University of Tokyo, March 2, 2012

Nuclear energy development in India, China, and ASEAN: Challenges after Fukushima

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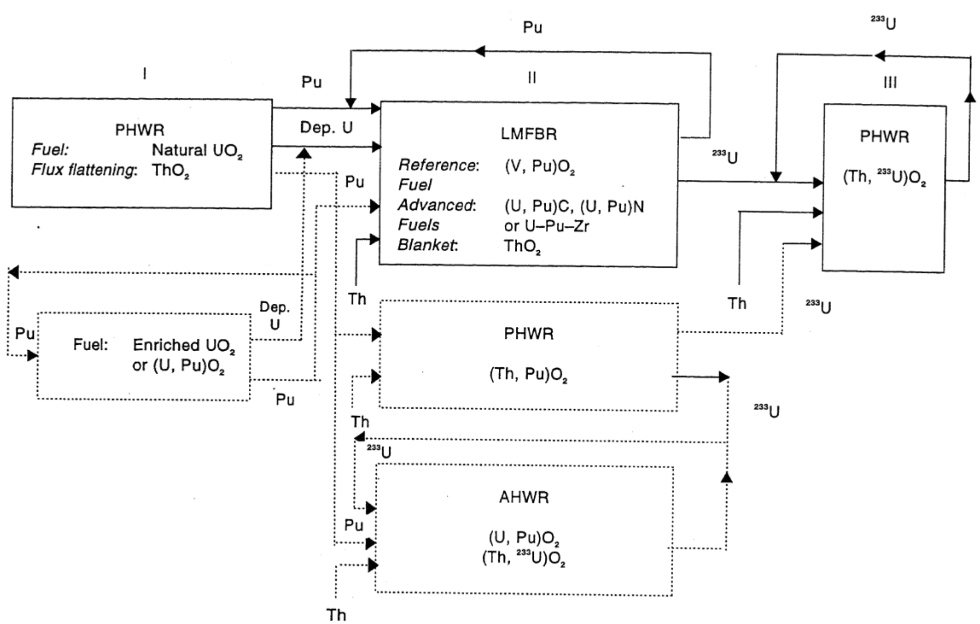
Nuclear Energy in India

- Homi Bhabha, Pandit Nehru, and India’s three-stage nuclear program.
- Thorium utilization for long term energy security, and heavy water reactor development to avoid expensive & technically difficult uranium enrichment path.
- Canada’s contribution to India; USA, Britain, France. NPT, India’s 1974 tests & international isolation.
- Slow growth of nuclear program, indigenous development of power program and nuclear fuel cycle; uranium shortage and difficulties.

DAE's (Bhabha's) Vision

	Stage 1	Stage 2	Stage 3
Reactor Type	PHWR	LMFBR	LMFBR/HWR
Fuel	Natural Uranium	U-Pu (oxide/carbide/metal)	Thorium-Uranium
Resource Potential	~340 GWe-yr	~16,000 GWe-yr	~168,000 GWe-yr



Reconnecting with the world

- July 2005: Expansion of bilateral trade and commerce in space, civil nuclear energy and dual-use technology.
- American motivation: Adjusting to new realities
- India's motivation: ending nuclear isolation and access to NSG; confluence of strategic interests
- Political costs: Short term difficulties with Iran and uncertainty over gas pipeline. China's concerns about emerging India-US relationship.
- Nuclear Expansion: With obstacles to uranium access and technology imports removed, India plans to add 20,000 MWe nuclear capacity on line by 2020 and 63,000 MWe by 2032. It aims to supply 25% of electricity from nuclear sources by 2050.

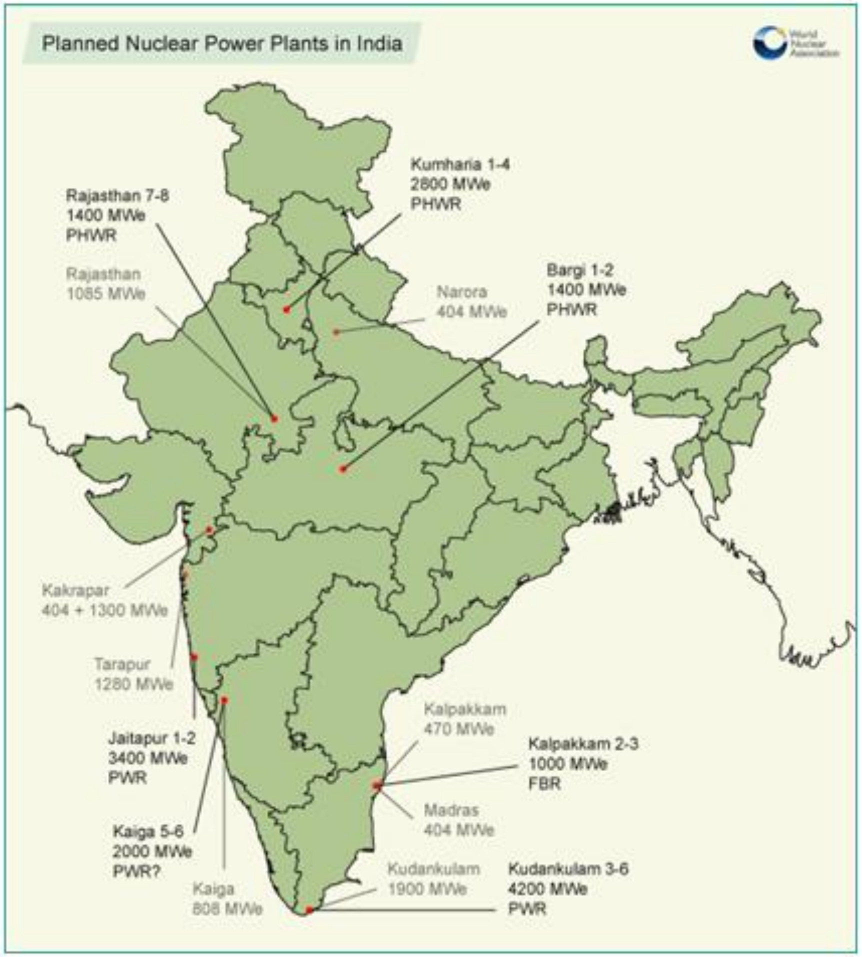
Operational reactors

Reactor	State	Type	MWe net, each	Commercial operation	Safeguards status
Tarapur 1 & 2	Maharashtra	BWR	150	1969	item-specific
Kaiga 1 & 2	Karnataka	PHWR	202	1999-2000	
Kaiga 3 & 4	Karnataka	PHWR	202	2007, (due 2011)	
Kakrapar 1 & 2	Gujarat	PHWR	202	1993-95	December 2010 under new agreement
Madras 1 & 2 (MAPS)	Tamil Nadu	PHWR	202	1984-86	
Narora 1 & 2	Uttar Pradesh	PHWR	202	1991-92	in 2014 under new agreement
Rajasthan 1	Rajasthan	PHWR	90	1973	item-specific
Rajasthan 2	Rajasthan	PHWR	187	1981	item-specific
Rajasthan 3 & 4	Rajasthan	PHWR	202	1999-2000	early 2010 under new agreement
Rajasthan 5 & 6	Rajasthan	PHWR	202	Feb & April 2010	Oct 2009 under new agreement
Tarapur 3 & 4	Maharashtra	PHWR	490	2006, 05	
Total (20)			**4385 MWe**		

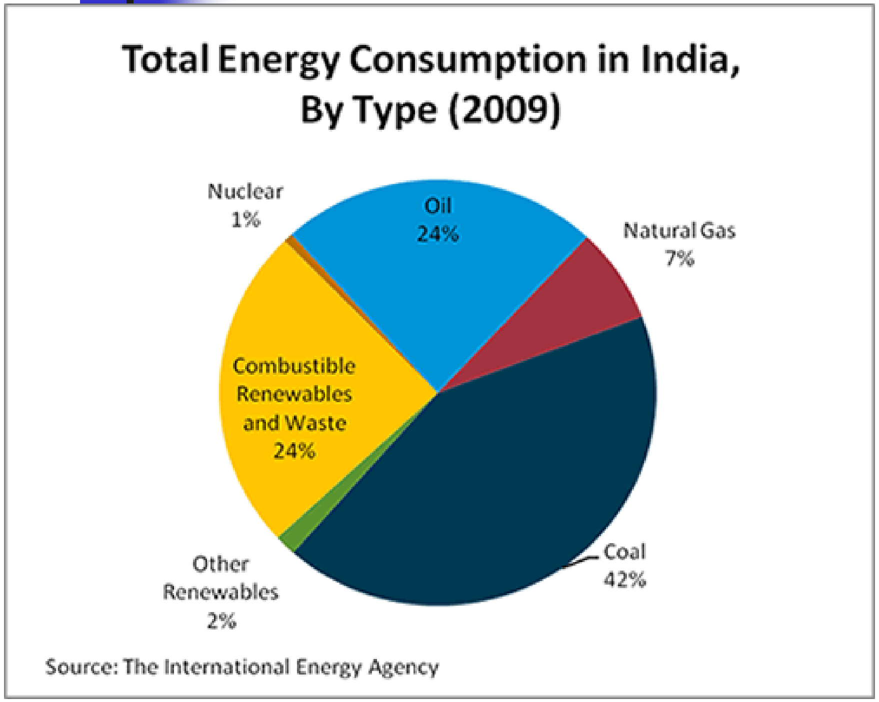
Reactors under construction

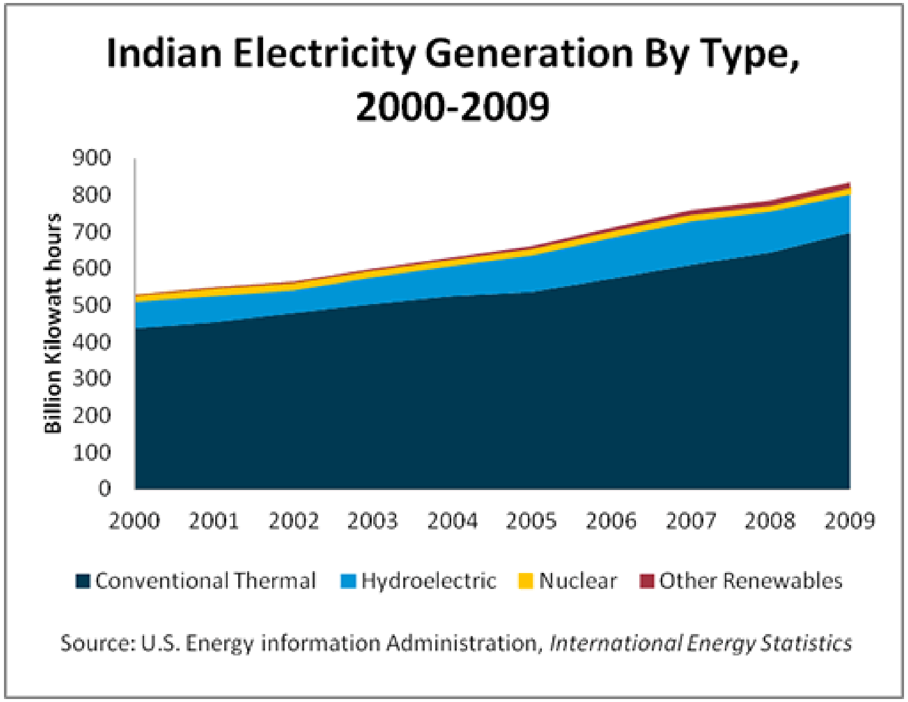
Reactor	Type	MWe gross, net, each	Project control	Construction start	Commercial operation due	Safeguards status
Kudankulam 1	PWR (VVER)	1000, 950	NPCIL	March 2002	3/2012	item-specific
Kudankulam 2	PWR (VVER)	1000, 950	NPCIL	July 2002	June 2012	item-specific
Kalpakkam PFBR	FBR	500, 470	Bhavini	Oct 2004	2012	-
Kakrapar 3	PHWR	700, 630	NPCIL	Nov 2010	June 2015	
Kakrapar 4	PHWR	700, 630	NPCIL	March 2011	Dec 2015	
Rajasthan 7	PHWR	700, 630	NPCIL	July 2011	Dec 2016	
Total (6)		4260 MWe net, 4600 MWe gross				

Geography of planned expansion



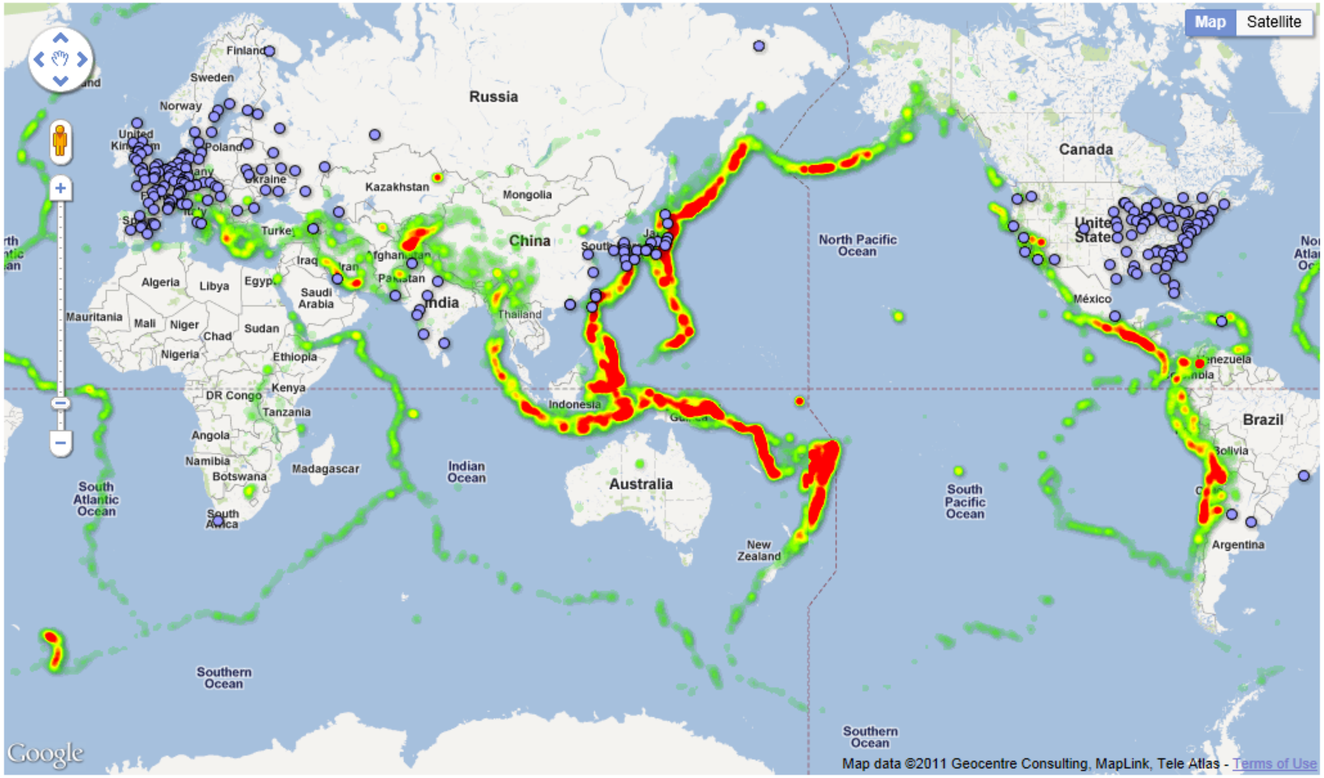
India: Energy and Electricity Overview





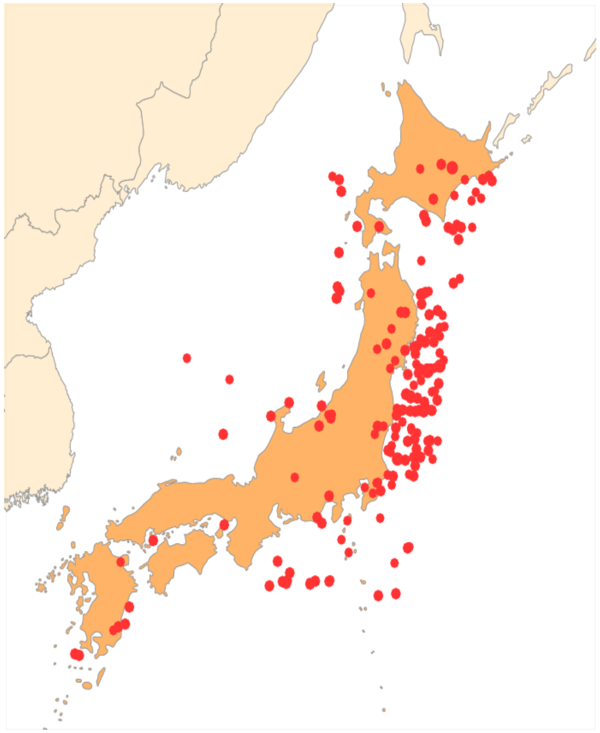
Electricity production in 2009 tripled from 1990 level. But one third is lost in T&D and theft. Per capita consumption is 500 kWhr. The next five year plan (2012-2017) targets adding at least 100 GWe—mostly coal, and some gas. Nuclear will add 3.4 GWe.

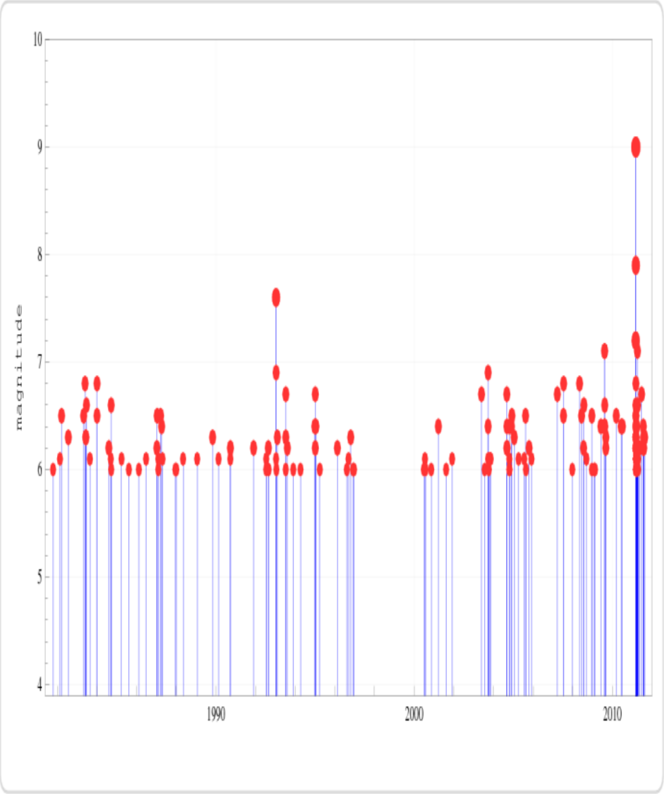
Nuclear Reactors and Seismic Zones



Source: http://maptd.com/map/earthquake_activity_vs_nuclear_power_plants/

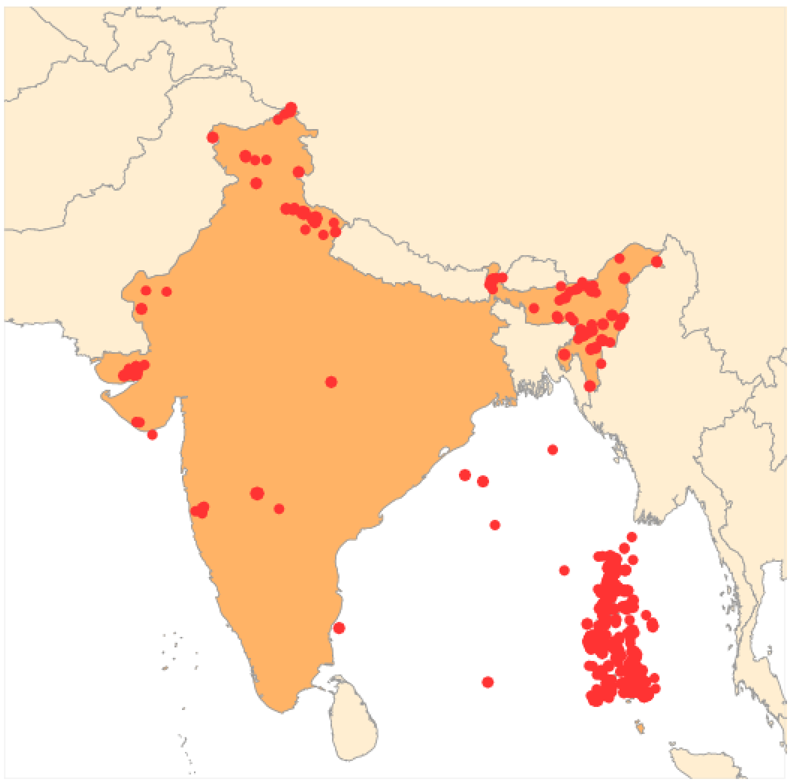
Japan's quake history

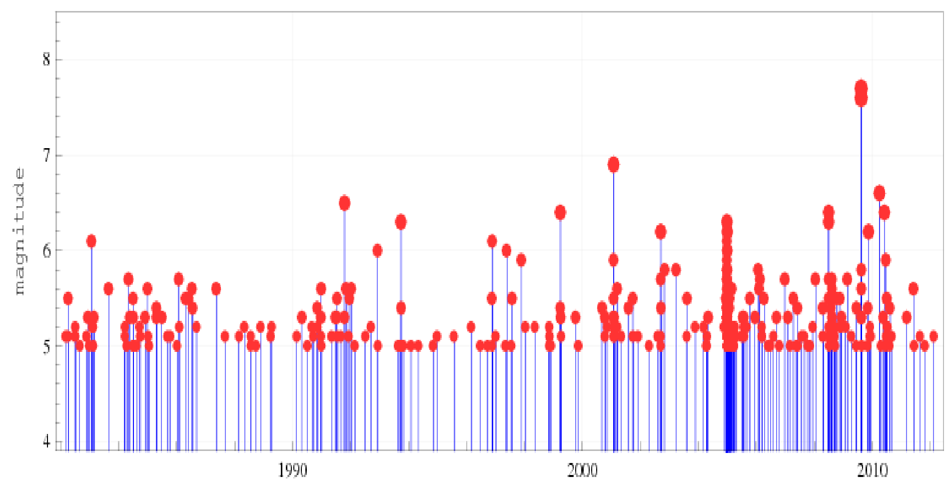




Graphical plots (generated by *Mathematica* 8) show magnitude 6 and above quakes in the last 30 years.

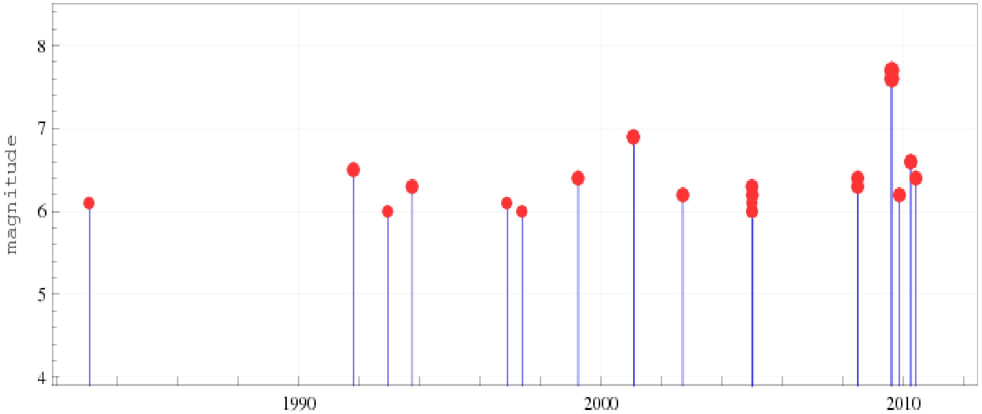
Earthquakes (>5R) in 30 years





Graphical plots (generated by *Mathematica* 8) show magnitude 5 and above quakes in the last 30 years.

Earthquakes (>6R) in 30 years



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Earthquakes (>6R) in 30 years

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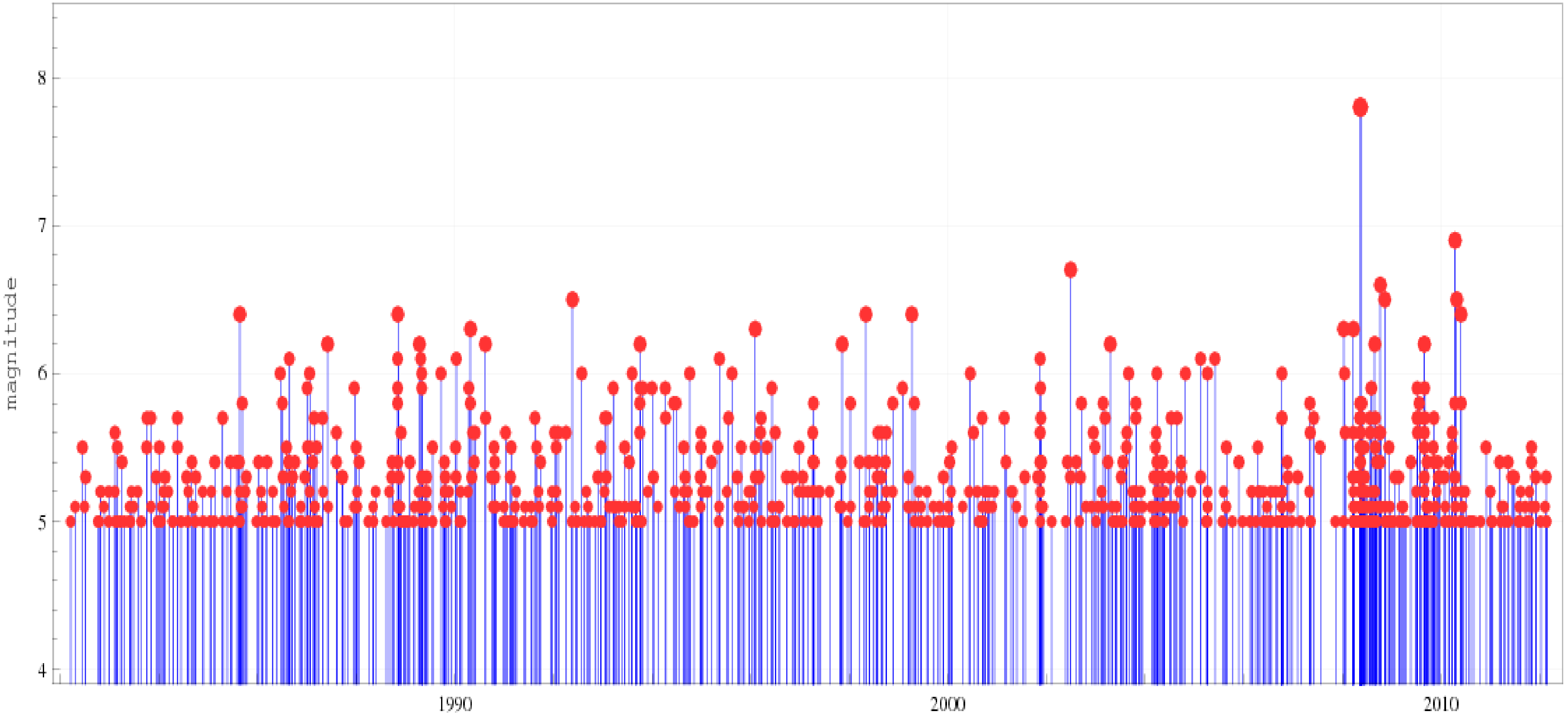
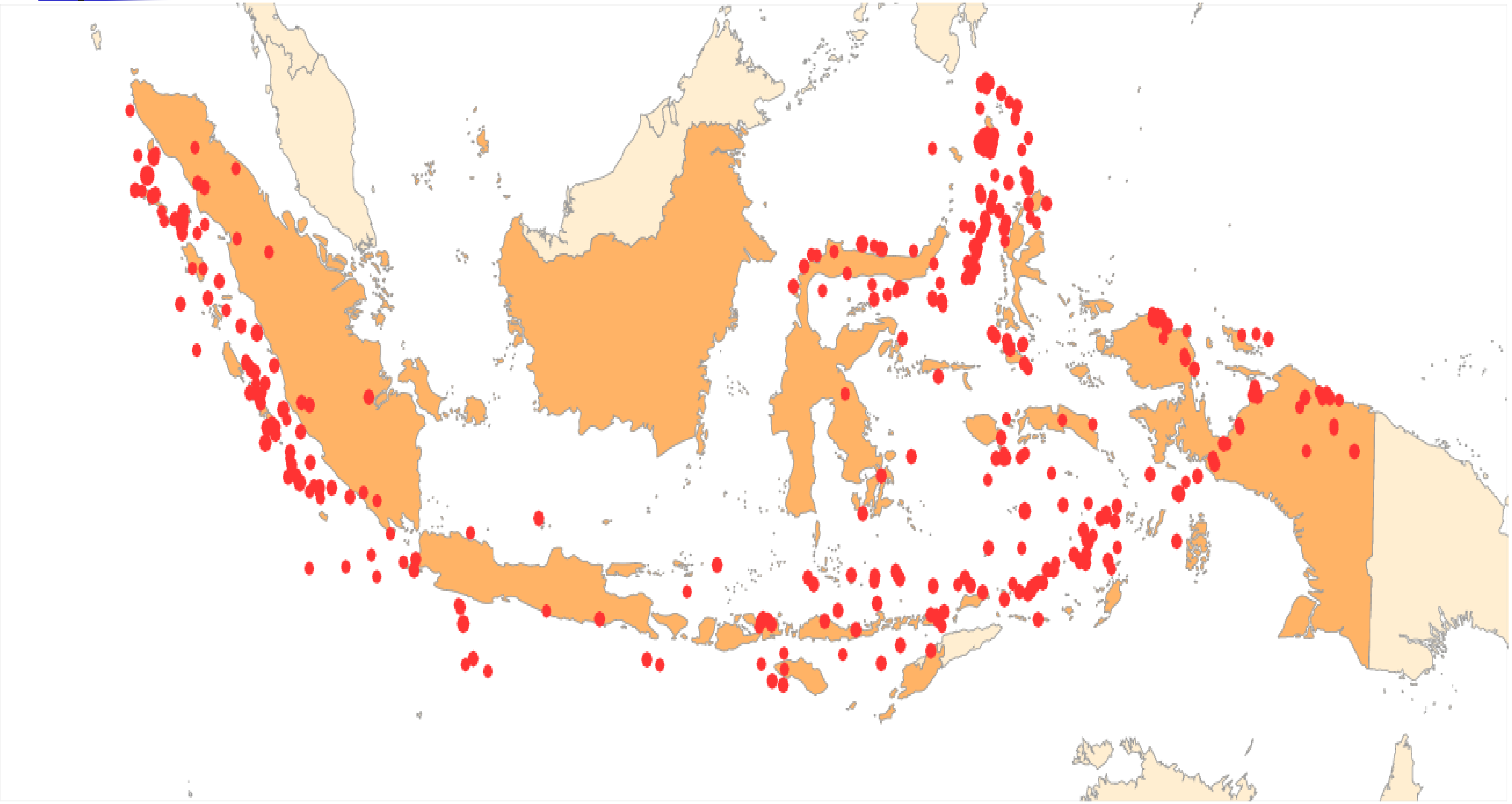
China earthquakes in 30 years



ASEAN earthquakes (>6R) in 30 years



ASEAN earthquakes (>5R) in 30 years

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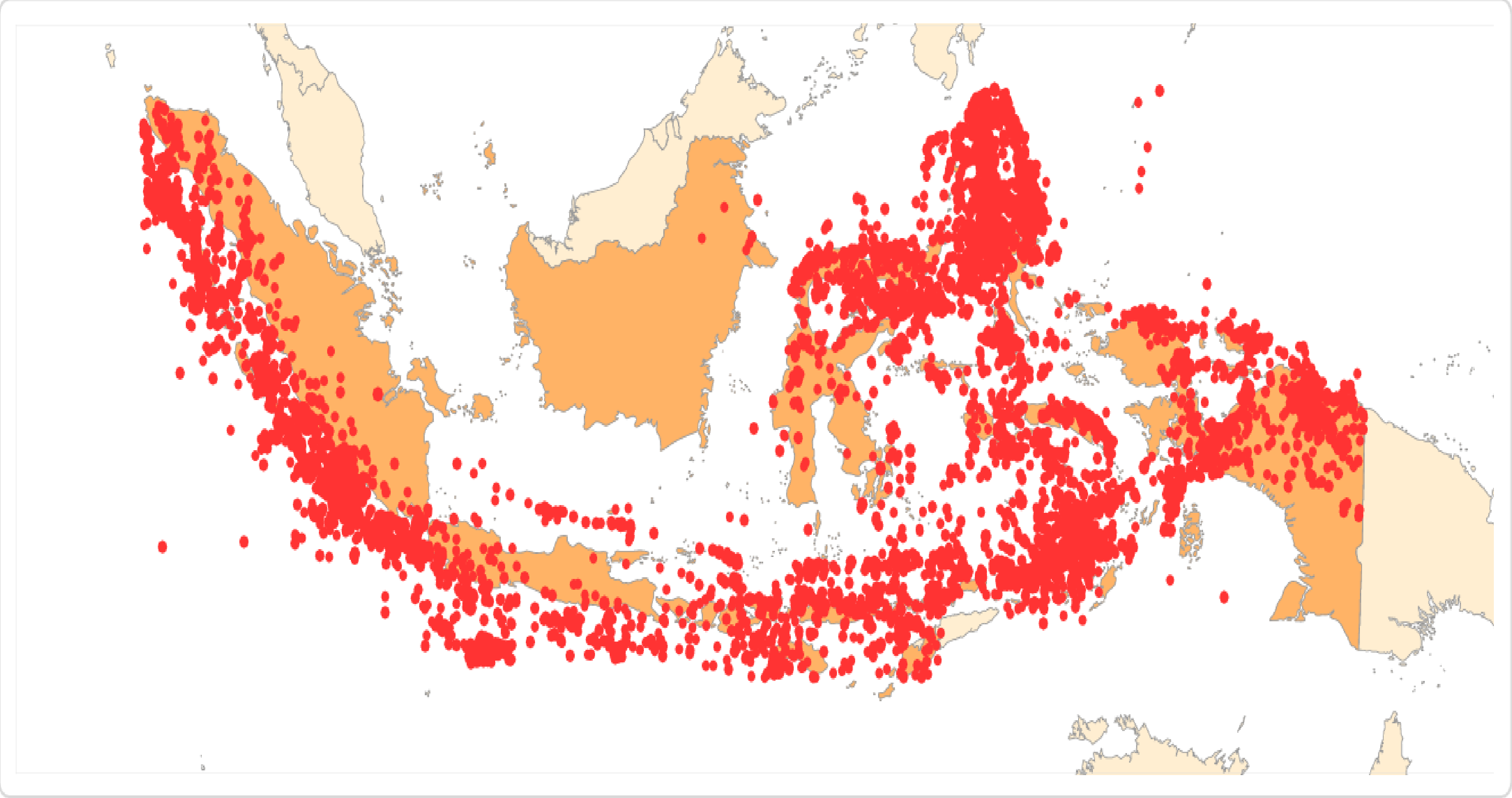

China's nuclear energy plans

- In 2007, State Council adopted the 'Nuclear Energy Mid-term and Long-Term Development Plan 2005-2020" which set the target to reach 40 GW of total nuclear installed capacity by 2020. In early 2008, this number was raised up to 60 GW until in 2010 the former head of energy commission Zhang Guobao announced the goal for Chinese nuclear power plants to reach 86 GW by 2020.
- Fukushima-Daiichi crisis has moderated Chinese government plans and forced the National Development and Reform Commission (NDRC) to stop issuing licenses for new nuclear plants and initiated inspections for existing plants.
- Fukushima crisis will enhance higher levels of security standards and more careful assessment of nuclear power plants construction sites.

China's nuclear energy plans

- Chinese nuclear power plants under operation are located in the coastal area. Before Fukushima, there was a strong shift in selecting new sites for the nuclear power plants: a lot of projects were proposed for the inland provinces. It was a part of the plan to reallocate more industrial production sites in the less developed areas, and bridge the gap between developed Eastern and developing Western China.
- Xianing (Hubei province) was supposed to be the first inland nuclear power plant. CGNPC has chosen this site for construction of two blocks with AP-1000 reactors by 2015, construction had to start in 2011.
- After Fukushima nuclear disaster, this project sparked a lot of concerns: experts warned that the plant could be damaged by the water floods as it is close to the Yangtze river basin.

New Challenges to Public Policy

- **Traditional public policy challenges**
  - Can public interest be served by current regulation and standards?
  - Does nuclear make economic sense compared to other sources?
  - Managing local communities and displaced people affected by nuclear projects
  - Nuclear proliferation: international security challenges posed by nuclear fuel cycle facilities
- **New public policy challenges**
  - Institutional reforms to achieve better regulation and standards, and emergency planning.
  - New economic difficulties due to higher risk premiums and nuclear liability issues.
  - Managing new constituencies outside of the local/displaced groups
  - Differing challenges in democracies and other political setups.

Nuclear Regulation Post Fukushima

- Regulatory capture and transparency in nuclear safety and regulatory function, including lessons learnt from Fukushima and other countries.
- In the case of Japan, nuclear regulation is shared by three agencies: The Nuclear Safety Commission of Japan (NSC); Nuclear Industrial Safety Agency (NISA; Nuclear Safety Division.
- During the 2011 Fukushima crisis, coordination and consistency was more difficult to achieve.
- Fukushima highlights several considerations necessary for a comprehensive and coherent regulatory framework.
- U.S. Nuclear Regulatory Commission (NRC) and the principles of good regulation — independence, openness, efficiency, clarity, and reliability.
- Impact of Fukushima in reforming regulatory functions has become even more urgent in India. India's nuclear regulation is inadequate.

Technology Challenges Post Fukushima

- **Traditional technology challenges**
  - Reactor safety based design philosophy of “defense in depth” to provides a series of physical protection barriers against accidental release of radioactivity to avoid LOCA and minimise the chances of core damage.
  - Acceptable way to dispose of the radioactive waste generated by nuclear power plants. Reactors in the United States are projected by 2020 to produce a quantity of nuclear waste of the order of 80,000 metric tons of heavy metal (uranium, plutonium, or thorium equivalent) of spent nuclear fuel and other nuclear waste. The comparable worldwide estimate is about 450,000 metric tons.
  - Environmental impact of low level radiation is yet to generate the same level of interest or anxiety like the first two challenges. These include thermal pollution and low-level release of radioactivity into the air and ground waters caused by the normal operation of nuclear-power and reprocessing plants.

Technology Challenges Post Fukushima

- **New technology challenges**
- Reactor safety and environmental issues will have to provide adequate reactor safety assurance beyond design basis accidents to include external events.
- In US, licensing process external events including seismic activity and flooding from various sources were considered. Japan perhaps overlooked the external factors by emphasising engineered safety features.
- Fukushima is likely to result in a more careful look at siting, which provides design independent safety. How to ensure safety when all AC power is lost?
- Challenges for India’s nuclear expansion: siting, public acceptance; regulation, safety concerns, international cooperation, and financing.

Fear, perception, and attitudes

- Public fear about getting cancer and dying from radiation sources.
- Nuclear fear is the residual equivalent of human response to the unknown.
- Earlier societies have responded to unknown in mostly irrational way.
- Current societal response to nuclear risks cannot be dismissed as irrational.
- Science of radiation and cancer risk poses tremendous challenges for public perception and regulatory oversight.

Health Effects of Exposure to Ionizing Radiation (Source: Singer, University of Illinois)

- Most exposures of people to radiation have been too low to produce prompt radiation sickness.
- Our understanding of the health effects of exposure to low-level ionizing radiation comes primarily from studies of Japanese atomic bomb survivors, and other studies (fetal exposure, Chernobyl; smokers; breast cancer diagnosis; mice studies, and background radiation studies).
- Doubling or tripling of background radiation levels has no statistically clear effect on public health overall.
- However, it cannot be precluded that extrapolation of atomic bomb survivor effects to low doses predicts increased mortality due to increased low-level radiation, with producing an overestimate by a factor of 3 or less for the general population, and an accurate estimate for exposure of children.