SAND2011-2631C

A Quake Felt Round the World: Fukushima and the Future of Nuclear Energy

Andrew Orrell
Director of Nuclear Energy & Fuel Cycle Programs
Sandia National Laboratories

April 19th, 2011

Sandia National Laboratories

SAND2011-2631C

Sandia National Laboratories is a multi-program laboratory operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

Discussion Outline

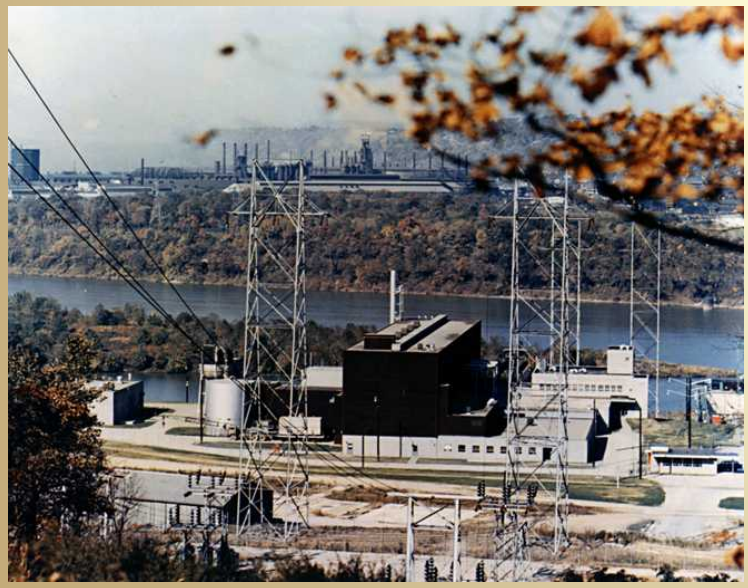
- The Rise, Fall and Rise of Nuclear Energy
  - A Brief History of US NE
- The International Element of NE
  - A Look at Issues in Europe and Asia
- The Events at Fukushima
  - What went right, what went wrong
- Consequences of Fukushima on US and International NE
  - Facts and Speculation
- Concluding Remarks

The Rise, Fall, and Rise of NE in the US

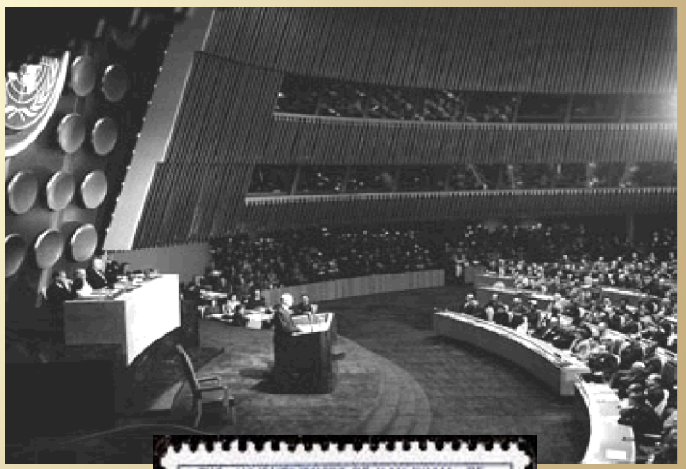
Birth of an Industry
Atoms for Peace - 1953

The first production of usable nuclear electricity occurred on 12/20/51, when four light bulbs were lit with electricity generated from the EBR-1 reactor.

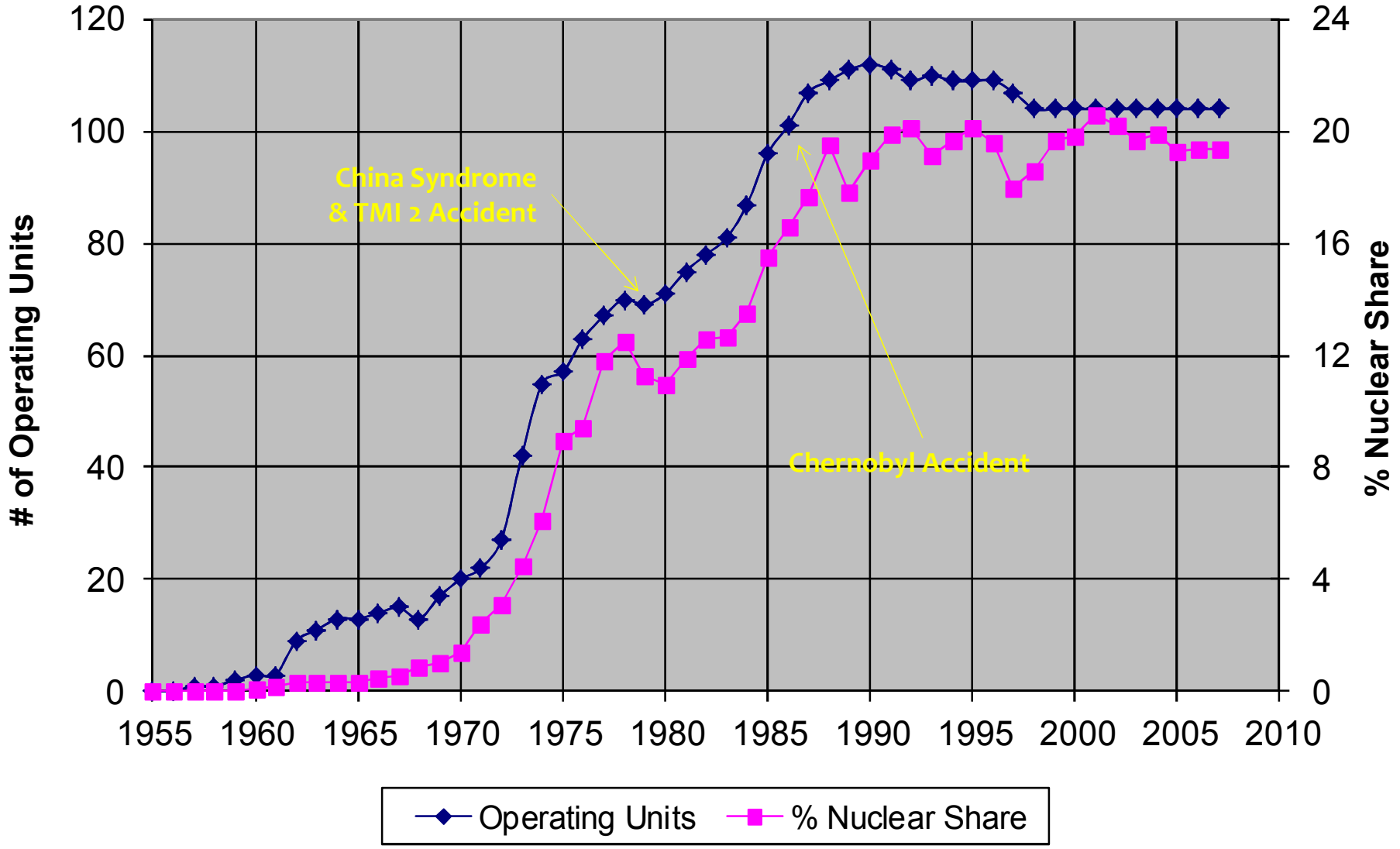
- Serve the peaceful pursuits of mankind provide abundant electrical energy in power starved areas of the world
- Encourage world-world investigations with the most effective peacetime uses of fissionable material
- Create international controls to prevent proliferation (IAEA)



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



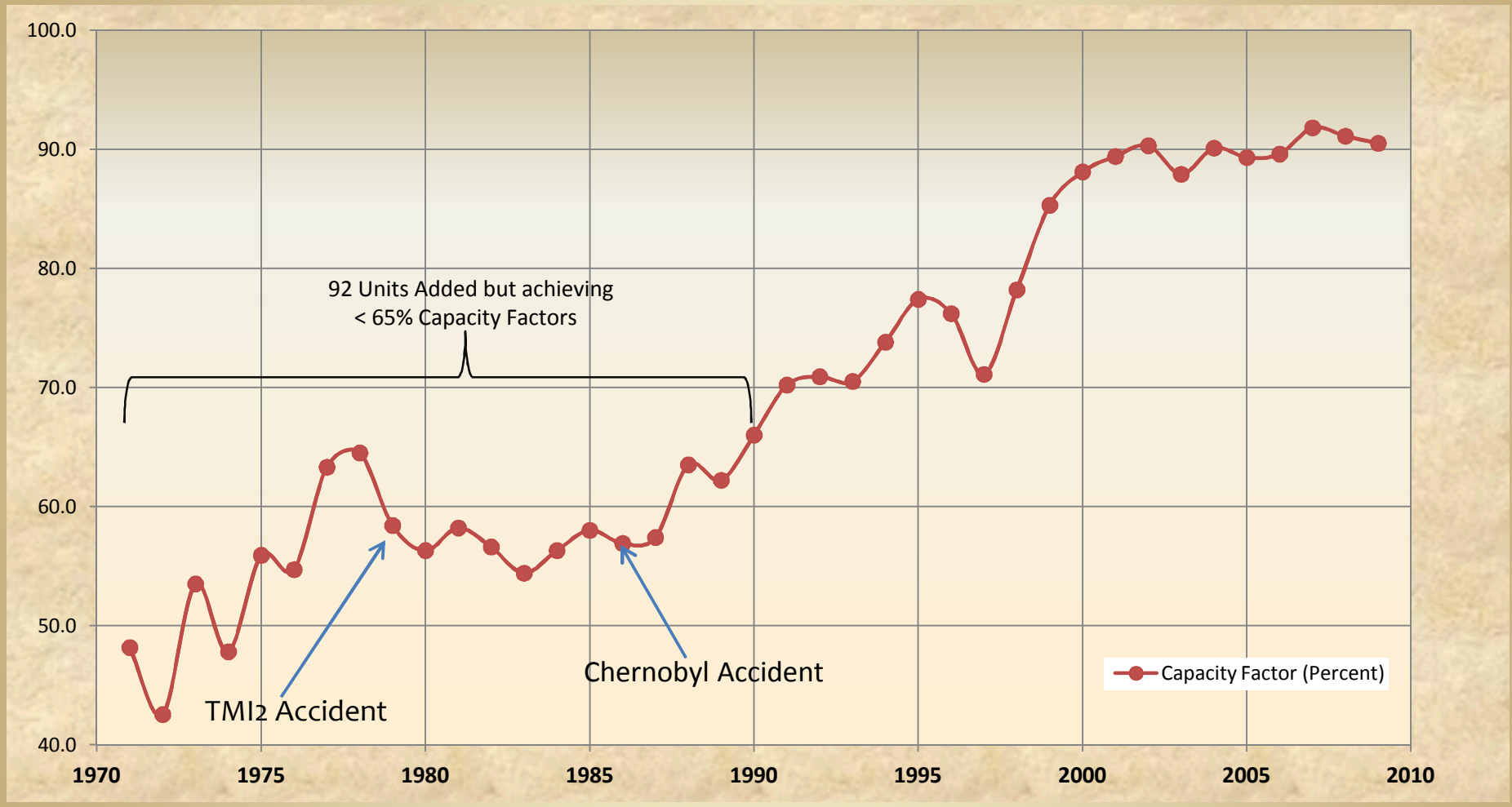
The Rise…



Between 1970 and 1990, the U.S. added 92 Operating Units, but…

The Fall…

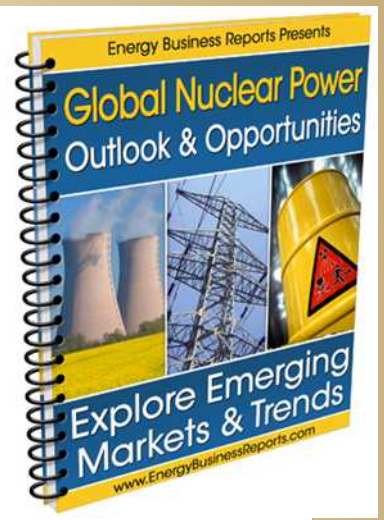
U.S. Nuclear Plant Capacity Factors

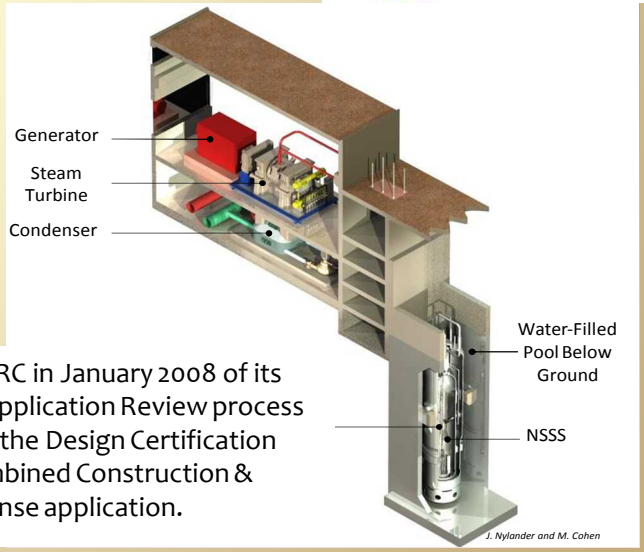


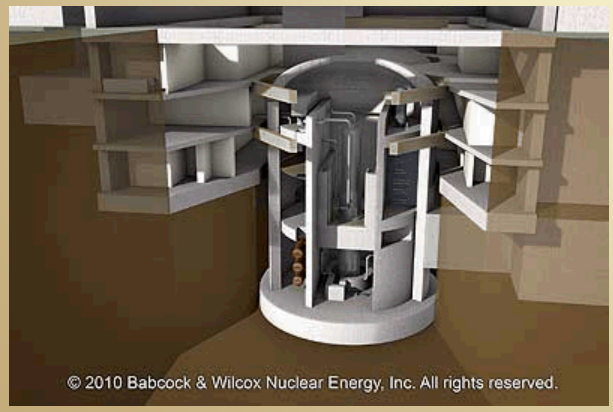
…capacity (efficiency) didn't keep pace.

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

The Rise of a U.S. Nuclear Renaissance ?

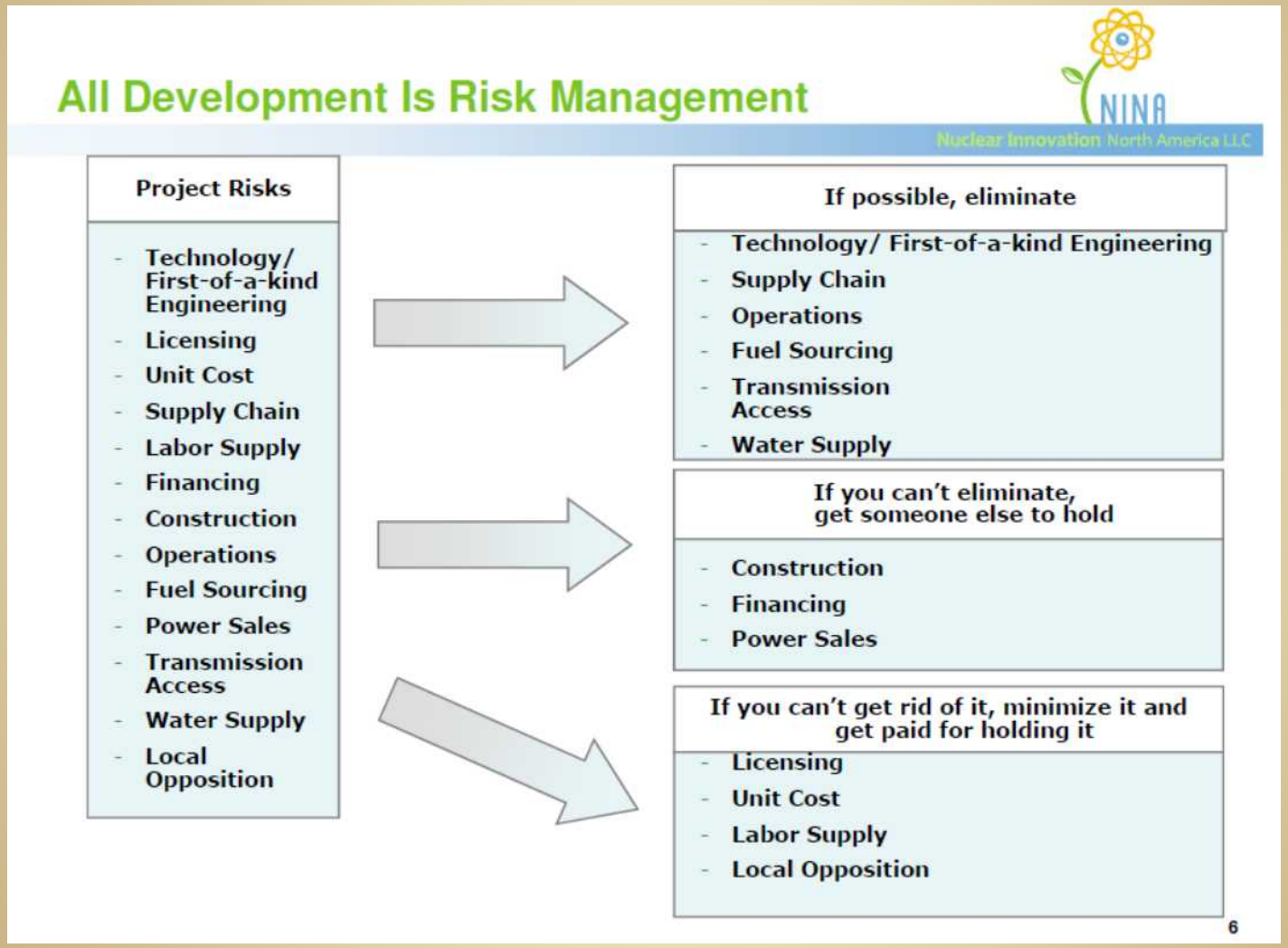






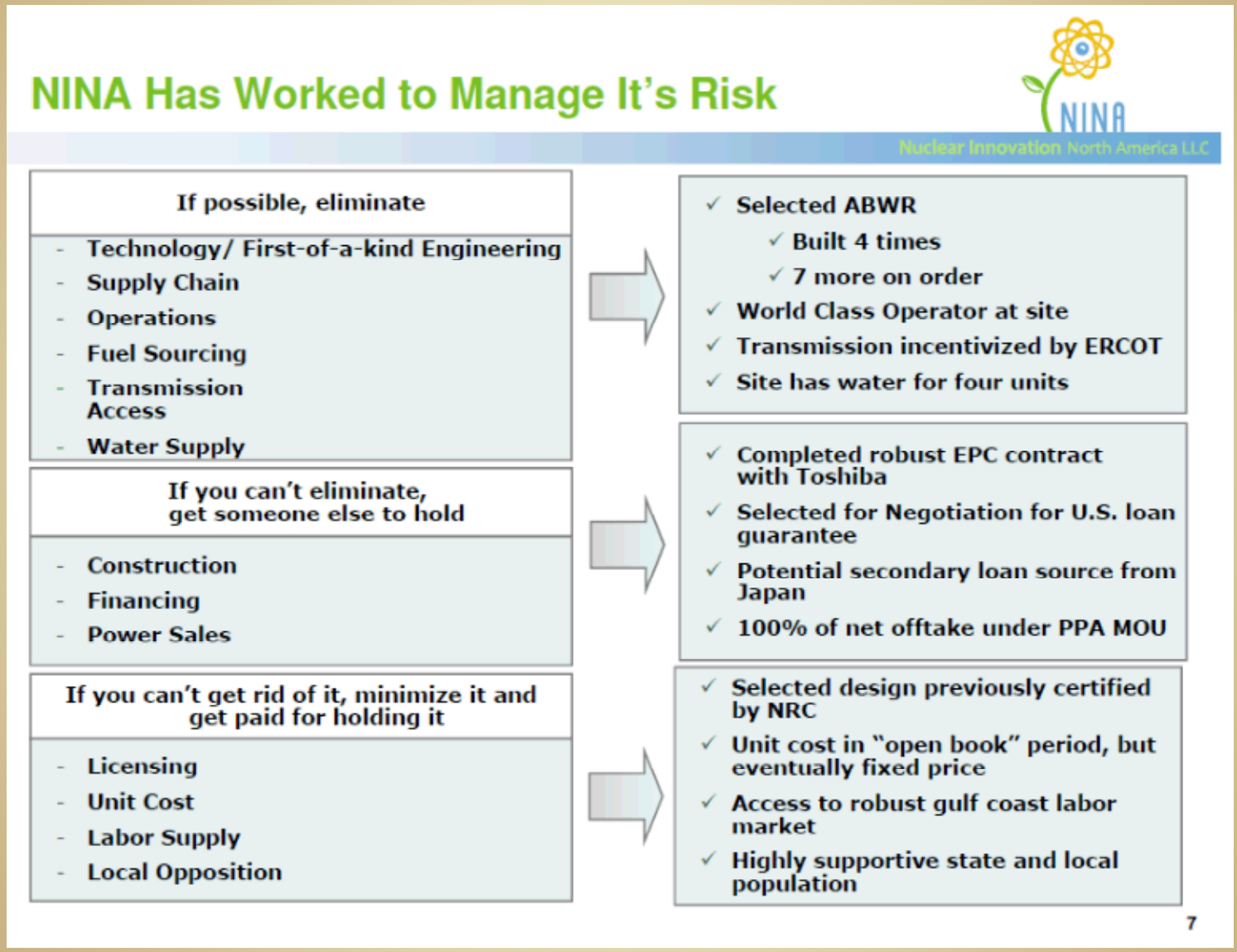
NuScale notified the NRC in January 2008 of its intent to begin the Pre-Application Review process for the preparation of the Design Certification request and the combined Construction & Operating License application.

It's All About Risk Management



From: NINA LLC, "Creating Cost Certainty for Nuclear Development"; October 26, 2009.

Managing Risks



From: NINA LLC, "Creating Cost Certainty for Nuclear Development"; October 26, 2009.

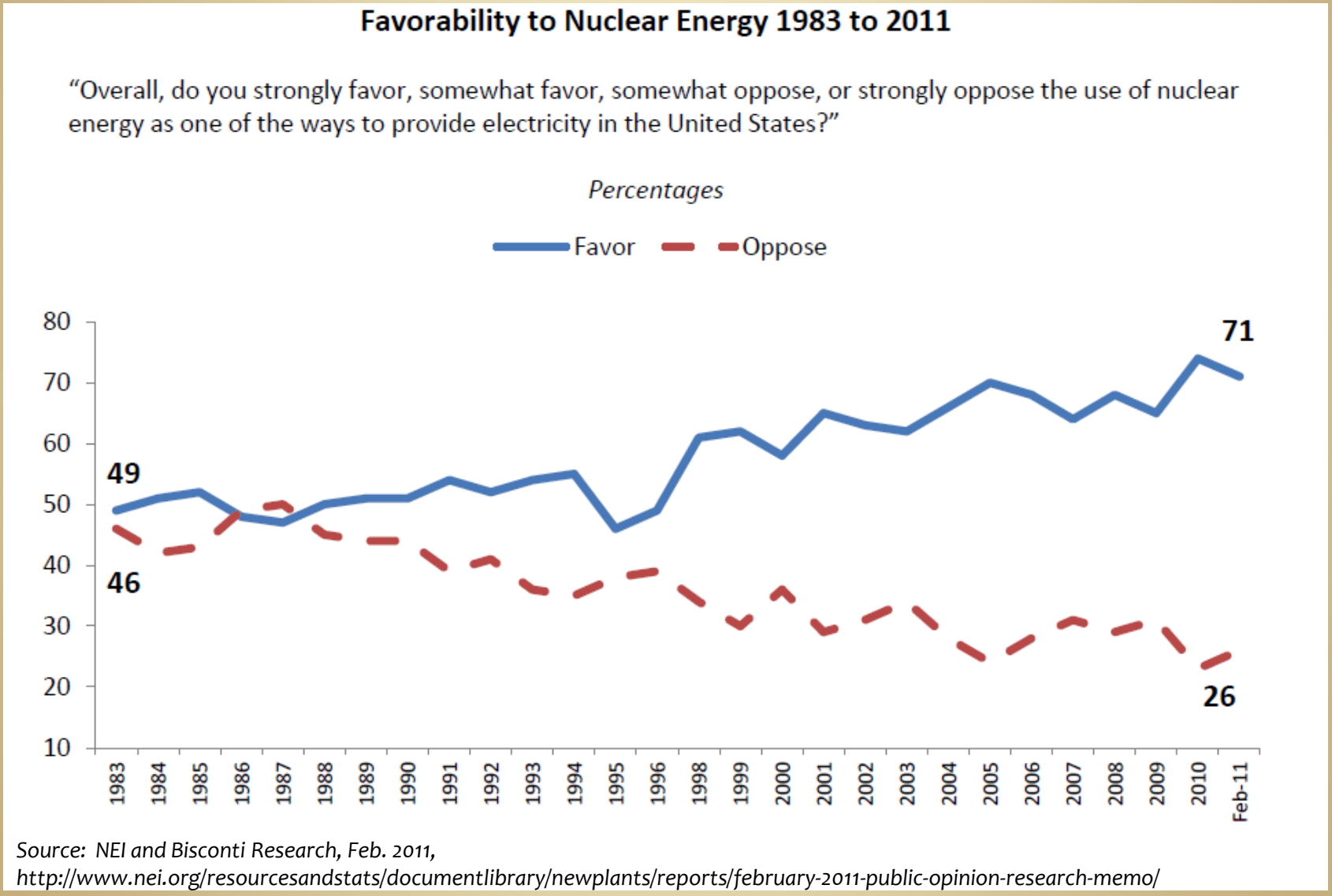
Factors Favoring a U.S. Nuclear Renaissance
Starting ~2001

- Economics of high-capacity factor plants (analogous to a Saudi oil well)
  - STP has the lowest production cost reported by nuclear power plants nationwide, at 1.356 cents per kilowatt-hour in 2006. STPS's combined operating, maintenance and fuel expenses were the lowest among plants that report those costs to federal regulators.
- 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 license (COL), the NRC authorizes the licensee to construct and operate a nuclear power plant at a specific site, valid for 40 years. A Combined Construction and Operating License
- U.S. Federal Loan Guarantees
  - $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
- Overseas construction experience provides construction schedule confidence
- Improved Public and Political Support

Improved Political Support

- 1984 Democratic Party platform:
  - "strongly oppose the Reagan Administration's policy of aggressively promoting" nuclear power.
- 2004 Democratic Party platform:
  - limited its comment merely to opposing the siting of a nuclear waste repository in Nevada.
- 2006:
  - Greenpeace Co-founder Patrick Moore now supports nuclear power: "Nuclear energy is the only large-scale, cost-effective energy source that can reduce these emissions while continuing to satisfy a growing demand for power. And these days it can do so safely."
  - House Speaker Nancy Pelosi (CA) : "In the early days of my life in Congress, I was an opponent of nuclear energy because of questions on how to dispose of the waste. Your question is good because the technology has changed, and I bring a more open mind to that subject now because I think we should look at this technology, and compare the alternatives…….It has to be on the table," February 8, 2006.
  - Senator Barbara Boxer (CA): "I am a pragmatist. The vast majority of the members on my committee support nuclear power, and so do the majority in the Senate…..I don't think there is any question that we are going to be seeing new plants."
- 2008 Democratic Party Platform:
  - "We will seek to double the International Atomic Energy Agency's budget, support the creation of an IAEA-controlled nuclear fuel bank to guarantee fuel supply to countries that do not build enrichment facilities, … [Energy security] requires addressing nuclear safety, waste, and proliferation challenges around the world; and more. … We will protect Nevada and its communities from the high-level nuclear waste dump at Yucca Mountain, which has not been proven to be safe by sound science."
  - President-elect Obama has said the nation must find "safer ways to use nuclear power and store nuclear waste.", and "I don't think that we can take nuclear power off the table..."
- 2010:
  - Secretary Chu tells Congress "*We need to reinvigorate America's nuclear power industry.* Earlier this year, DOE made a conditional commitment to finance construction of what will be the first nuclear reactor to break ground in the U.S. in decades. In FY 2011, the Department is requesting an additional $36 billion in loan guarantee authority for nuclear power. "

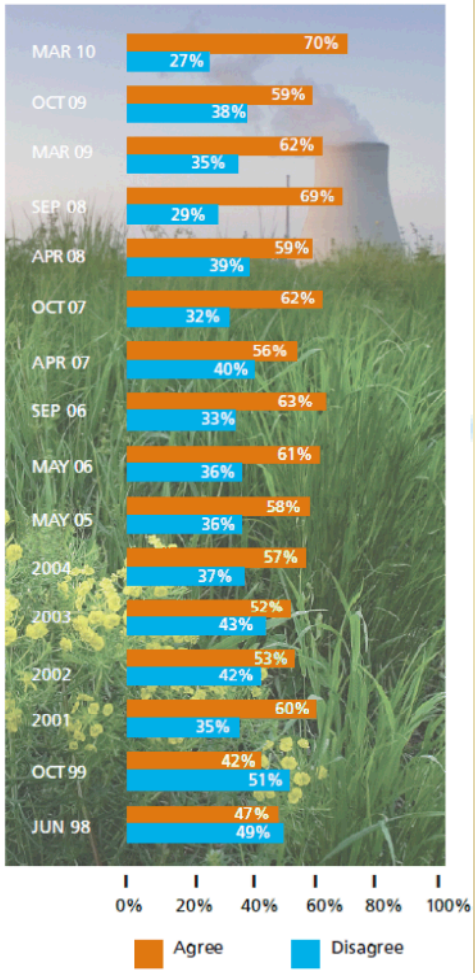
Improved Public Support



Source: NEI and Bisconti Research, Feb. 2011,
http://www.nei.org/resourcesandstats/documentlibrary/newplants/reports/february-2011-public-opinion-research-memo/

Growing Support for New Reactor Development

Perspective on Public Opinion, NEI June 2010



Seventy percent support building nuclear power plants in the future, compared with 47 percent in 1998, when the question was first asked.

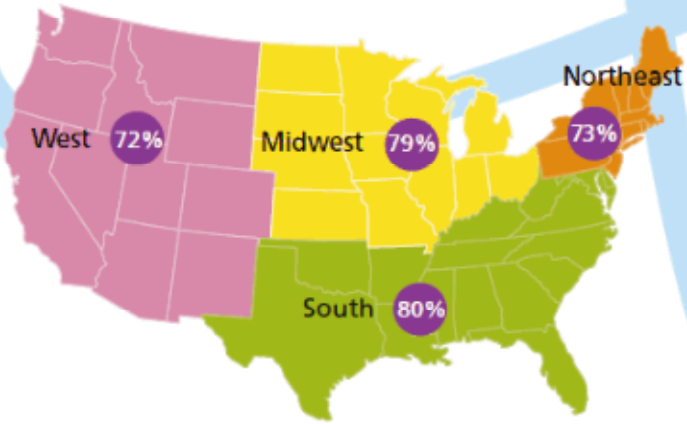
Percent Agree/Disagree We Should Definitely Build More Nuclear Power Plants in the Future

"PLEASE TELL ME IF YOU PERSONALLY STRONGLY AGREE, SOMEWHAT AGREE, SOMEWHAT DISAGREE, OR STRONGLY DISAGREE WITH THE FOLLOWING STATEMENT: WE SHOULD DEFINITELY BUILD MORE NUCLEAR POWER PLANTS IN THE FUTURE."

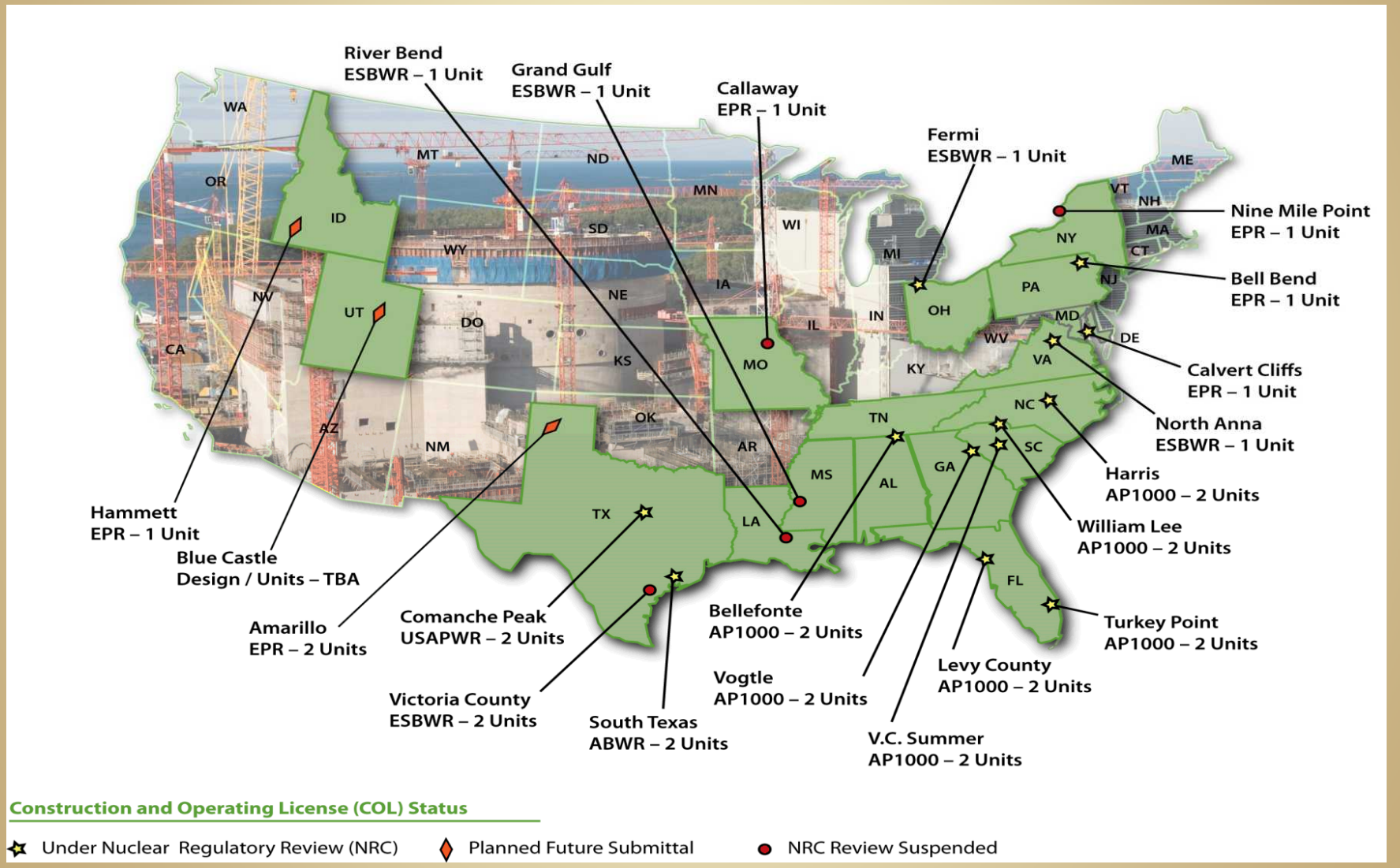
A record-high 77 percent said that a new reactor would be acceptable at the nearest nuclear power plant site. This high number reflects increases in all regions, with particularly strong acceptability in the South and Midwest.

Acceptability of Adding a New Reactor Next to the Nearest Operating Nuclear Power Plant

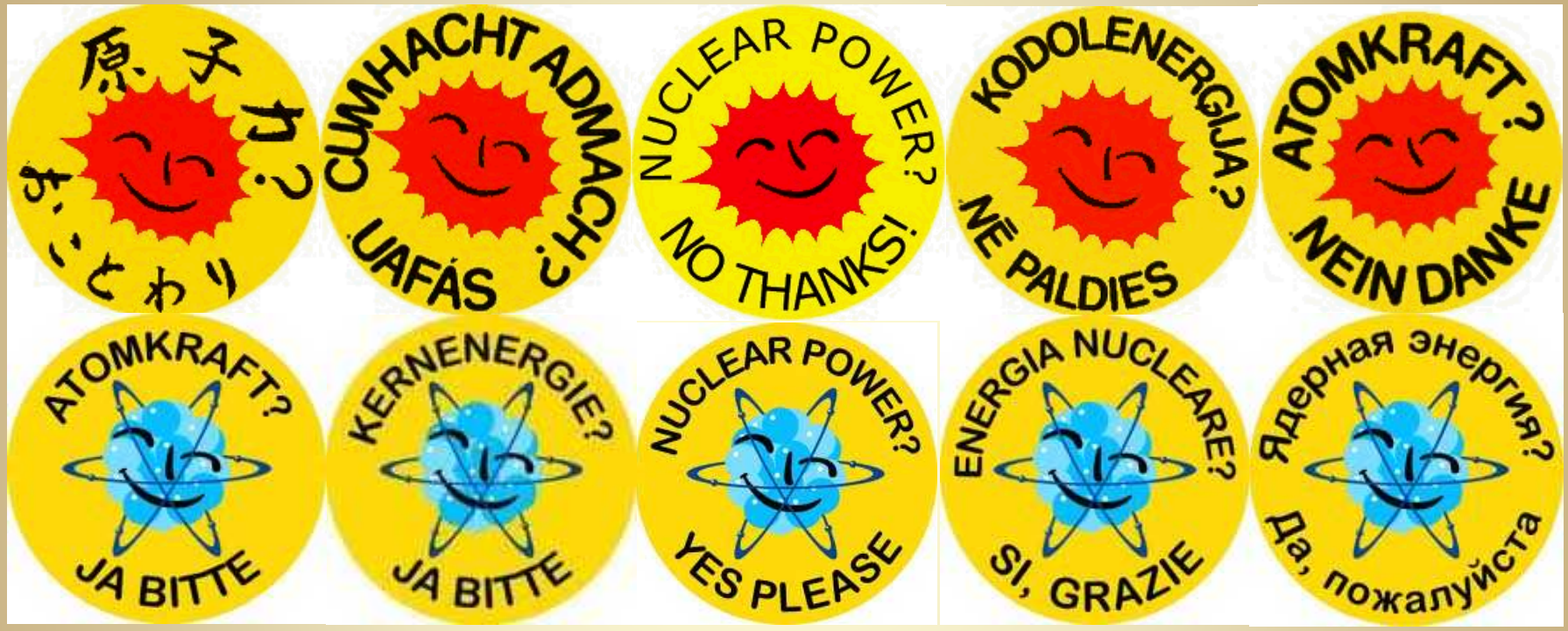
"IF A NEW POWER PLANT WERE NEEDED TO SUPPLY ELECTRICITY, WOULD IT BE ACCEPTABLE TO YOU OR NOT ACCEPTABLE TO YOU TO ADD A NEW REACTOR AT THE SITE OF THE NEAREST NUCLEAR POWER PLANT THAT IS ALREADY OPERATING?"



Investor Confidence Yields Plans for New Build



What About the International Markets?



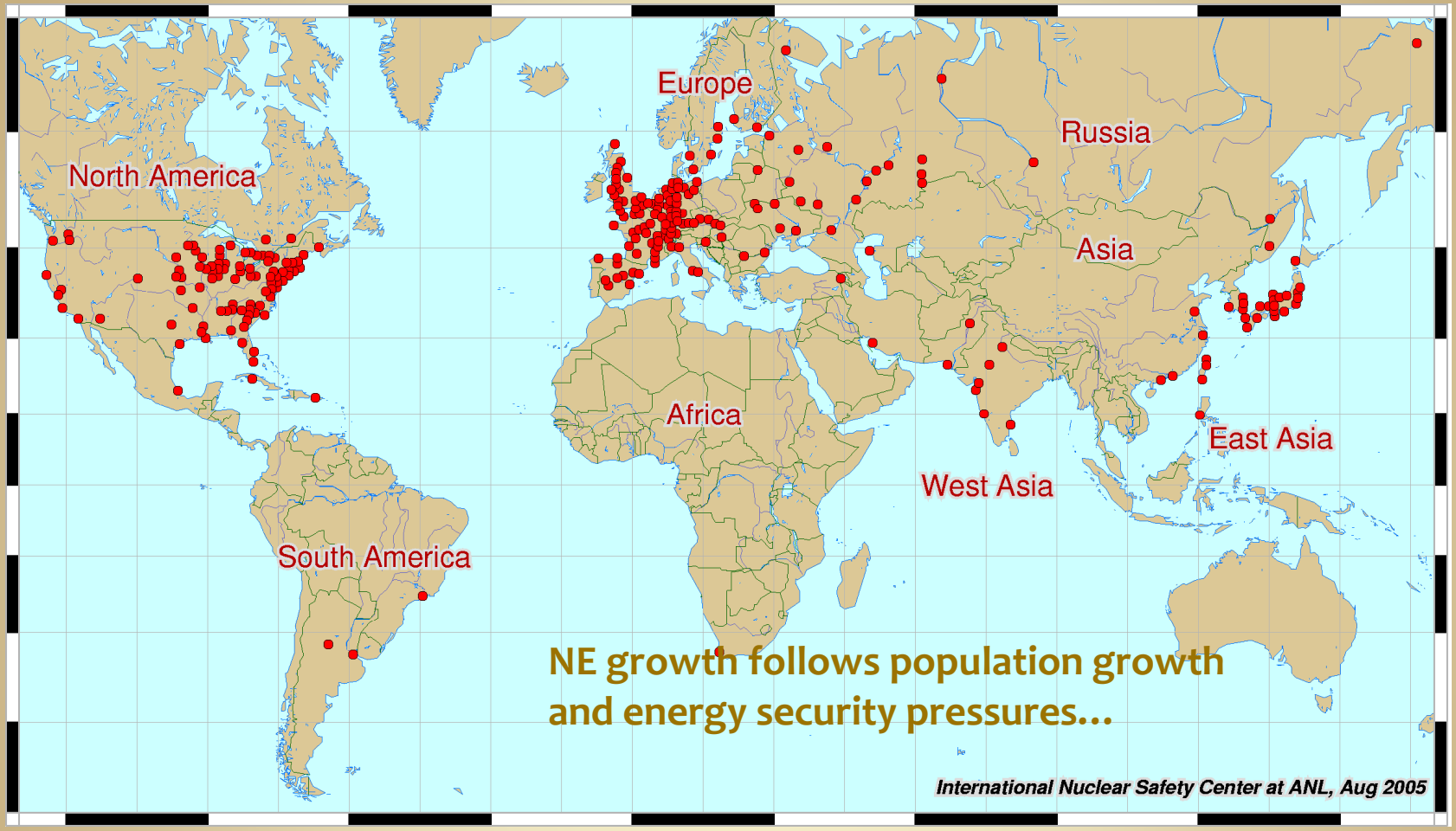
World Nuclear Association

Representing the people and organisations of the global nuclear profession

WANO

AEN NEA Agence pour l'énergie nucléaire
Nuclear Energy Agency

World NPP Locations



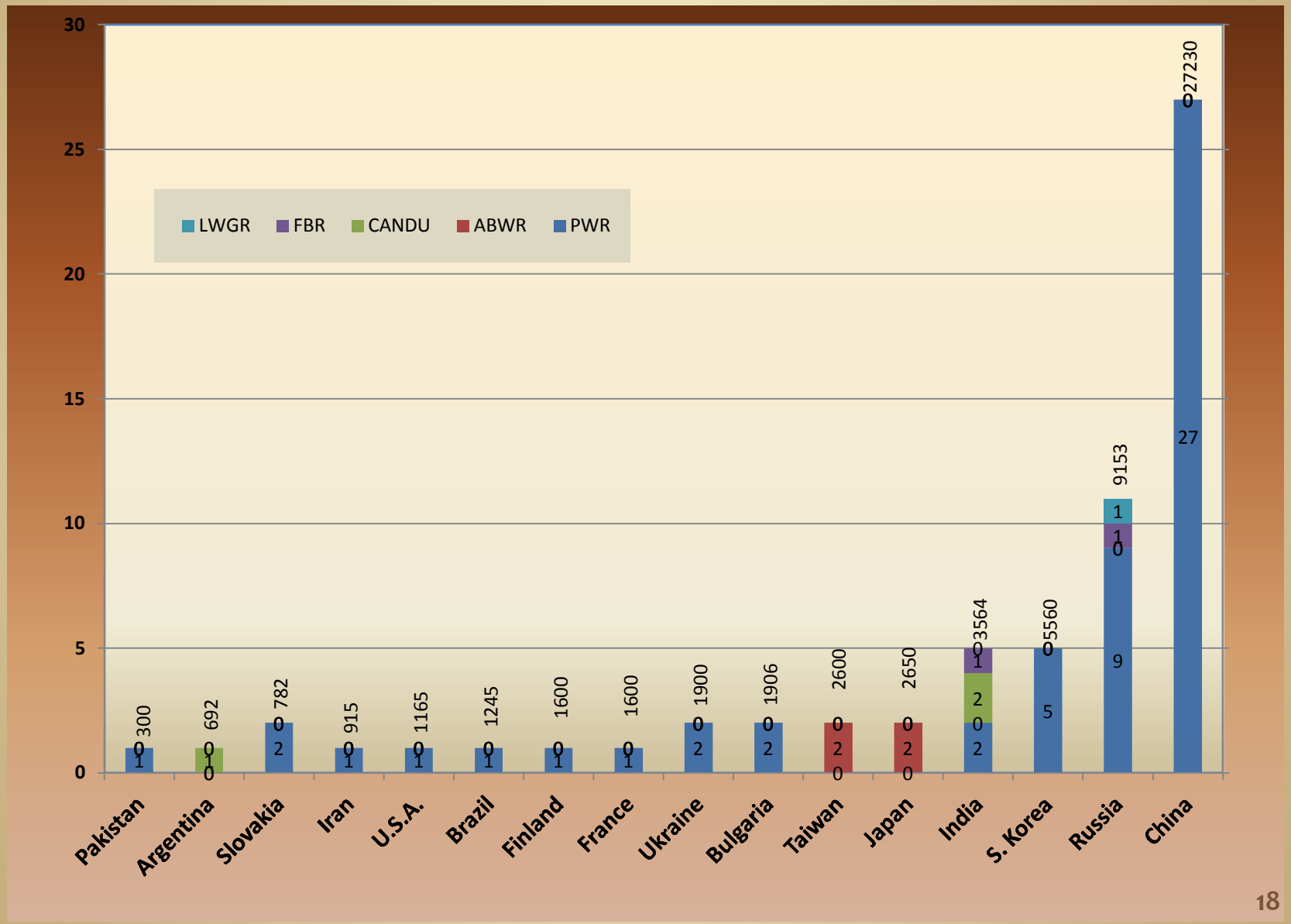
- As of March 2011, there were 442 nuclear reactors operating in 30 countries, with a total capacity of 372 GWe
- 61 plants with an installed capacity of 45 GWe are under construction in 14 countries
- The **United States, France and Japan** have > half of the world's nuclear generating capacity, 16 countries relied on nuclear energy to generate over 25% of their electricity.

A Global Nuclear Rise?

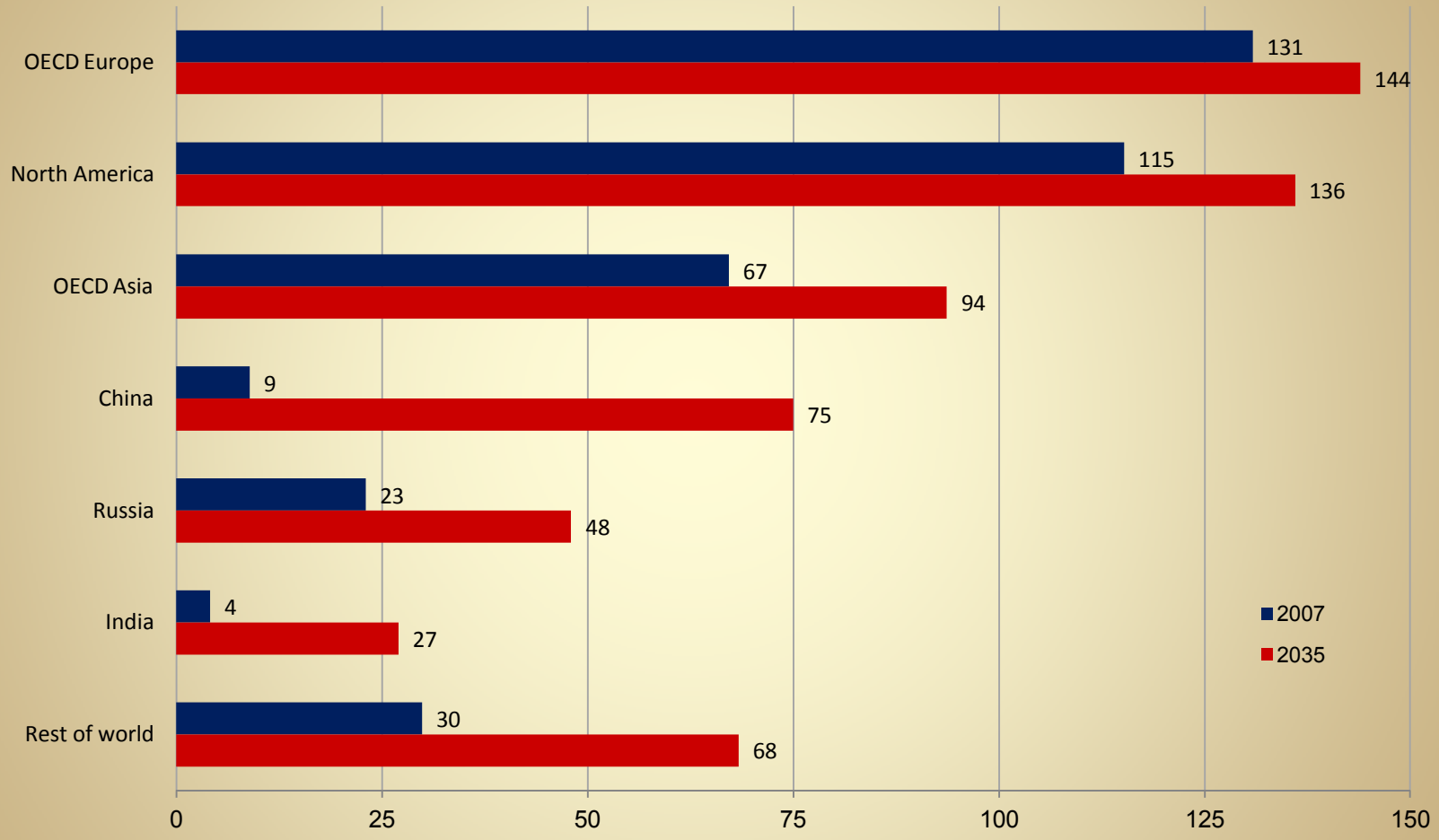
- 10/2006: Brazil announced the construction of seven nuclear plants by 2025 to ensure energy sufficiency with economic efficiency
- 08/2008: China head of National Energy Administration targets nuclear power share to 5% for 2020
- 10/2008: Industry Minister Scajola announces Italy may start work by 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)

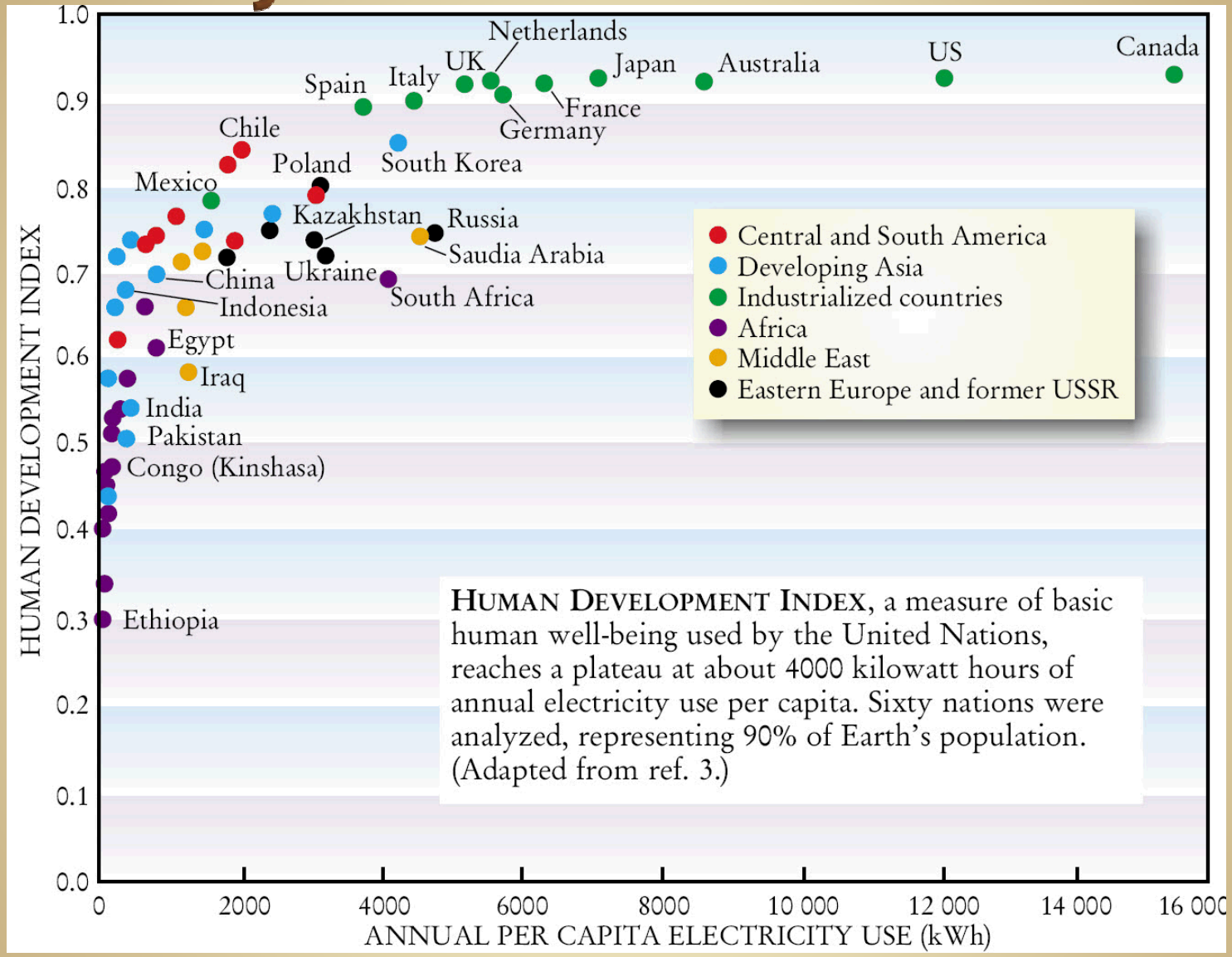


World Nuclear Generating Capacity (GW) by Region
2007 and 2035



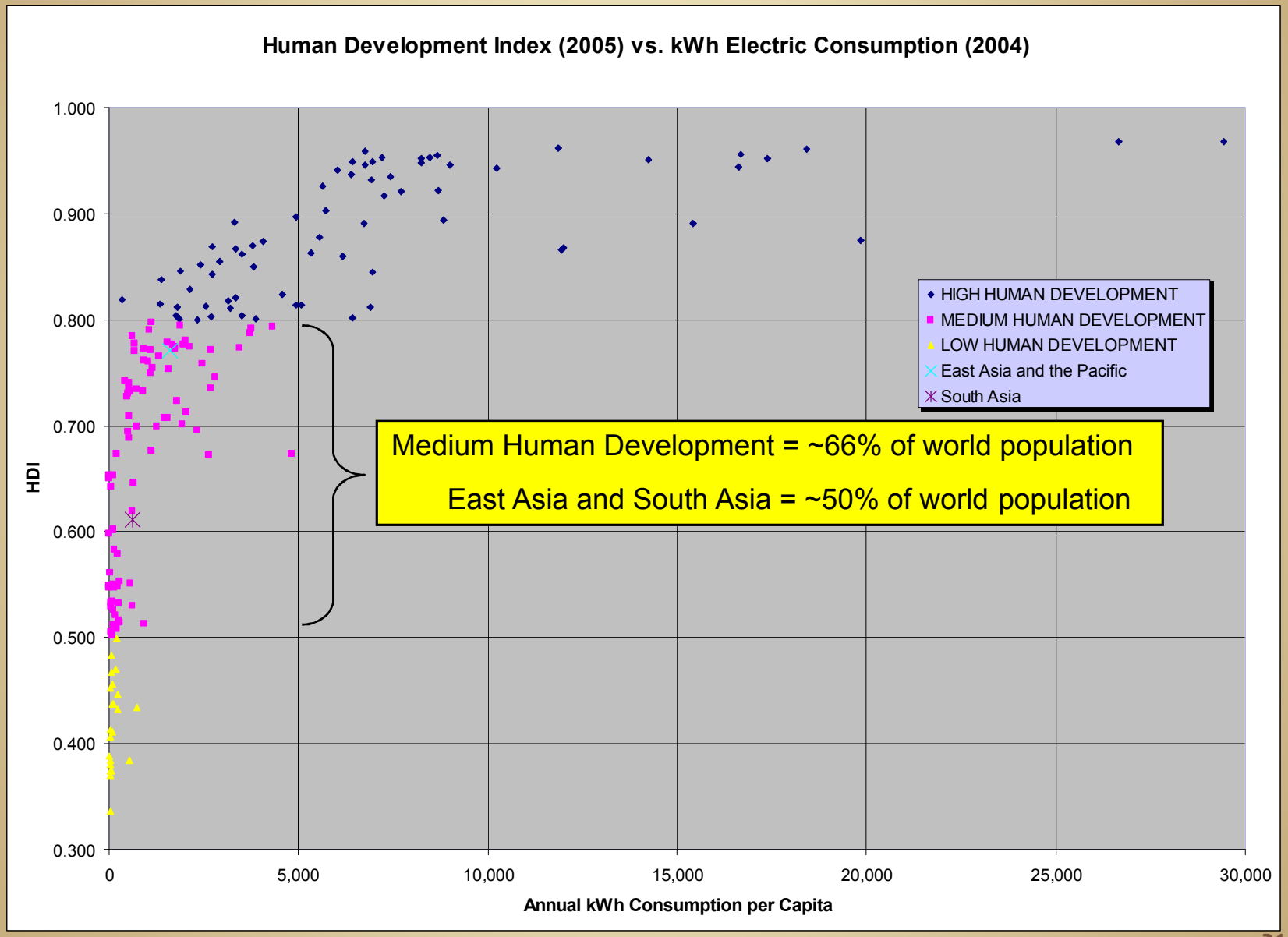
EIA, International Energy Statistics database (as of November 2009),
web site www.eia.gov/emeu/international. Projections: EIA, World Energy Projection System Plus (2010).

Why the Nuclear Interest?

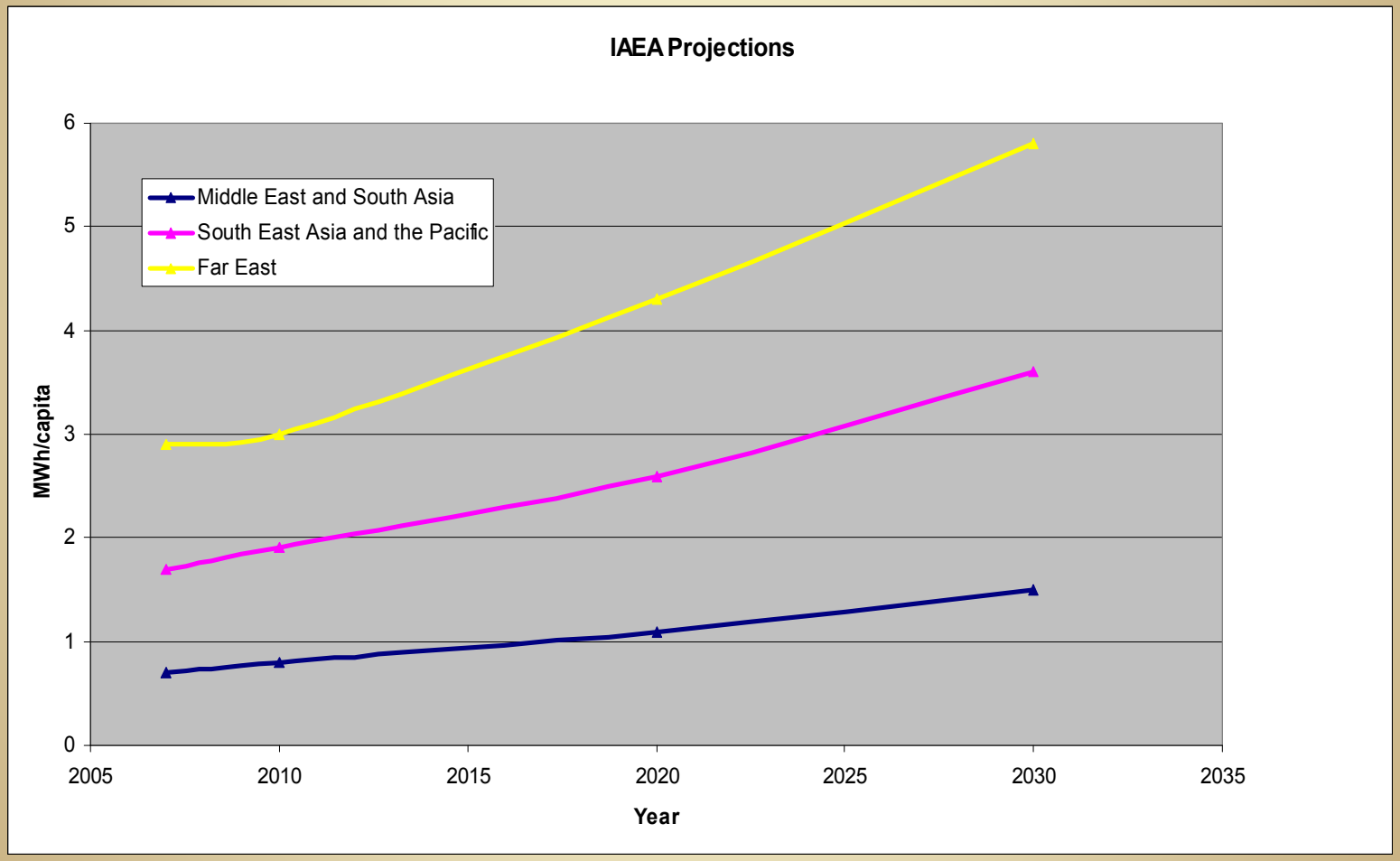


Alan Pasternack showed in 2000 that the Human Development Index, an index combining normalized measures of life expectancy, literacy, health, education, standard of living, and Gross Domestic Product per Capita, correlates reasonably well with annual per capita electricity use.

Potential Asian Influence on the Development of Nuclear Energy

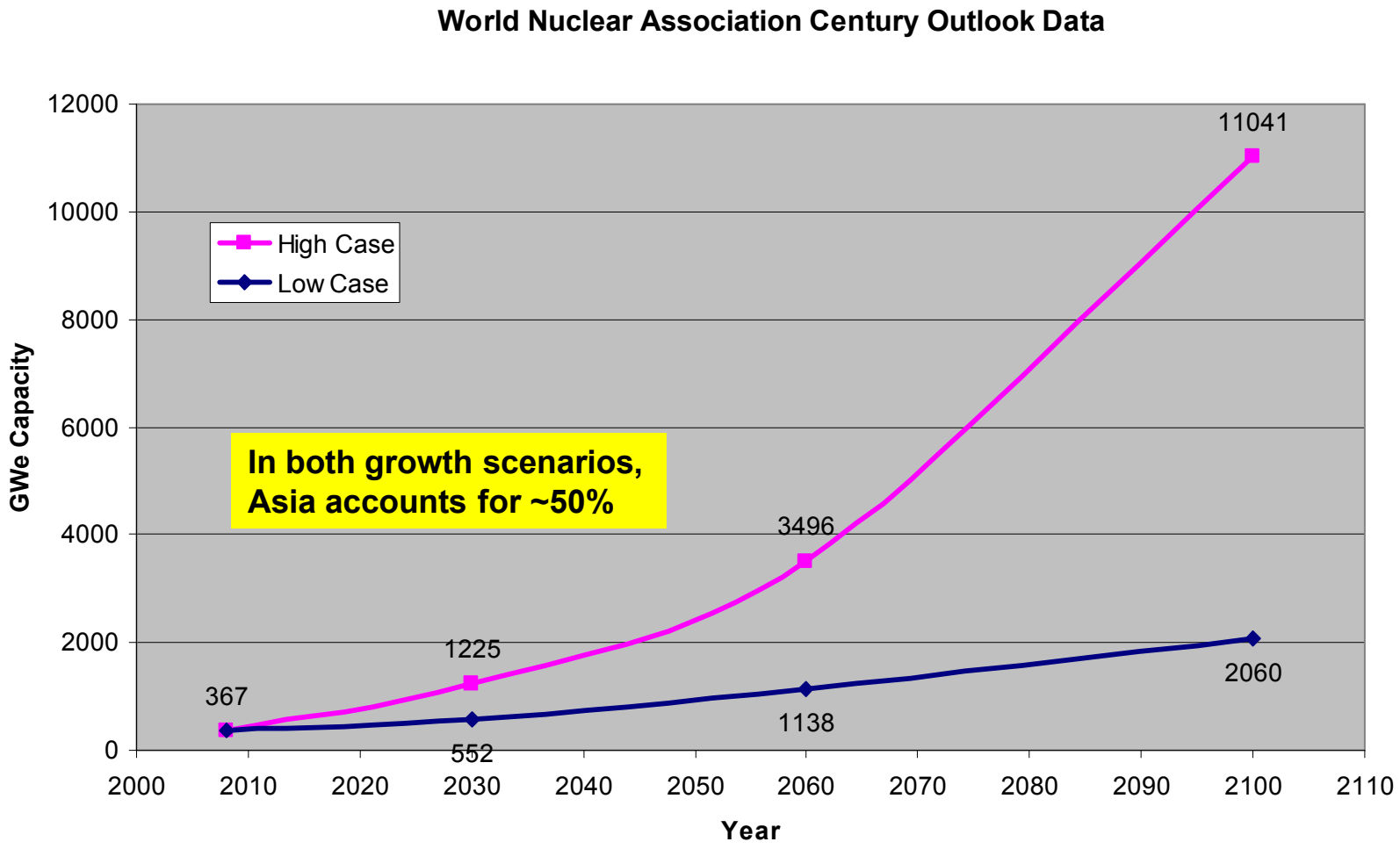


Asian Capacity Demands Double in 20 Years



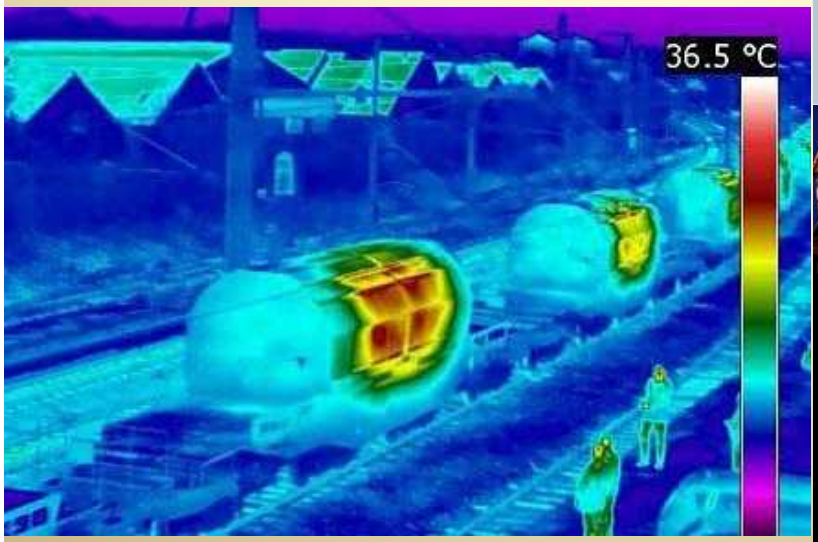
Data from IAEA 2008 edition of *Energy, Electricity and Nuclear Power Estimates for the Period to 2030*

Asia Accounts for ~50% of WNA Projections



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



Some Risks are Difficult to Manage

Remaining Components of Cost Risk

NINA
Nuclear Innovation North America LLC

Risk Component	Rough % of Unit Cost Exposed	Relative Volatility	Comment
Yen/ Dollar For-Ex	20%	High	All U.S. units will be exposed to a significant percentage of foreign sourced components
Transport	5%	High	Highly volatile over the last twenty four months, touches every delivered material. Correlated with overall economic activity
Labor Cost	25%	Low	Wages are sticky and generally modestly upward sloping
Manufactured Goods	10%-20%	Moderate	ABWR has previously manufactured components with known suppliers
Base Commodities	30%	High	Steel, Concrete and similar items are correlated with overall economic activity
Interest Rates	20%	Moderate	Due to loan guarantees, interest during construction tied to U.S. and Japanese sovereign interest rates

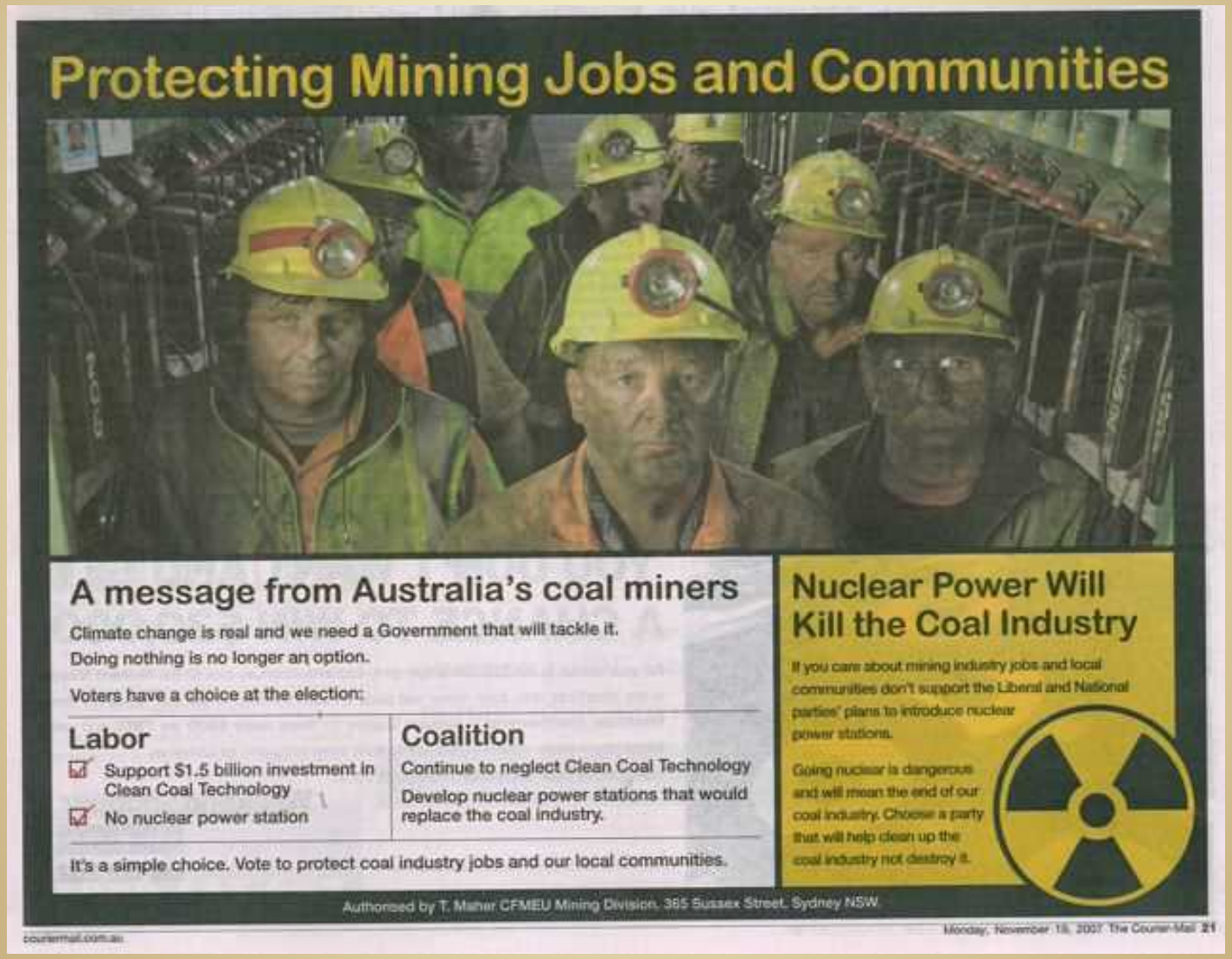
STP 3&4 will eliminate nearly all of these risks by FNTP (2012)

10

From: NINA LLC, "Creating Cost Certainty for Nuclear Development"; October 26, 2009.

Climate vs. Jobs

War of the Fuels



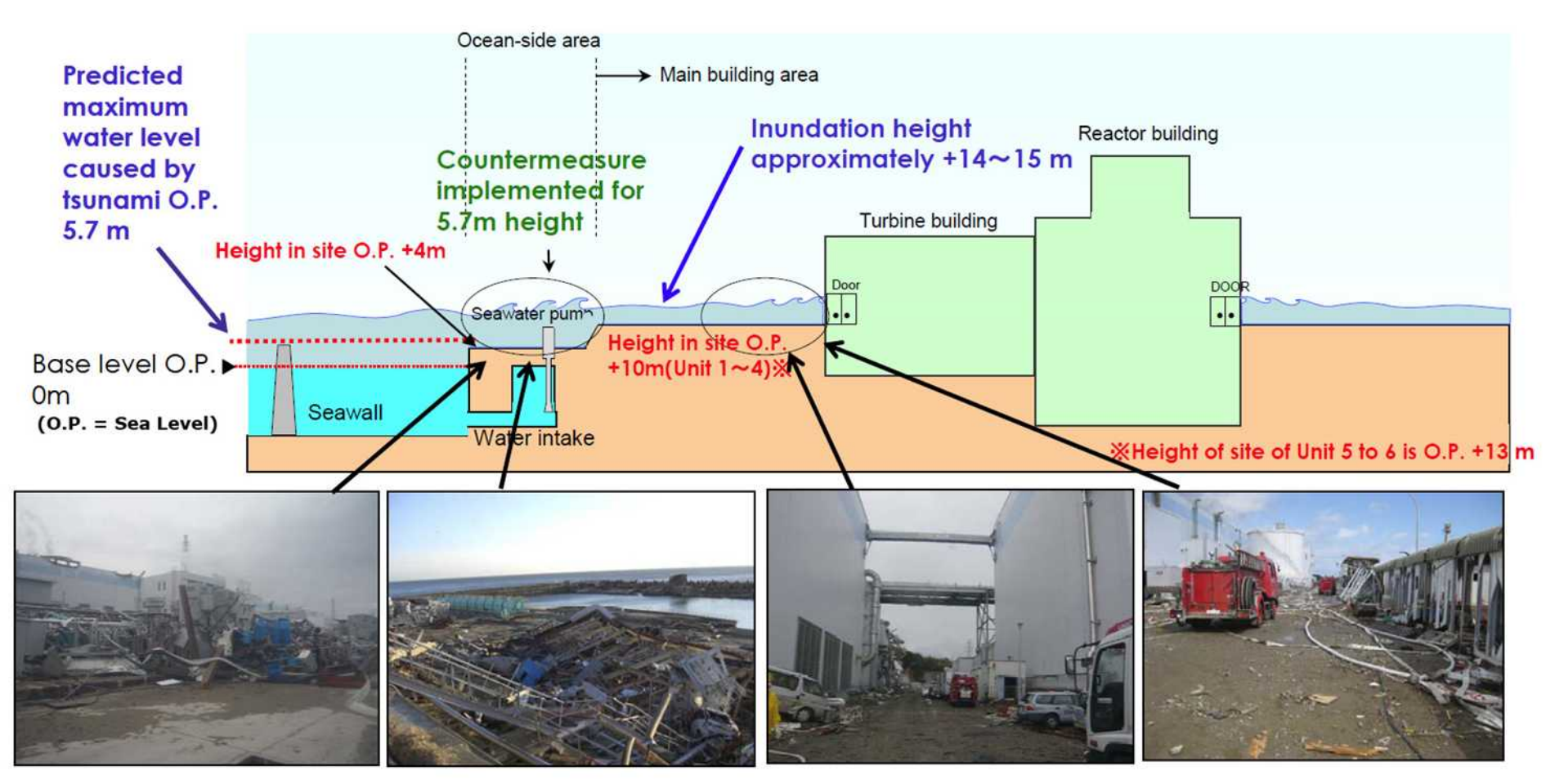
Tentative Pre-Quake Conclusion

- By all accounts and projections, nuclear energy will grow significantly in the next 25 years
  - Whether led by the US or not, whether with large LWRs or small modular reactors, 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, here and abroad

March 10th 2011

- **Unit 1**: 439 MWe BWR, 1971 (unit was in operation)
- **Unit 2**: 760 MWe BWR, 1974 (unit was in operation)
- **Unit 3**: 760 MWe BWR, 1976 (unit was in operation)
- **Unit 4**: 760 MWe BWR, 1978 (unit was in outage)
- **Unit 5**: 760 MWe BWR, 1978 (unit was in outage)
- **Unit 6**: 1067 MWe BWR, 1979 (unit was in outage)

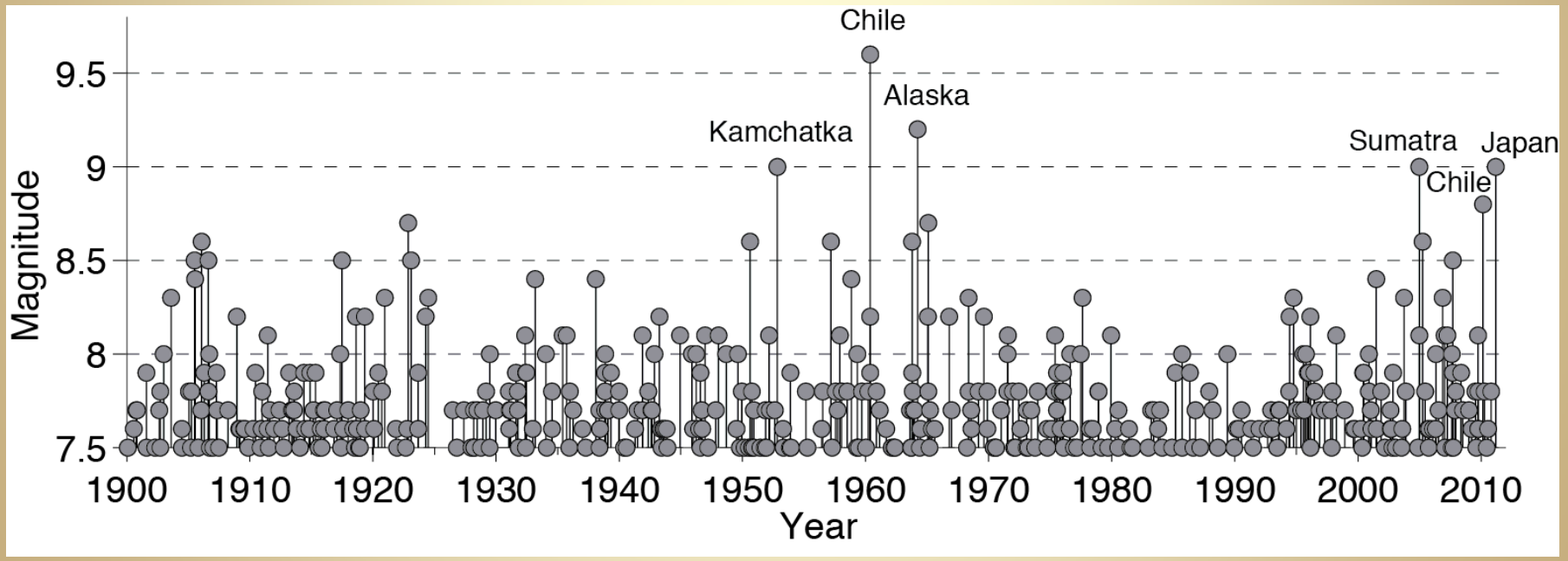
And then the 'beyond design basis' happened…



A remarkable earthquake and tsunami: a 1-2 punch

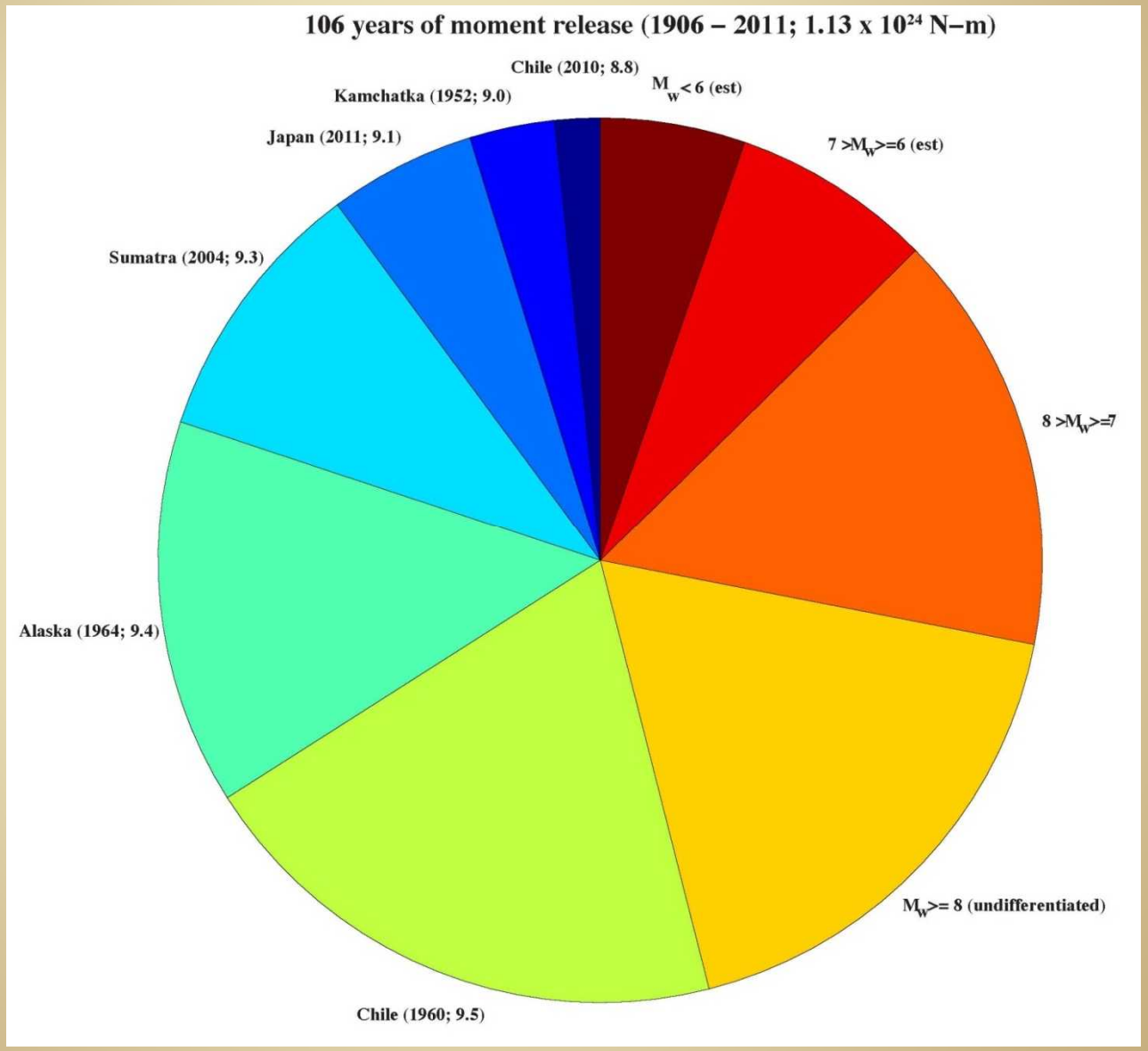
First the Tohoku Earthquake

- 4th largest earthquake since 1900
- Largest in Japan in the era of instrumental recording,
- Largest known event along Japan Trench since year 869



The Quake Size

It is striking that only 6 earthquakes over the last 106 years account for over half of the energy released during that time.



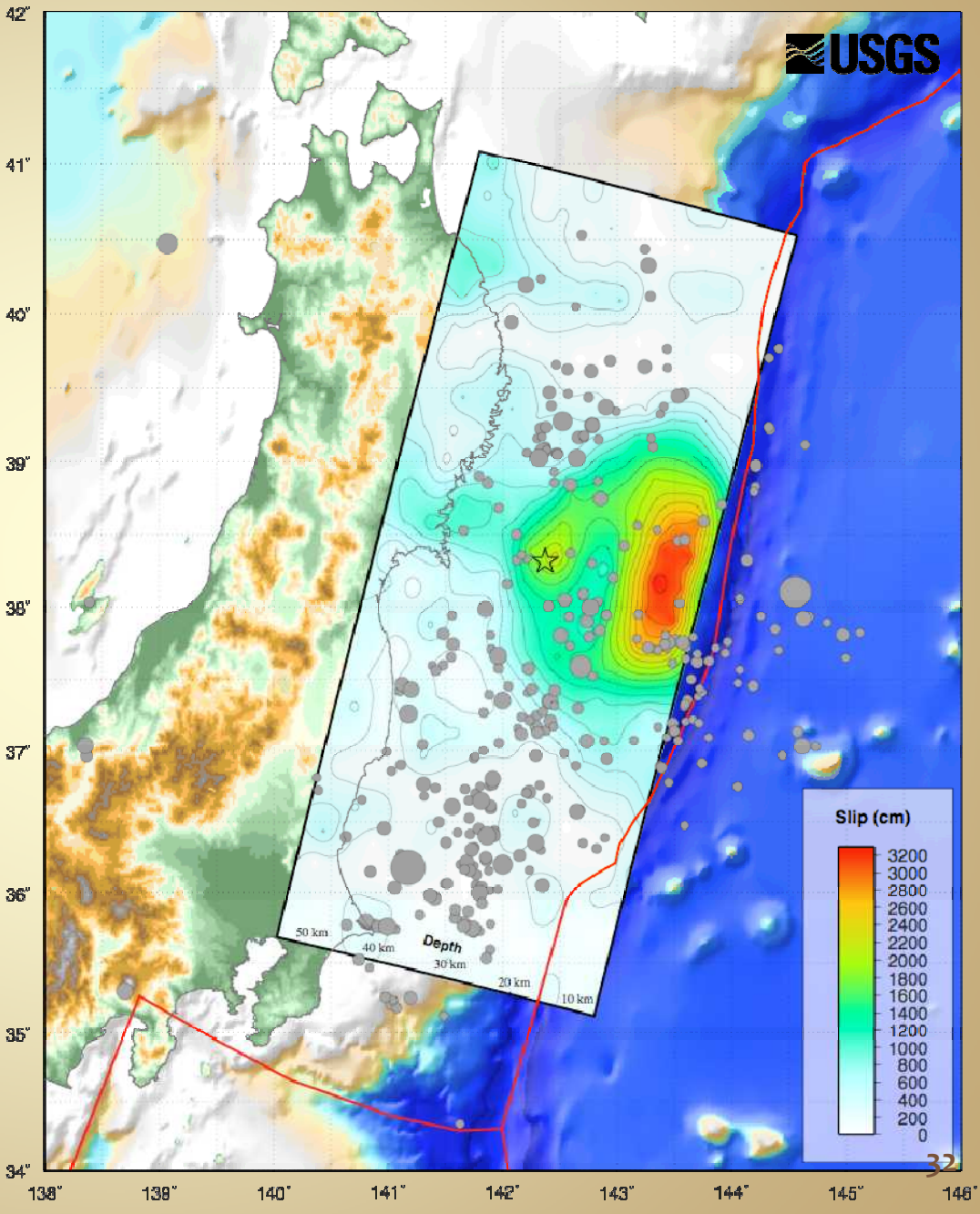
Tohoku, Japan Earthquake: Finite Fault Model
USGS V2 - 2011/03/18

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

Size of the tsunami was a surprise

- "A big story for Japan is … the unexpected size of the tsunami. And the major component of the tragedy, despite the enormous earthquake, is going to be the damage due to the tsunami." Rick Aster, President of the Seismological Society of America and Professor, New Mexico Tech

Timing of First 24-48 Hours Events

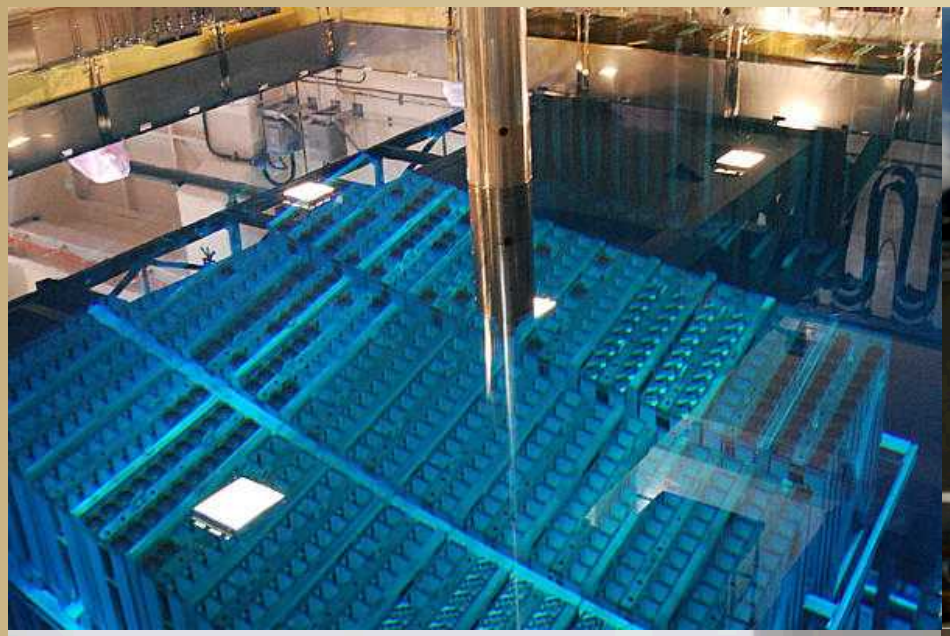
Earthquake Begins	Fri. 2:46 PM JST
Reactor shuts down	Fri. 2:48 PM JST
Off-grid, diesels provide power	Seconds later
Reactor cooled by emergency systems	After diesels start
Tsunami fails diesel generators	Fri. ~3:45 PM JST
Battery powers control of steam-driven Reactor Core Isolation Cooling (RCIC) and automatic depressurization	After diesels fail
Battery power exhausted	Sat. ~12:00 AM JST
Report of suppression pool (wet well) becoming saturated	Sat. ~2:00 AM JST
Containment pressure 0.6 MPa (0.4 MPa normal)	Sat. ~2:00 AM JST
Steam vented from reactor to Refueling Bay	Sat. 5:30 AM JST
Water level drops to top of active fuel	-
Core oxidation occurs, releasing hydrogen	-
Hydrogen Explosion/Deflagration	Sat. 3:36 PM JST
Seawater injection begins	Sun 8:20 PM JST

In this March 20, 2011 aerial photo taken by a small unmanned drone and released by AIR PHOTO SERVICE, the crippled Fukushima Dai-ichi nuclear power plant is seen in Okumamachi, Fukushima prefecture, northern Japan. From top to bottom: Unit 1, Unit 2, Unit 3 and Unit 4. (AP Photo/AIR PHOTO SERVICE)

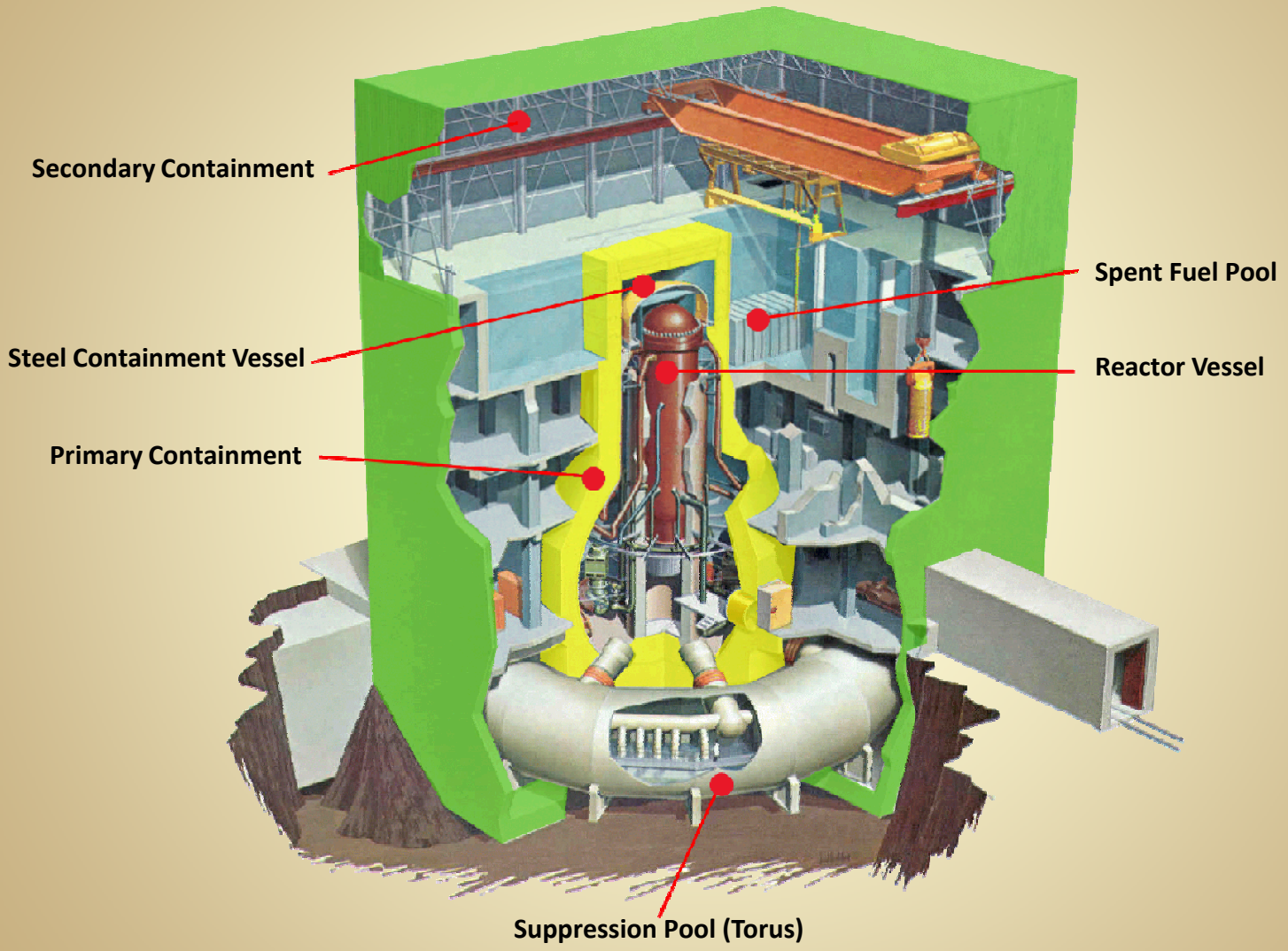
- March 11, 2011: About 14:46, a 9.0 magnitude earthquake struck
- Plant design basis earthquake: 8.2 Plant safety systems reportedly function satisfactorily.
- Units 1,2 & 3 Scram & Unit 4 has 100 day old core offloaded into Unit 4 Spent Fuel Pool
- ~ 1 hour later, a tsunami 14-15 meters high inundates 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.

Fukushima Dai-Ichi Summary

- The earthquake and tsunami event caused a loss of power at the Fukushima site. With both off-site (AC Grid) and on-site (Emergency Diesel Generators) power lost, and batteries depleted, the event is a total station blackout, with a resulting loss of cooling, fuel damage and release of radiation.
- Had either normal or backup power been restored before the batteries were depleted, sufficient cooling could likely have been achieved to avoid core damage. The prolonged station blackout resulted in the inability to cool the reactor cores in Units 1, 2, and 3, the spent fuel pools for all six units, and the consolidated spent fuel pool.
- To provide cooling, emergency generators, pumps, and fire trucks were brought in.



Boiling Water Reactor Design at Fukushima Daiichi



Fuel Status as of 3/11/2011

Unit	1	2	3	4	5	6
Number of Fuel Assembly in the Core	400	548	548	-	548	764
Number of Spent Fuel Assembly in the Spent Fuel Pool	292	587	514	1,331	946	876
Number of New Fuel Assembly in the Spent Fuel Pool	100	28	52	204	48	64
Water Volume (m^3)	1,020	1,425	1,425	1,425	1,425	1,497

Condition of the fuel in the Spent Fuel Pool

Unit 1	Unit 2	Unit 3	Unit 4
-Most recent shut down was on Sep.27,2010	- Most recent shut down was on Nov.18,2010	- Most recent shut down was on Sep.23,2010	-Most recent shut down was on Nov.29,2010 -All fuel assembly was removed from the core and located in the pool due to the core shroud replacement

Common Spent Fuel Pool 6375 Assemblies, Dry Casks 408

Status of nuclear power plants in Fukushima as of 18:00, April 17th (Estimated by JAIF)

Power Station	Fukushima Dai-ichi Nuclear Power Station					
Unit	1	2	3	4	5	6
Electric / Thermal Power output (MW)	460 / 1380	784 / 2381	784 / 2381	784 / 2381	784 / 2381	1100 /3293
Type of Reactor	BWR-3	BWR-4	BWR-4	BWR-4	BWR-4	BWR-5
Operation Status at the earthquake occurred	In Service -> Shutdown	In Service -> Shutdown	In Service -> Shutdown	Outage	Outage	Outage
Fuel assemblies loaded in Core	400	548	548	No fuel rods	548	764
Core and Fuel Integrity (Loaded fuel assemblies)	Damaged (70%*1)	Damaged (30%*1)	Damaged (25%*1)	No fuel rods	Not Damaged	
Reactor Pressure Vessel structural integrity	Unknown	Unknown	Unknown	Not Damaged	Not Damaged	
Containment Vessel structural integrity	Not Damaged (estimation)	Damage and Leakage Suspected	Not damaged (estimation)	Not Damaged	Not Damaged	
Core cooling requiring AC power 1 (Large volumetric freshwater injection)	Not Functional	Not Functional	Not Functional	Not necessary	Functional	
Core cooling requiring AC power 2 (Cooling through Heat Exchangers)	Not Functional	Not Functional	Not Functional	Not necessary	Functioning (in cold shutdown)	
Building Integrity	Severely Damaged (Hydrogen Explosion)	Slightly Damaged	Severely Damaged (Hydrogen Explosion)	Severely Damaged (Hydrogen Explosion)	Open a vent hole on the rooftop for avoiding hydrogen explosion	
Water Level of the Rector Pressure Vessel	Fuel exposed partially or fully	Fuel exposed partially or fully	Fuel exposed partially or fully	Safe	Safe	
Pressure / Temperature of the Reactor Pressure Vessel	Gradually increasing / Decreased a little after increasing over 400℃ on Mar. 24th	Unknown / Stable	Unknown	Safe	Safe	
Containment Vessel Pressure	Decreased a little after increasing up to 0.4Mpa on Mar. 24th	Stable	Stable	Safe	Safe	
Water injection to core (Accident Management)	Continuing (Switch from seawater to freshwater)	Continuing (Switch from seawater to freshwater)	Continuing (Switch from seawater to freshwater)	Not necessary	Not necessary	
Water injection to Containment Vessel (AM)	(To be confirmed)	to be decided (Seawater)	(To be confirmed)	Not necessary	Not necessary	
Containment Venting (AM)	Temporally stopped	Temporally stopped	Temporally stopped	Not necessary	Not necessary	
Fuel assemblies stored in Spent Fuel Pool	292	587	514	1331	946	876
Fuel Integrity in the spent fuel pool	Unknown	Unknown	Damage Suspected	some of the spent fuel may have been damaged*3	Not Damaged	
Cooling of the spent fuel pool	Water spray started (freshwater)	Continued water injection (Switch from seawater to freshwater)	Continued water spray and injection (Switch from seawater to freshwater)	Continued water spray and injection (Switch from seawater to freshwater) Hydrogen from the pool exploded on Mar. 15th	Pool cooling capability was recovered	
Main Control Room Habitability & Operability	Poor due to loss of AC power (Lighting working in the control room at Unit 1 and 2.)		Poor due to loss of AC power (Lighting working in the control room at Unit 3 and 4.)		Not damaged (estimate)	
Environmental effect	●Status in Fukushima Dai-ichi NPS site Radiation level: 520μSv/h at the south side of the office building, 67μSv/h at the Main gate, 27μSv/h at the West gate, as of 09:00, Apr. 17th Small amount of plutonium was detected from the soil sampled at Fukushima Dai-ichi NPS site.(3/21-4/4). Radioactive materials were detected from underground water sampled near the turbine buildings. (3/30). The concentration of the radioactive materials has increased and the monitoring of the underground water is to be expanded. (4/16~) There is highly radioactively contaminated water accumulated on the basement of Unit 2 turbine building and in the concrete tunnel for piping outside the building. Radioactive materials exceeding the regulatory limit have been detected from seawater sample collected in the sea surrounding the Fukushima Dai-ichi NPS since Mar. 21st. I-131detected at near the discharge outlet is 1600 times as much as legal limit.(4/14) TEPCO and MEXT has expanded the monitoring for the surrounding sea area since Apr 4th. ●Influence to the people's life Radioactive material was detected from milk and agricultural products from Fukushima and neighboring prefectures. The government issued order to limit shipment (3/21~) and intake (3/23~) for some products. Radioactive iodine, exceeding the provisional legal limit, was detected from tap water sampled in some prefectures. Small fish caught in waters off the coast of Ibaraki on Apr. 4 have been found to contain radioactive cesium and iodine above the legal limit.(4/5) Small amount of strontium was detected from some samples of soil and plants taken in the area that is 20-80 km far from the power station. On Apr. 17th, TEPCO announced that that it plans to expand the monitoring of the evacuation area and then decontaminate the houses and soils in the area to reduce the level of radioactive materials within about 3 to 6 months.					
Evacuation	<1> Shall be evacuated for within 3km from NPS, Shall stay indoors for within 10km from NPS (issued at 21:23, Mar. 11th) <2> Shall be evacuated for within 10km from NPS (issued at 05:44, Mar. 12th) <3> Shall be evacuated for within 20km from NPS (issued at 18:25, Mar. 12th) <4> Shall stay indoors (issued at 11:00, Mar. 15th). Should consider leaving (issued at 11:30, Mar. 25th) for from 20km to 30km from NPS <5>The 20km evacuation zone around the Fukushima Daiichi NPS is to be expanded so as to include the area, where annual radiation exposure is expected to be above 20mSv. People in the expanded zone are ordered to evacuate within a month or so. People living in the 20 to 30km and other than the expanded evacuation area mentioned above, are asked to get prepared for staying indoors or evacuation in an emergency (issued on Apr. 11th).					
INES (estimated by NISA)	Level 7*2 ※Cumulative amount of radioactivity from Fukushima Dichi NPS has reached the level to be classified as level 7. Total amount of radioactive materials released to the environment in this accident is one tenth as much as one in the Chernobyl accident so far.			Level 3 *2	–	–
Remarks	●Progress of the work to recover injection function High radiation circumstance hampering the work to restore originally installed pumps for injection at unit-1,2 and 3. Discharging radioactive water in the basement of the buildings of Unit 1through 3 continue to improve this situation. Highly radioactively contaminated water accumulated inside the concrete tunnel for piping outside the building is being transferred to the condenser at Unit 2 as of Apr. 13. The transfer lowered the water level in the tunnel by 8 centimeters, but it began rising again, exceeding the previous level. Work for securing and confirming the tightness of the radioactive waste process facility, where the contaminated water in the tunnel is to be transferred, and the hoses are continued on Apr. 16th. On Apr. 17th, TEPCO announced that that it will fill the containment vessels of Unit 1 and 3 with water up to the levels of covering the fuels in the reactors while considering fixing the damaged containment vessel of Unit 2. It will also install heat exchangers to remove the decay heat from the reactors and lead them into cold shutdown within about 3 to 6 months. ●Function of containing radioactive material It is presumed that radioactive material inside the reactor vessel may leaked outside at Unit 1, 2 and Unit 3, based on radioactive material found outside. NISA announced that the reactor pressure vessel of Unit 2 and 3 may have lost air tightness because of low pressure inside the pressure vessel. NISA told that it is unlikely that these are cracks or holes in the reactor pressure vessels at the same occasion. Nitrogen gas injection into the Unit 1containment vessel has been continued to reduce the possibility of hydrogen explosion since Apr. 6th. The pressure of the vessel has hardly risen for the past a few days and leakage of the vessel is suspected. While the originally planned amount of nitrogen has been injected by Apr. 16th, injection will be continued for a while to maintain the concentration of nitrogen in the vessel. On Apr. 17th, TEPCO announced that it will install facilities and tanks to process and store the highly radioactive water accumulated in the buildings and tunnels. It will also install huge covers with special filters to contain the reactor buildings so as to control the release of radioactive materials to the environment within about 3 to 6 months. ●Cooling the spent fuel pool Steam like substance rose intermittently from the reactor building at Unit 1, 2, 3 and 4 has been observed. Injecting and/or spraying water to the spent fuel pool has been conducted. ●Prevention of the proliferation of contaminated dust: Testing the spraying synthetic resin to contain contaminated dust began on Apr. 1st.					

[Source]
Government Nuclear Emergency Response Headquarters:

[Abbreviations]
MEXT: Ministry of Education, Culture, Sports, Science and Technology
INES: International Nuclear Event Scale
NISA: Nuclear and Industrial Safety Agency
TEPCO: Tokyo Electric Power Company, Inc.
NSC: Nuclear Safety Commission of Japan

*1 TEPCO's estimation based on the radiation level in the CV
*2 Correction: Rating was raised from 5 to 7 for the accident of Unit 1 through 3
*3 It is presumed that some of the spent fuel may have been damaged based on radioactive substance detected from the water sample taken from the pool of Unit 4.

[Significance judged by JAIF]
Low
High
Severe (Need immediate action)

Now What?

International

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.
- In Germany Chancellor Angela Merkel ordered all nuclear plants operating before 1980 to be closed for three months.
- 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."
- Vietnamese government has said that 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, and expressed 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 whether the willingness of the private sector to invest in new nuclear plants would be affected.

US Summary

- "US reactors are designed to cool the reactor core during a station blackout of only a fairly short duration. It is assumed that either the connection to an energized electrical grid or the repair of an emergency diesel generator will occur before the batteries are depleted. Eleven US reactors are designed to cope with a station blackout lasting eight hours, as were the reactors in Japan. Ninety-three of our reactors are designed to cope for only four hours."
  - David Lochbaum, Director of the Nuclear Safety Project at the Union of Concerned Scientists, *Testimony before the US Senate Energy and Natural Resources Committee, 29 March 2011*

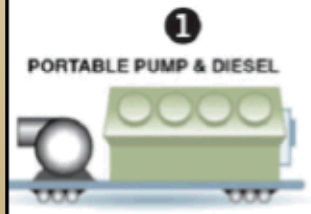
- The "station blackout" rule requires every plant in this country to analyze what the plant response would be if it were to lose all alternating current so that it could respond using batteries for a period of time, and then have procedures in place to restore alternating current to the site and provide cooling to the core. … The hydrogen rule requires modifications to reduce the impacts of hydrogen generated for beyond-design-basis events and core damage. … With regard to the type of containment design used by the most heavily damaged plants in Japan, *the NRC has had a Boiling Water Reactor Mark I Containment Improvement Program since the late 1980s*.
  - NRC Chairman Jaczko testimony to Senate Energy & Water Subcommittee, 30 March 2011

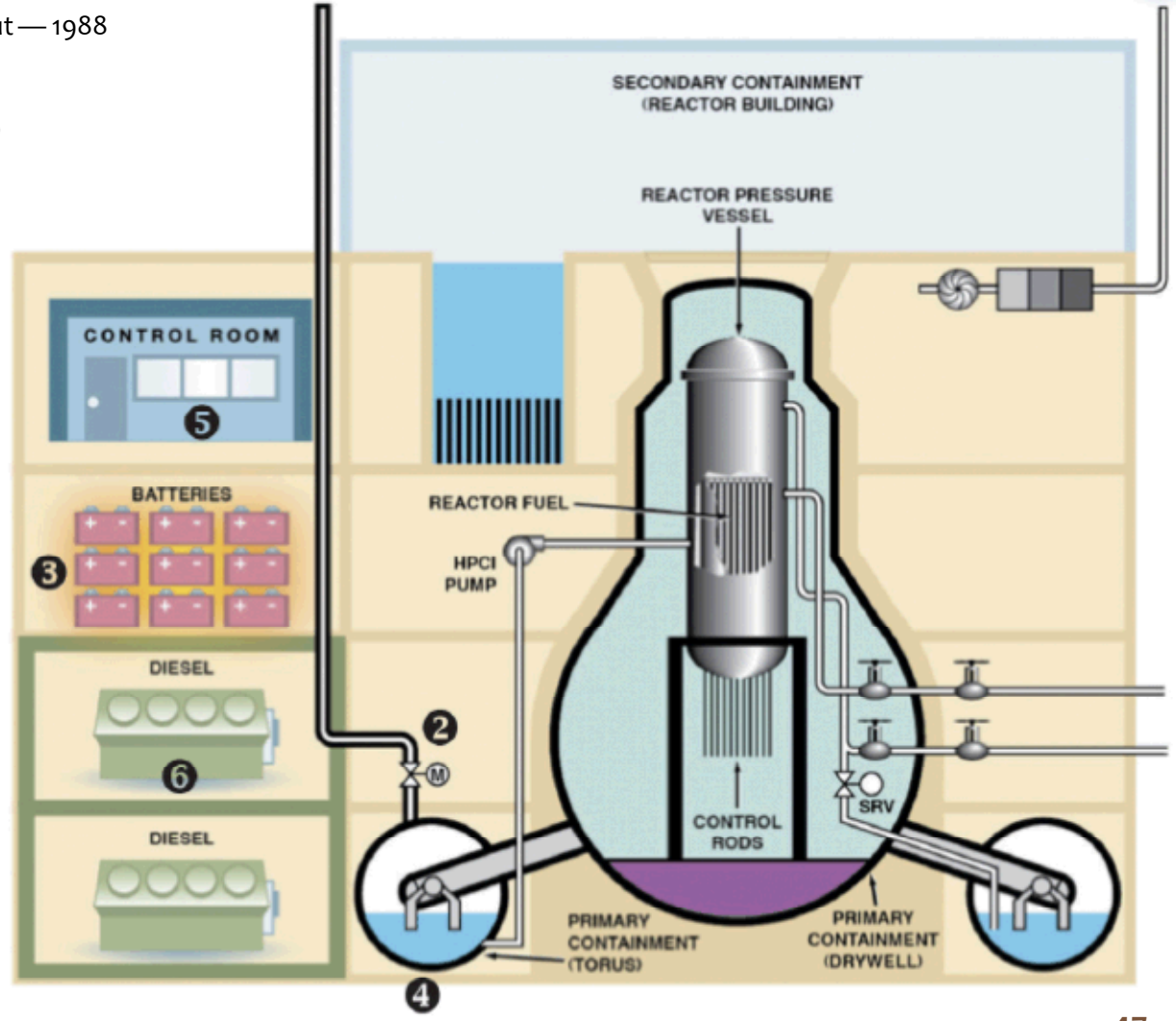
- NRC has also begun a 90 day short-term review, and a longer-term 6 month review to evaluate all technical and policy issues related to the event to identify additional potential research, generic issues, changes to the reactor oversight process, rulemakings, and adjustments to the regulatory framework that may warrant action by the NRC.

Major Modifications & Upgrades to U.S. BWRs with Mark 1 Containment Systems

1. Added spare diesel generator and portable water pump —2002
2. Added containment vent — 1992
3. More batteries in event of station blackout — 1988
4. Strengthened torus — 1980
5. Control room reconfiguration — 1980
6. Back-up safety systems separated — 1979

Reactor Name	State
Browns Ferry (3 Units)	Alabama
Brunswick (2 Units)	North Carolina
Cooper	Nebraska
Dresden (2 Units)	Illinois
Duane Arnold	Iowa
Edwin I. Hatch (2 Units)	Georgia
Fermi 2	Michigan
Hope Creek 1	New Jersey
James A. Fitzpatrick	New York
Monticello	Minnesota
Nine Mile Point 1	New York
Oyster Creek 1	New Jersey
Peach Bottom (2 Units)	Pennsylvania
Pilgrim 1	Massachusetts
Quad Cities (2 Units)	Illinois
Vermont Yankee 1	Vermont





Poll: Support for New Nuclear Plants Drops

Building More Nuclear Power Plants								
	NOW	7/08	4/07	6/01	6/91	5/86	4/79	7/77
Approve	**43%**	57%	45%	51%	41%	34%	46%	69%
Disapprove	**50%**	34%	47%	42%	48%	59%	41%	21%

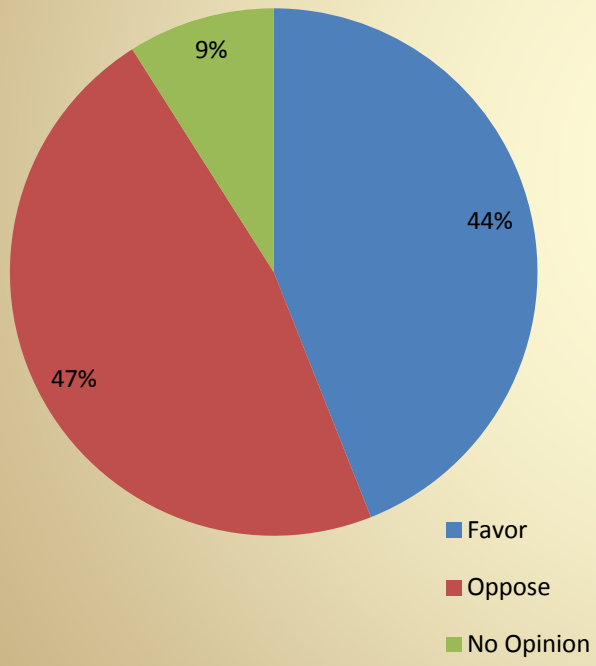
- Americans largely see U.S. nuclear power plants as safe but many still do not support building new plants, particularly in their community, according to a new CBS News poll.
- The poll, taken following the start of the crisis at the Fukushima Daiichi nuclear plant in Japan, found that 50 percent of Americans disapprove of building new nuclear plants. That's an increase of 16 points since the question was last asked in 2008.
- Only 43 percent, meanwhile, approve of building more nuclear plants—a drop of 14 points from the 2008 poll.

Source: CBS News Poll, March 22, 2011, http://www.cbsnews.com/8301-503544_162-20046020-503544.html?tag=latest

USA TODAY/Gallup Poll

Do you favor or oppose the construction of nuclear power plants in the USA?

USA TODAY/Gallup Poll Wednesday of 1,004 adults. Margin of error: +/- 4 percentage points



Support for using nuclear energy was at 57% when Gallup asked a similar question about a week before Friday's earthquake and tsunami.

A PUC Example

- 4/15/11: North Carolina's public advocate for utility customers says the state and its utilities need to hold off on decisions concerning new nuclear construction for now, in the wake of the nuclear crisis in Japan.

- Robert Gruber, executive director of the Public Staff of the N.C. Utilities Commission, says new design regulations and safety requirements are likely to be imposed by the U.S. Nuclear Regulatory Commission once officials determine what happened at the four damaged Japanese reactors. Those rules may drive construction costs for new U.S. nuclear plants prohibitively high.

Utility Examples

- Nuclear energy will be part of the energy mix in the U.S. despite declining public support for nuclear power because of the crisis in Japan, the president of New Jersey-based PSEG Power, a subsidiary of Public Service Enterprise Group (PSEG), said on 3/23/11.

- President and Chief Operating Officer William Levis said it isn't "clear yet" how the Japan crisis will impact licensing renewals for existing plants or investment in new ones--"I'm not going to speak for investors," he said. "Obviously some of those economics are impacted by additional regulation that gets put into effect," Levis said. "You can build these plants on time and on budget with the certainty of a regulatory structure that supports it and, frankly, a public that supports it."

- The nuclear accident in Japan and resulting public concern about earthquake safety at Diablo Canyon (California) nuclear power plant have prompted PG&E to ask the NRC to delay final implementation of the license renewal process for the plant. Diablo Canyon's two operating licenses are due to expire in 2024 and 2025. PG&E has applied to extend the licenses another 20 years each. In addition to requesting a delay in license renewal, the utility says it will accelerate completion of the seismic studies.

And a Local Example…

With TEPCO as a Potential Co-Owner, South Texas Project Companies Delay Work on New Reactors

- Partners in an effort to build two new reactors near Houston have put the brakes on the project following accidents at Tokyo Electric Power Co.'s Fukushima Daiichi nuclear plant.

- TEPCO last year promised to invest $155 million in South Texas Project units 3 and 4, conditioned upon the reactors receiving a Department of Energy loan guarantee. That included a $30 million option payment that would allow the company to buy roughly another 10 percent of the project. Nuclear Innovation North America, jointly owned by NRG Energy and Toshiba, would hold an 83 percent stake in the reactors after Tepco's initial investment. CPS Energy owns a 7.6 percent share in the project.
  - If the option were exercised, TEPCO would own a roughly 18 percent stake in the new reactors.

- On Monday, though, NINA indicated it would stop most work on the plant following a string of accidents at six of TEPCO's Japanese reactors following the March 11 earthquake and tsunami.

- "Our best course of action in this immediate period of uncertainty is to minimize project spend, continue with those activities we can control and wait until there is more information upon which we can base our long-term decisions. This is the financially disciplined course of action in uncertain and challenging times," said NINA chairman and NRG Energy CEO David Crane in a release.
  - Development of the project will now be limited to work related to licensing and obtaining the loan guarantees.

- *From Nuclear Street News Team, 3/22/11*

Investor Response (Short-Term)

iShares S&P Global
Clean Energy Index Fund
NASDAQ:ICLN

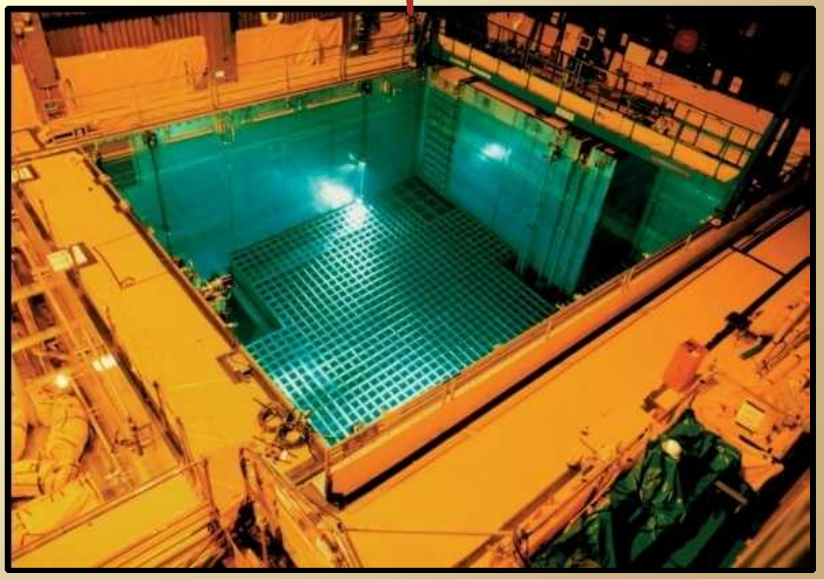
iShares S&P Global
Nuclear Energy Index Fund
NASDAQ:NUCL

Investor Response (Long-Term)

iShares S&P Global
Clean Energy Index Fund
NASDAQ:ICLN

iShares S&P Global
Nuclear Energy Index Fund
NASDAQ:NUCL

Concluding Remarks



BACKUP