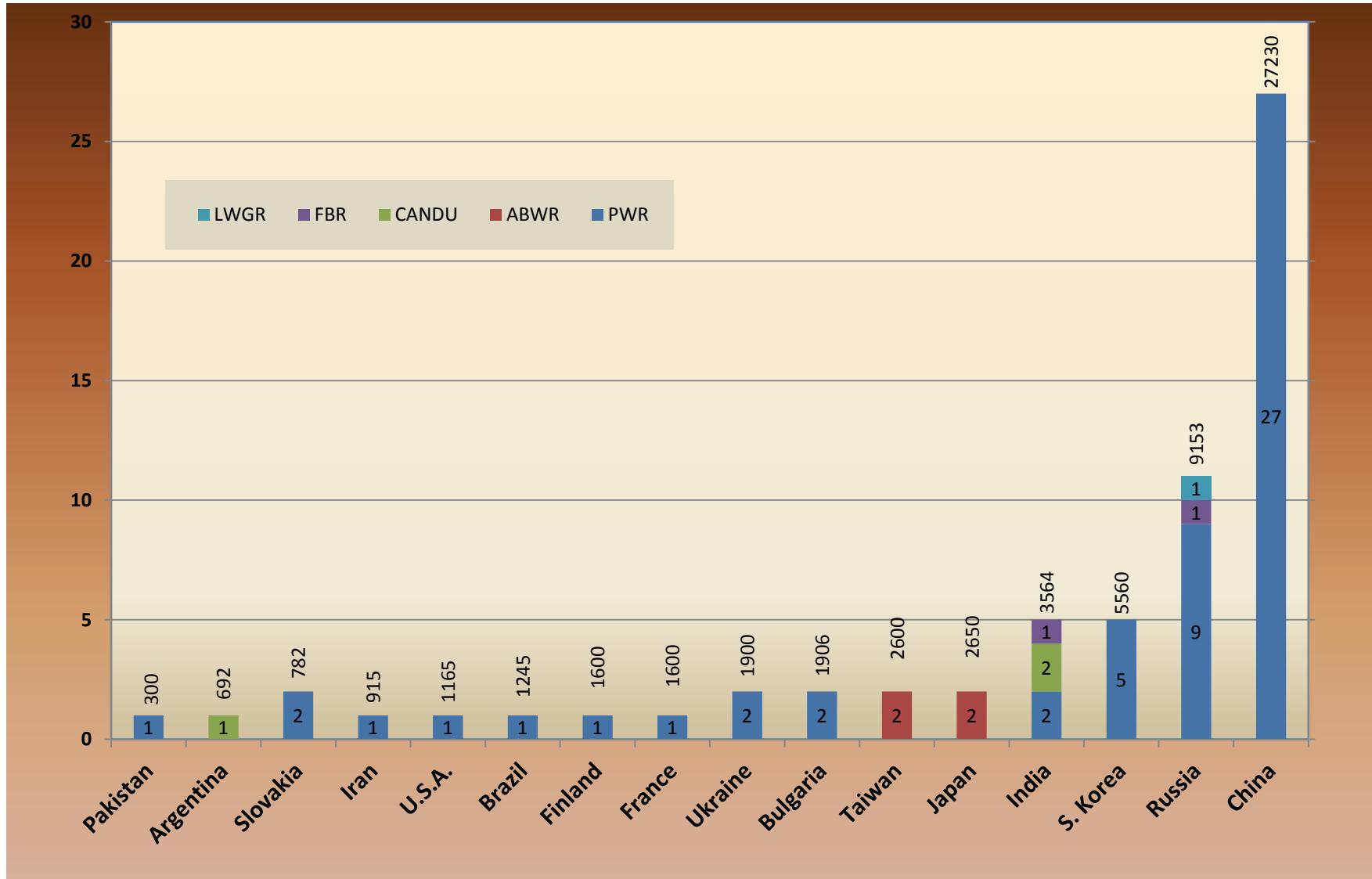
A Global Nuclear Rise?

- 10/2006: **Brazil** announced the construction of seven nuclear plants by 2025 to ensure energy sufficiency with economic efficiency
- 08/2008: **China** head of National Energy Administration targets nuclear power share to 5% for 2020
- 10/2008: Industry Minister Scajola announces **Italy** may start work by 2013 “reversing the 'terrible mistake' made in phasing out nuclear power”, to build the first of as many as 10 nuclear reactors over the next two decades
- 1/2009: **India** envisages a capacity of 60,000 MW by 2032 and to increase nuclear energy's share from 4.1% of total domestic energy production to 9% within the next 25 years.
- 2/2009: Italy and **France** pen a deal to revive Italian nuclear industry
- 12/2009: Emirates Nuclear Energy Corporation awards **Korea** Electric Power Corporation (KEPCO) a \$20 billion bid to build the first nuclear power plant in the **UAE**.
- 10/2010: The **UK** Energy Secretary gives the go-ahead for eight new nuclear power stations in Britain
- 10/2010: **Vietnam** signed an agreement with Russia for the construction of the country's first nuclear power plant, with plans to build fourteen reactors at eight locations by 2030.



Worldwide Nuclear Units Under Construction

Source: IAEA PRIS database as of 1/11 (# of Units & MW)



But Challenges Remain...

- Commodity Costs
- Capital credit market, global recession, deficits
- Weak dollar (FEX), need for foreign goods (ultra-heavy forgings)
- Construction schedule duration uncertainty
- Workforce availability
- Low Natural Gas prices
- Public Perceptions and Acceptance
- Waste disposal uncertainty



Pre-Fukushima Conclusion

- By all accounts and projections, nuclear energy will grow significantly in the next 25 years
 - Whether led by the US or the EU or China, significant growth was expected
 - Nuclear is one of the best means to add such dense baseload capacity, addressing climate concerns, energy security
 - Challenges were being overcome, in the US, the EU and Asia

And then...



- March 11, 2011: About 14:46, a 9.0 magnitude earthquake struck
- Plant design basis earthquake: 8.2 Plant safety systems reportedly function satisfactorily.
- Units 1,2 & 3 Scram & Unit 4 has 100 day old core off-loaded into Unit 4 Spent Fuel Pool
- ~ 1 hour later, a tsunami 14-15 meters high inundates the site, whose design basis was 5.7 meters, the reactors and backup diesel power sit roughly 10 to 13 meters above sea level
- The impacts up and down the northeast coast result in tragic loss of 13,000+ lives, damage, and destruction of infrastructure.

Tohoku, Japan Earthquake: Finite Fault Model

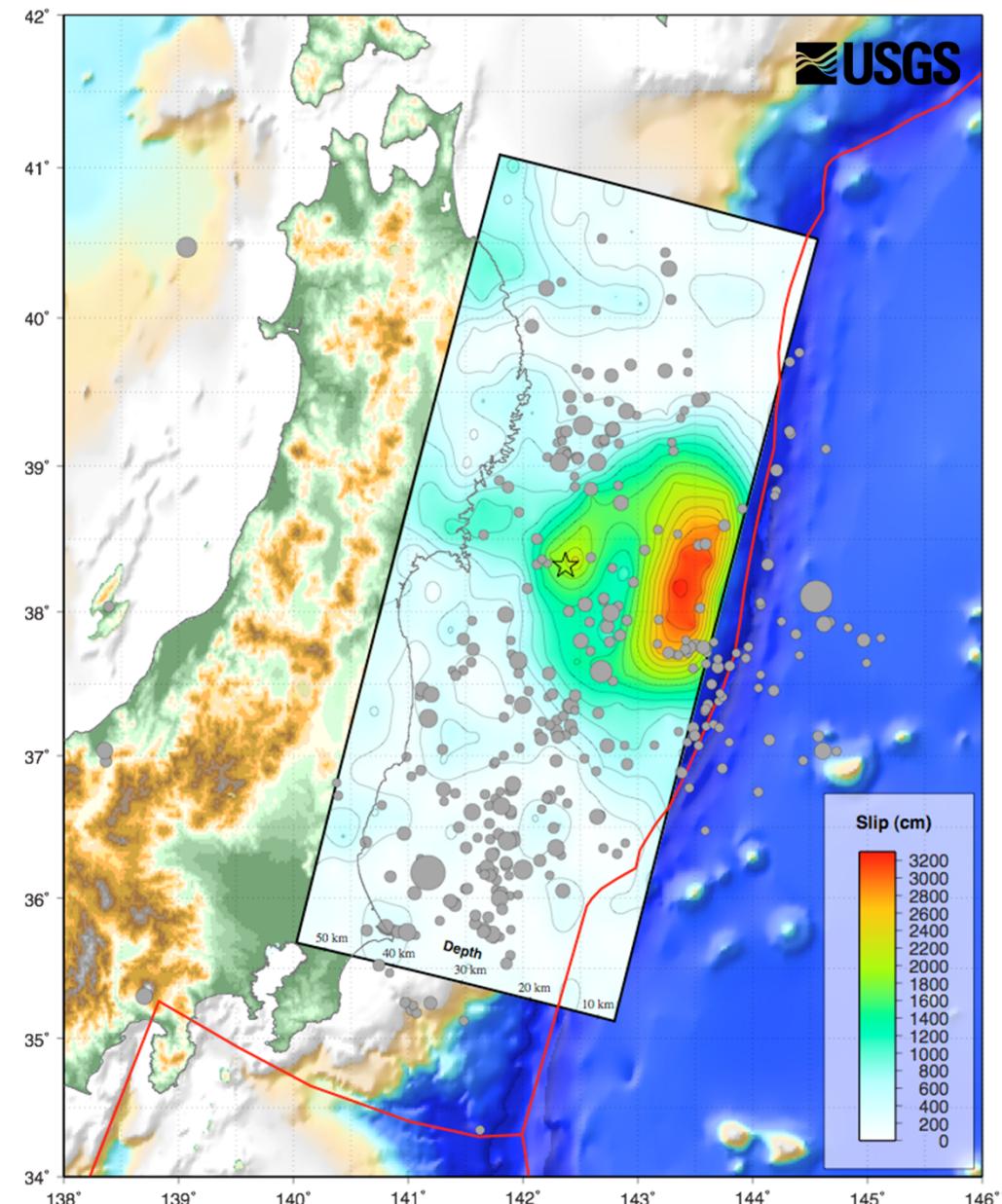
USGS V2 - 2011/03/18

Updated modeling shows peak slips of 30+ m, depending on the parameterization of rupture velocity. This updated model shows peak slip of ~32 m, using a range of rupture velocity from 1.25 - 3 km/s.

Models with constant rupture velocity show slips of 40-50 m, all at shallow depths. This may imply that the up-dip nature of rupture is well resolved, but peak slips are not. ‘Low’ slip regions near the fault edges, and fault base, are also poorly resolved.

(Vertical seafloor rise of >7m reported)
(> 1035 quakes since March 11, 57 > M6)

<http://www.japanquakemap.com/>



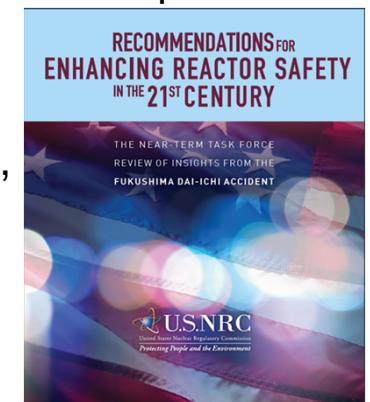
Then the Tsunami...



Immediate Aftermath International Response

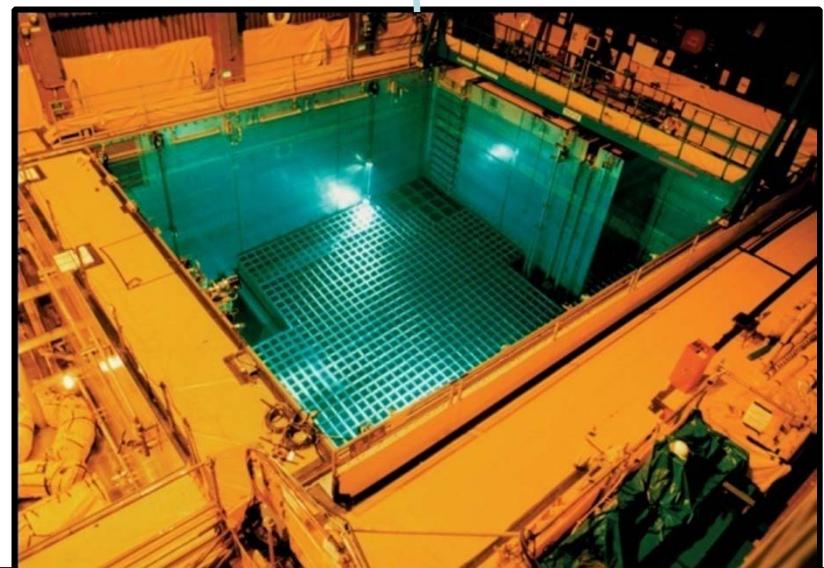
Most (but not all) international nuclear programs declare a moratorium or time-out to conduct safety reviews, and incorporate lessons learned.

- **China** has temporarily suspended work on 26 or so nuclear reactors currently under construction, pending revision of its safety standards, and since resumed construction.
- In **Germany** Chancellor Angela Merkel ordered all nuclear plants operating before 1980 to be closed for three months, and has moved to abandon nuclear energy by 2022.
- The **Italian** government put a one-year moratorium on plans to revive nuclear power
- In the **UAE**: "Once we fully understand the details of what has happened in Japan, we will use this information to enhance the safety of the peaceful nuclear power program here in the U.A.E."
- The **Vietnamese** government states it intends to forge ahead with a plan to build the country's first nuclear power plants, with Japanese and Russian assistance.
- In the **UK**, the Secretary of State for Energy and Climate Change, asked for a report 'on the implications of the situation and the lessons to be learned for the UK nuclear industry, expressing regret that that some European politicians were 'rushing to judgment' before assessments had been carried out, and said that it was too early to determine if the private sector willingness to invest in new nuclear plants would be affected.
- In the **US**, the NRC issued temporary instructions to assess the licensee's capability to mitigate conditions that result from beyond design basis events, with focus on determine that the severe accident management guidelines (SAMGs) are available and how they are being maintained. Implemented a 90 day short-term and 9 month long-term review of regulatory processes



Post-Fukushima Nuclear Energy

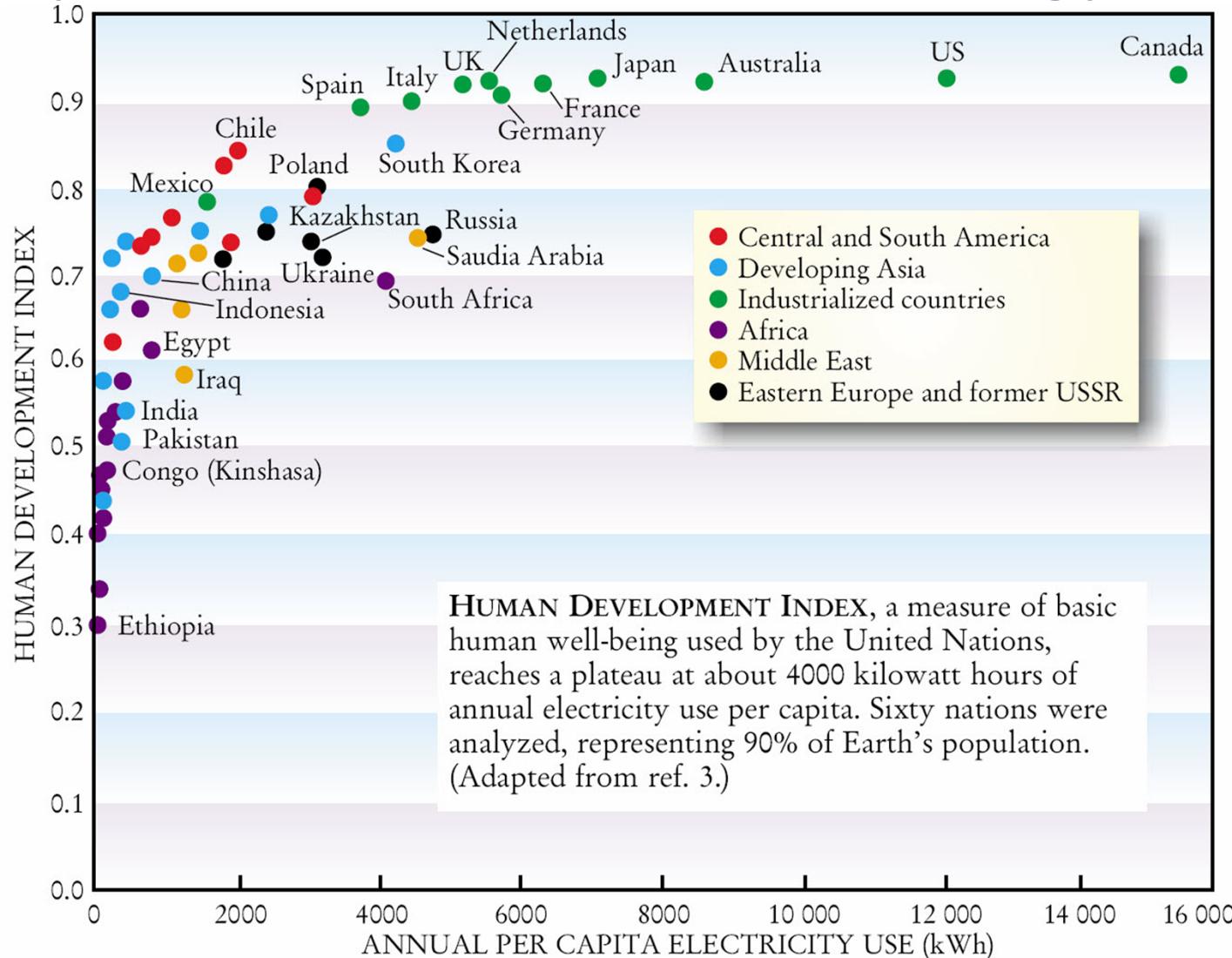
So is this the end of nuclear power?



The Practicality of NE

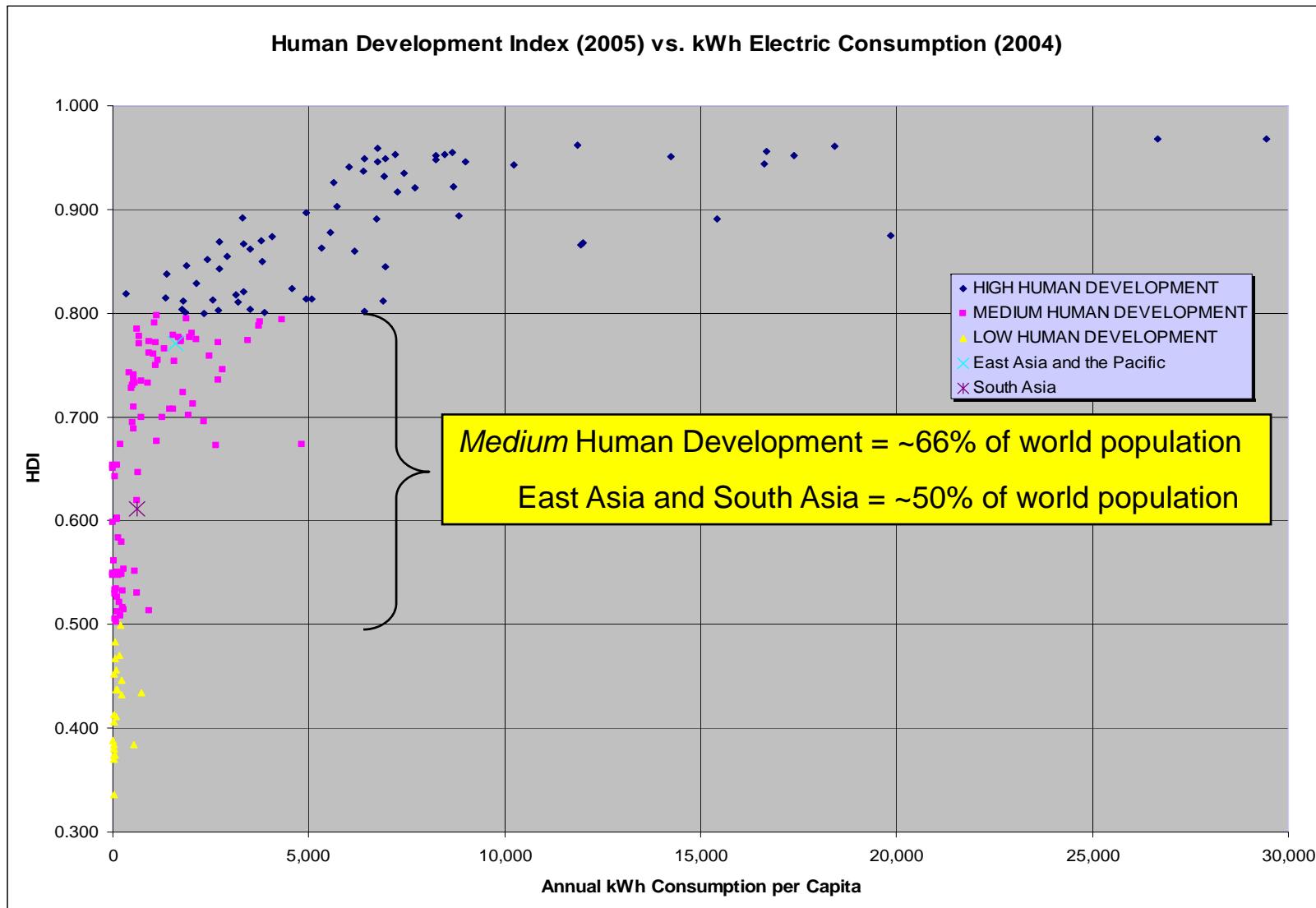
- "Shortly after the Fukushima accident in March 2011, **German** leaders ordered closed the eight reactors that began operation in or before 1980, with a plan to close the remaining 15 by 2022. Germany's third largest aluminum producer has filed for bankruptcy as trade groups call for affordable power supply equivalent to the nuclear capacity taken off the grid as a response to the Fukushima accident. The industry should not suffer, said Grillo [president of Germany's trade body for the metal industry], because of "electricity price rises that result clearly from the state support system for renewable energies, and especially photovoltaics."
- Support for nuclear energy as part of the **UK's** energy mix has increased over the last year with 63% agreeing that it has a role to play, an opinion poll commissioned by EDF Energy has found.
- Citing the plant's low-carbon power production and economic contribution, the **Spanish** government has wiped away a previous ruling to close the Garoña nuclear power plant in July 2013 - opening the possibility for it to operate until 2019.
- The **Japanese** government has announced it will be able to scale back energy saving targets in some areas thanks to the restart of Kansai Electric's Ohi 3. The 1180 MWe unit reached full capacity in the early hours of 9 July, becoming the first Japanese reactor to restart following suspension for periodic inspection since the March 2011 Fukushima Daiichi nuclear accident. Its sister unit, Ohi 4, is expected to follow later this month."
 - Source: *Researched and written by World Nuclear News: <http://www.world-nuclear-news.org/sectionhub.aspx?fid=800>*
- *Concerns over energy security (availability) are strong among nations most sensitive to energy shortages.*

Why the Interest in Nuclear Energy?

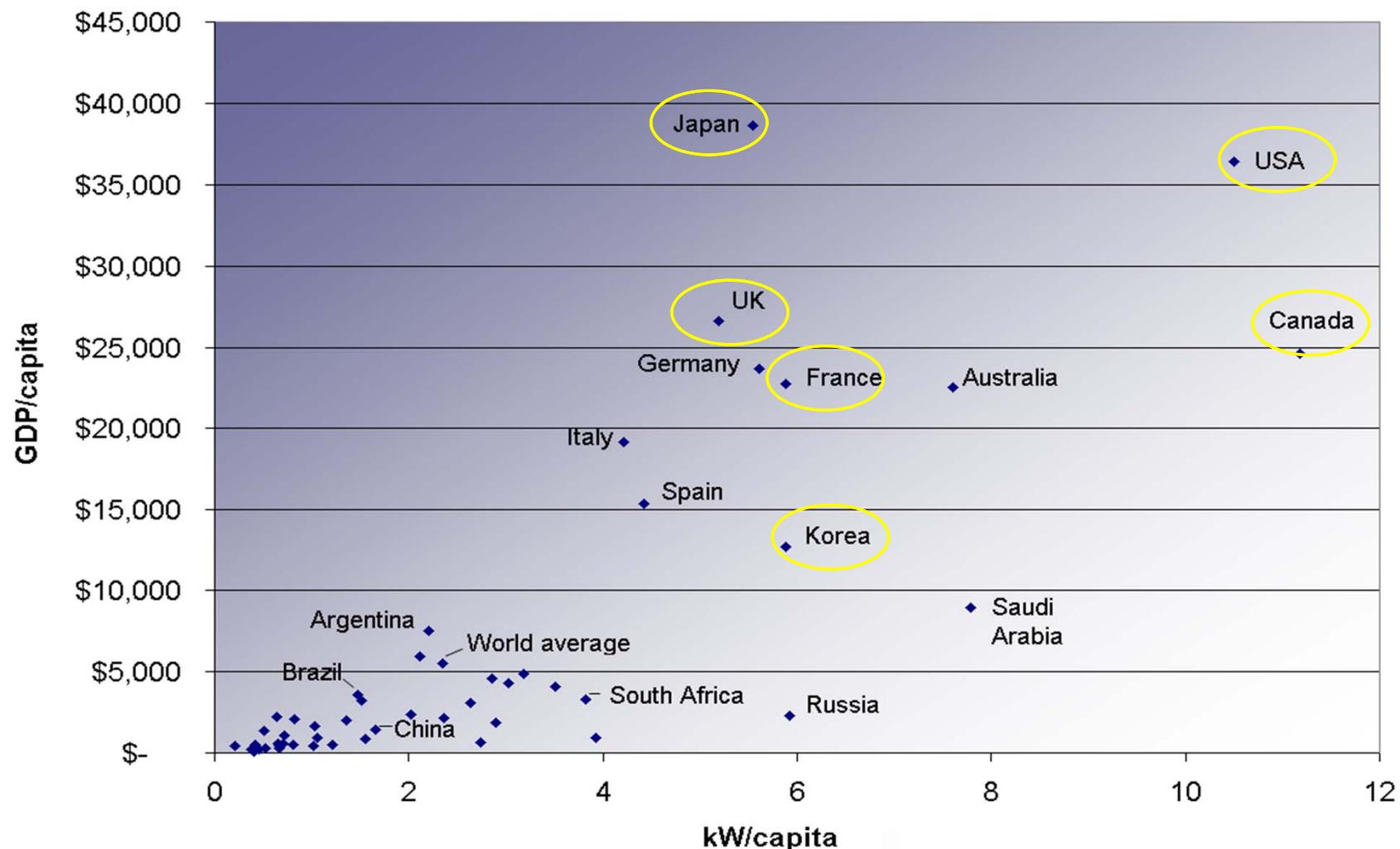


Alan Pasternack showed in 2000 that the Human Development Index, an index combining normalized measures of life expectancy, literacy, health, education, standard of living, and Gross Domestic Product per Capita, correlates reasonably well with annual per capita electricity use.

Potential Asian Influence on the Development of Nuclear Energy

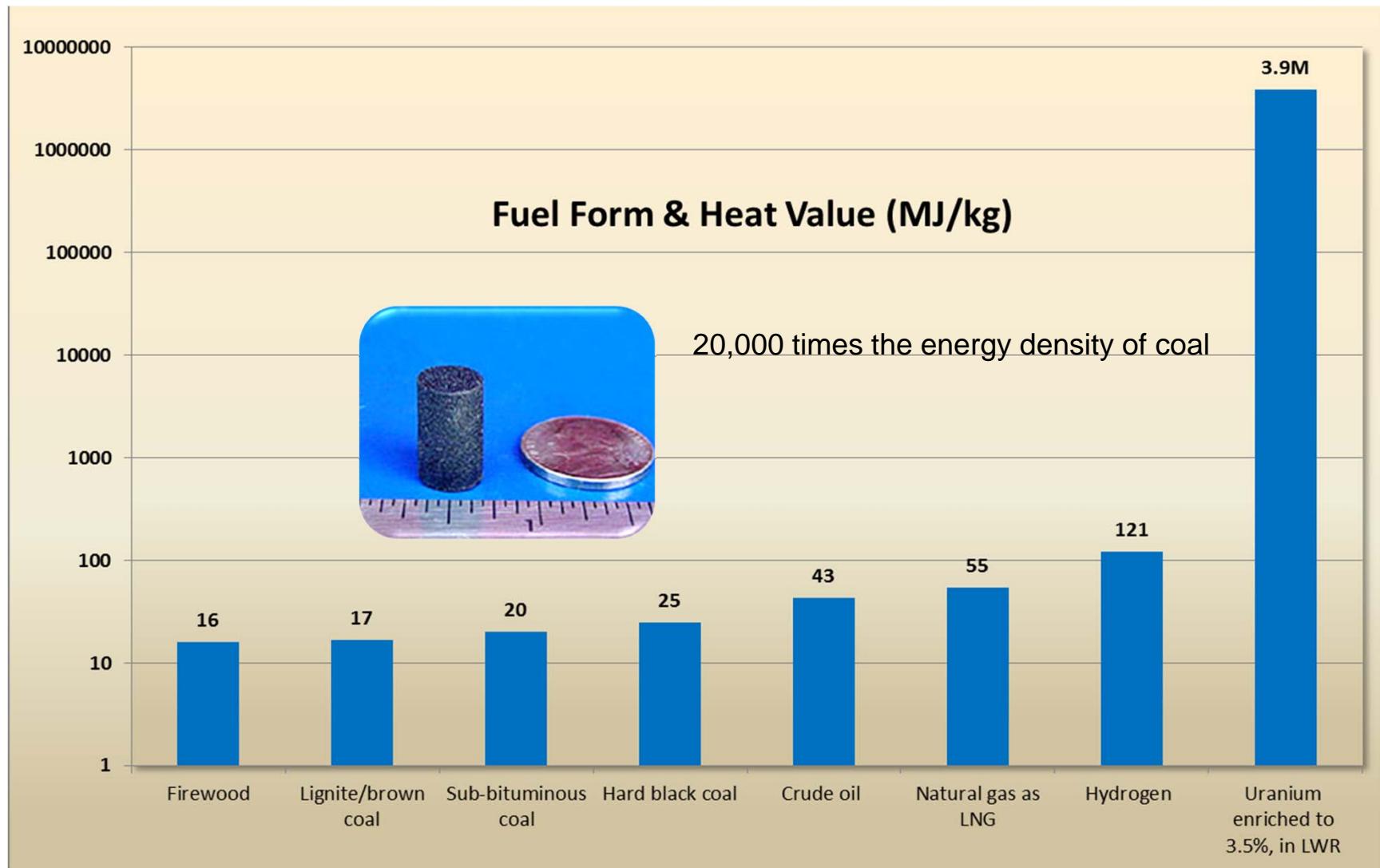


GDP & Energy Consumption



Source: Graph produced from data in the 2006 **Key World Energy Statistics** from the International Energy Agency, by Frank van Mierlo

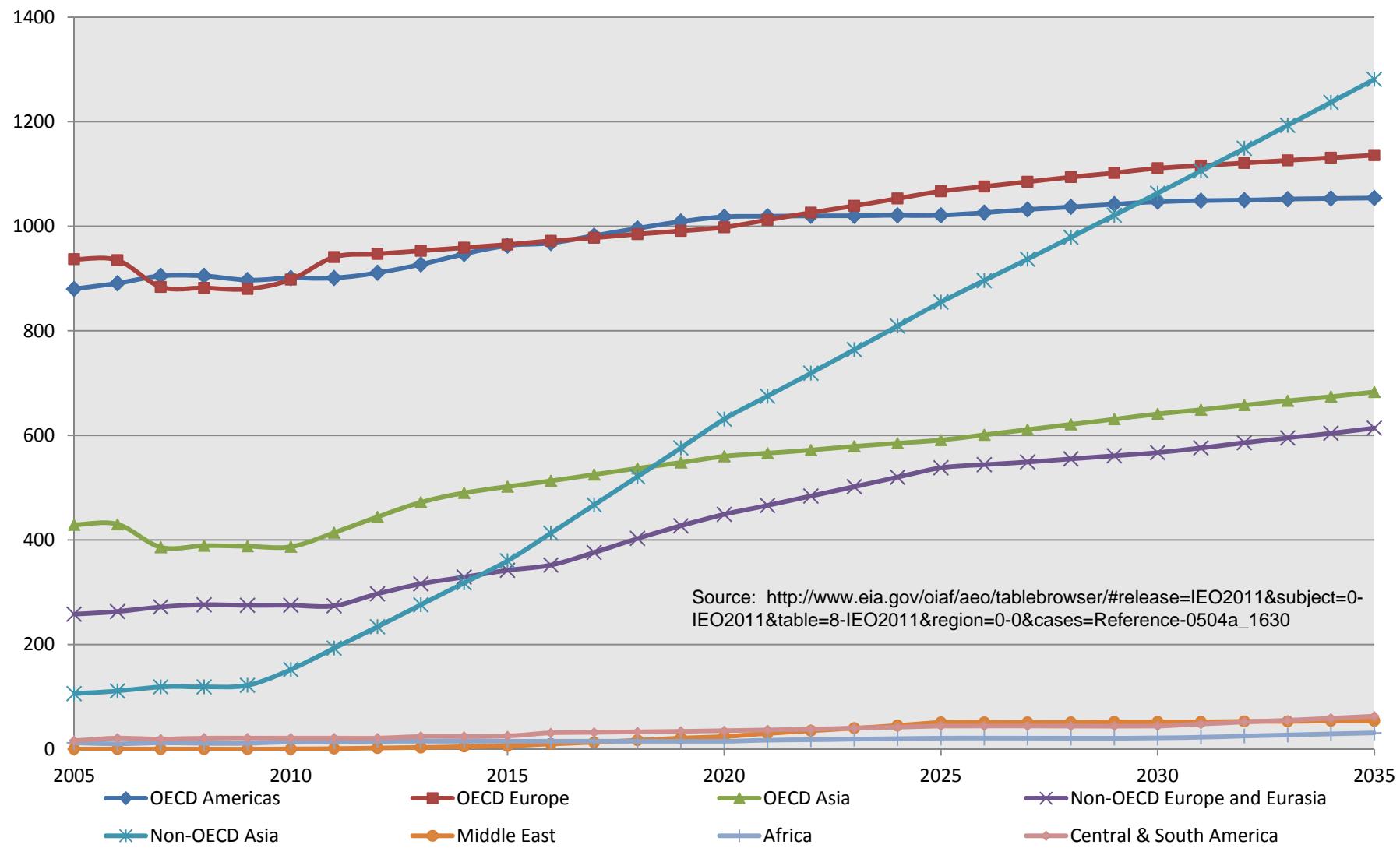
Energy Content of Fuels



Adapted from: <http://world-nuclear.org/info/energy-conversion-heat-values-fuels.html>

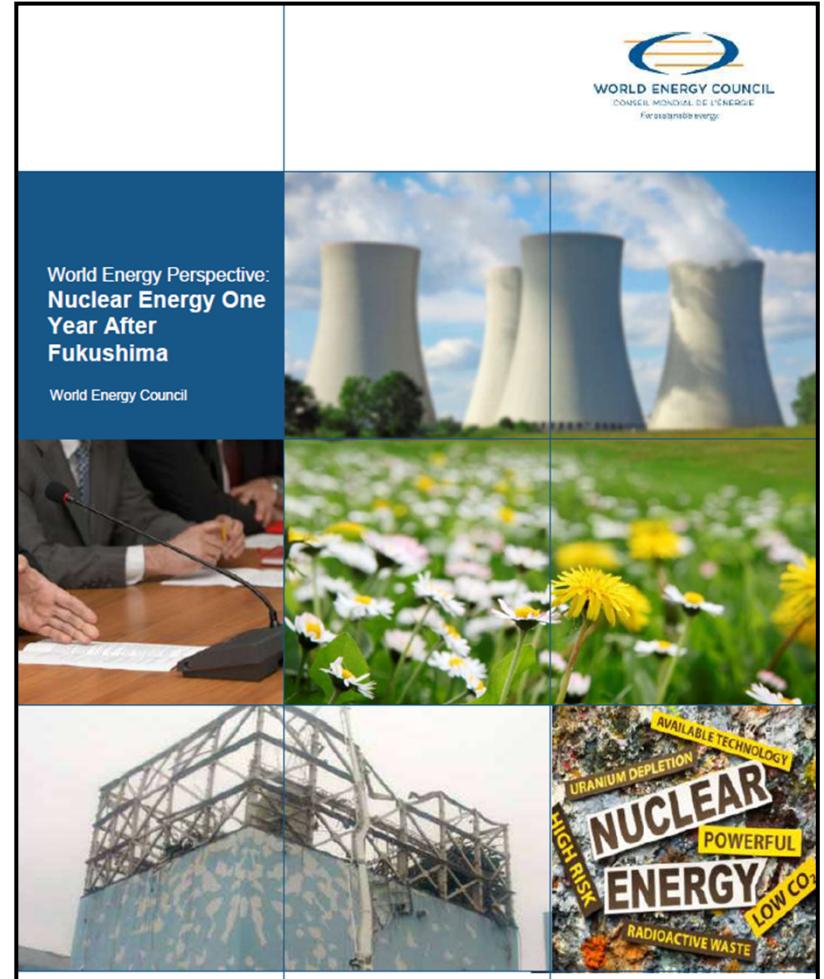
World Nuclear Energy Consumption

Billion kilowatt-hours



Post-Fukushima Conclusion...

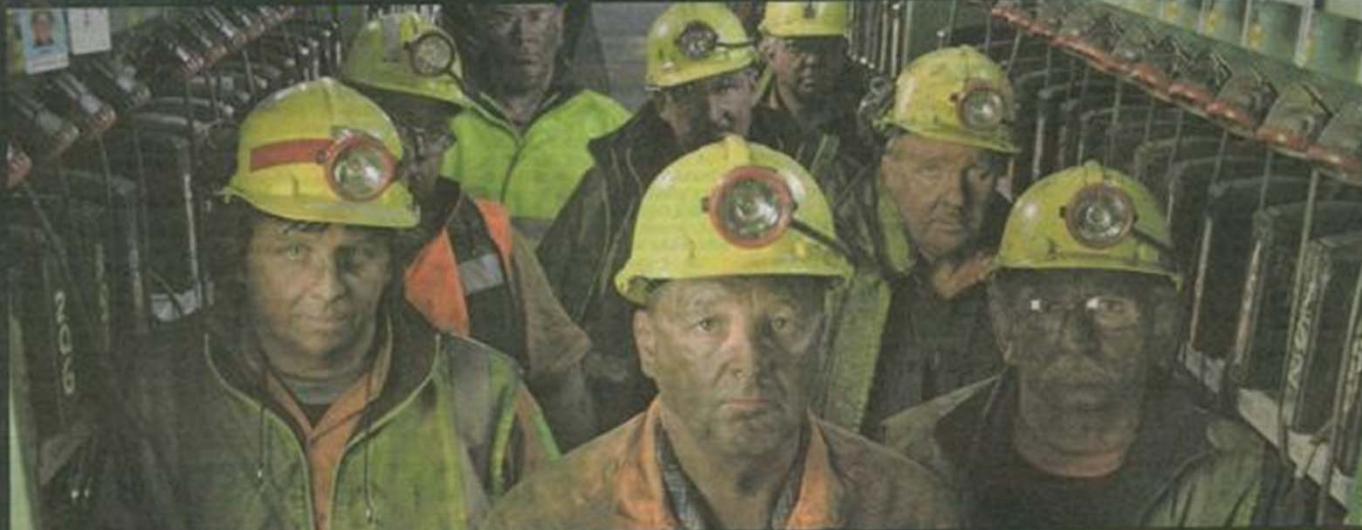
- "The IAEA argues that Fukushima has not led to a significant retraction in nuclear power programmes outside Europe, except for Japan. Progress in several national programmes, especially in countries new to nuclear power, has been delayed, especially with regard to near-term decisions to start such programmes. Generally, however, these countries have not shown any indication that their pursuit of nuclear power has declined after Fukushima. It seems likely that greater attention will be paid to issues of safety and regulation, including education, and that ambitious construction timelines may give way to more realistic schedules"



Source: World Energy Council, "World Energy Perspective: Nuclear Energy One Year After Fukushima"

Nuclear Energy, Climate, Jobs/Economy, Security

Protecting Mining Jobs and Communities



A message from Australia's coal miners

Climate change is real and we need a Government that will tackle it.
Doing nothing is no longer an option.

Voters have a choice at the election:

Labor	Coalition
<input checked="" type="checkbox"/> Support \$1.5 billion investment in Clean Coal Technology	Continue to neglect Clean Coal Technology
<input checked="" type="checkbox"/> No nuclear power station	Develop nuclear power stations that would replace the coal industry.

It's a simple choice. Vote to protect coal industry jobs and our local communities.

Authorised by T. Maher CFMEU Mining Division, 365 Sussex Street, Sydney NSW.

Monday, November 19, 2007. The Courier-Mail 21

Nuclear Power Will Kill the Coal Industry

If you care about mining industry jobs and local communities don't support the Liberal and National parties' plans to introduce nuclear power stations.

Going nuclear is dangerous and will mean the end of our coal industry. Choose a party that will help clean up the coal industry not destroy it.

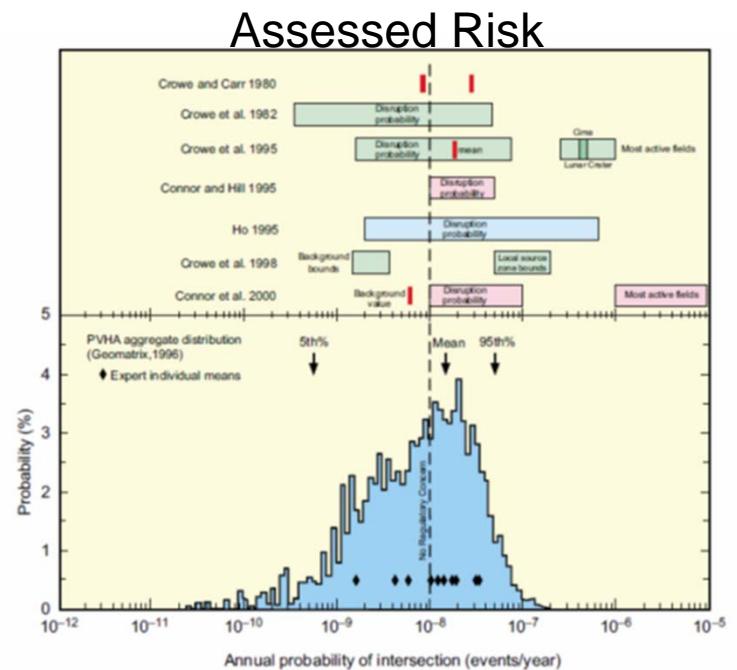


Nuclear Energy & Geologic Issues

- As a profession, there will be renewed calls for deeper understanding of the geologic features, events and processes, both nominal and extreme, that potentially affect the safety of nuclear facilities, including the siting of NPPs, interim storage facilities, siting and closure of deep geologic repositories, and other nuclear service facilities.
 - The events at Fukushima have highlighted the failure to understand the importance of time in assessing geologic hazards. Over time even rare events become likely.



Perceived Risk



Nuclear Energy & Geologic Issues

- As a profession, there will be continuing challenges in the sequestration of carbon AND nuclear waste
 - The attributes of nuclear energy and the ever-increasing desire for energy security suggest nuclear energy will be a significant and increasing portion of the world energy portfolio; nuclear waste inventories will continue to climb
 - We know how to sequester nuclear waste at scale, but it still needs to be done in many more places, each with specific technical and sociopolitical challenges.

Property	Salt	Shale	Granite	Deep boreholes
Thermal conductivity	High	Low	Medium	Medium
Permeability	Practically impermeable	Very low to low	Very low (unfractured) to permeable (fractured)	Very low
Strength	Medium	Low to medium	High	High
Deformation behavior	Visco-plastic (creep)	Plastic to brittle	Brittle	Brittle
Stability of cavities	Self-supporting on decade scale	Artificial reinforcement required	High (unfractured) to low (highly fractured)	Medium at great depth
In situ stress	Isotropic	Anisotropic	Anisotropic	Anisotropic
Dissolution behavior	High	Very low	Very low	Very low
Sorption behavior	Very low	Very high	Medium to high	Medium to high
Chemical	Reducing	Reducing	Reducing	Reducing
Heat resistance	High	Low	High	High
Mining experience	High	Low	High	Low
Available geology*	Wide	Wide	Medium	Wide
Geologic stability	High	High	High	High
Engineered barriers	Minimal	Minimal	Needed	Minimal

Favorable property
 Average
 Unfavorable property



Concluding Remarks

- Nuclear energy is, and probably will be, a fundamental contributor to the global energy portfolio
- All nuclear energy fuel cycles need geologic repositories
 - Geologic repositories – properly sited and built – will be safe
 - There is no reasonable alternative to deep geological disposal
- No safe and secure geological repositories without
 - Sound engineering concepts
 - Suitable geological environments
- Geologic repository implementation is a technically and socially challenging and interdisciplinary task
- No societally accepted geological repositories without competent and communicative engineers and geologists.
- Following presentations will address several of these issues in more detail

THE DISPOSAL OF RADIOACTIVE WASTE ON LAND

Report of the
Committee on Waste Disposal
of the
Division of Earth Sciences

Committee Members

Harry H. Hess, Chairman	
John N. Adkins	William B. Heroy
William E. Benson	M. King Hubbert
John C. Frye	Richard J. Russell
	Charles V. Theis

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Thank You!

