Responses to the Fukushima Nuclear Disaster

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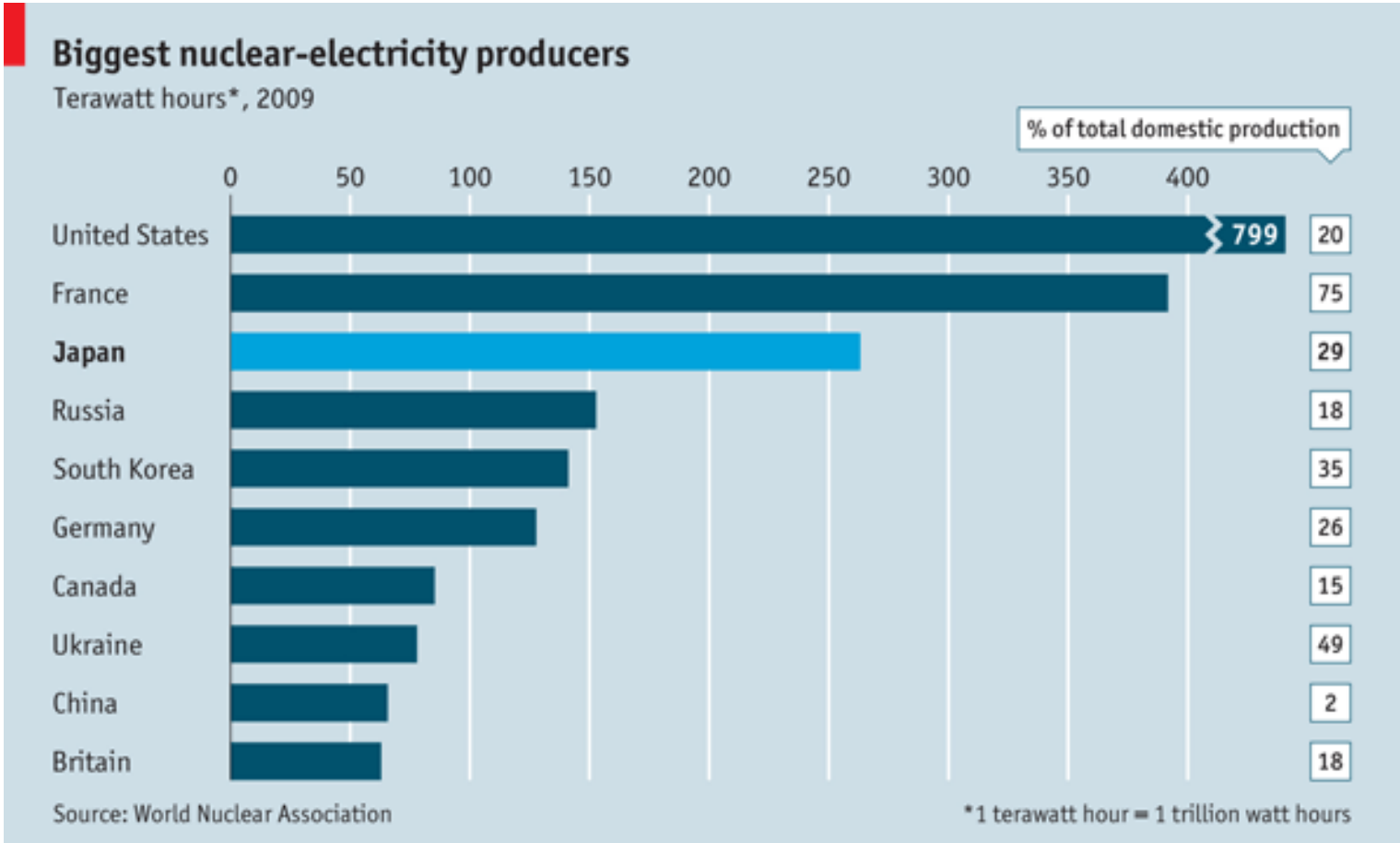
Scope of Nuclear Power

- There are 438 nuclear reactors worldwide.
- The largest number is in the US with 104.
- Nuclear power generates 20% of the electrical power of the US.
- Many of the US reactors are 30 years old.
- Japan has 54 reactors which used to generate 30% of its power.
- France has 58 reactors, which generate 80% of its electricity.

Nuclear Energy Production in Terawatt Hours. The US production is twice the length shown. This is what counts for offsetting CO2 pollution



What Happened at Fukushima

- The Fukushima disaster was the result of a rare 9.0 earthquake on a subduction fault with 50 meters maximum slip, and extending over 300 km (180 miles) along the fault.
- This generated a 48 foot high tsunami that inundated reactor sites which only were prepared for 22 foot tsunamis.
- Although the reactors "shut down" by inserting control rods, the quake took out external power needed to pump water to cool the reactors down, which takes several days. The reactors are still heated by radioactive decays.
- The backup generators themselves were damaged, and clogged roads prevented new ones from reaching the plant.
- Containment vessel vents could not be opened to relieve pressure and let in cooling water. The reactor cores melted down on three reactors, generating hydrogen gas.
- Valves to vent the hydrogen could not be opened, and the hydrogen exploded, blowing apart the surrounding building.
- The lack of power and generators also meant that the spent fuel cooling ponds did not have cooling water.
- The brave workers at the plant did not abandon it, but eventually brought it under some sort of control.
- However, much radioactive matter was leaked to the atmosphere, and radioactive water to the ocean.
- The high contamination area is uninhabitable, and local food and water cannot be used in a 50 mile radius.

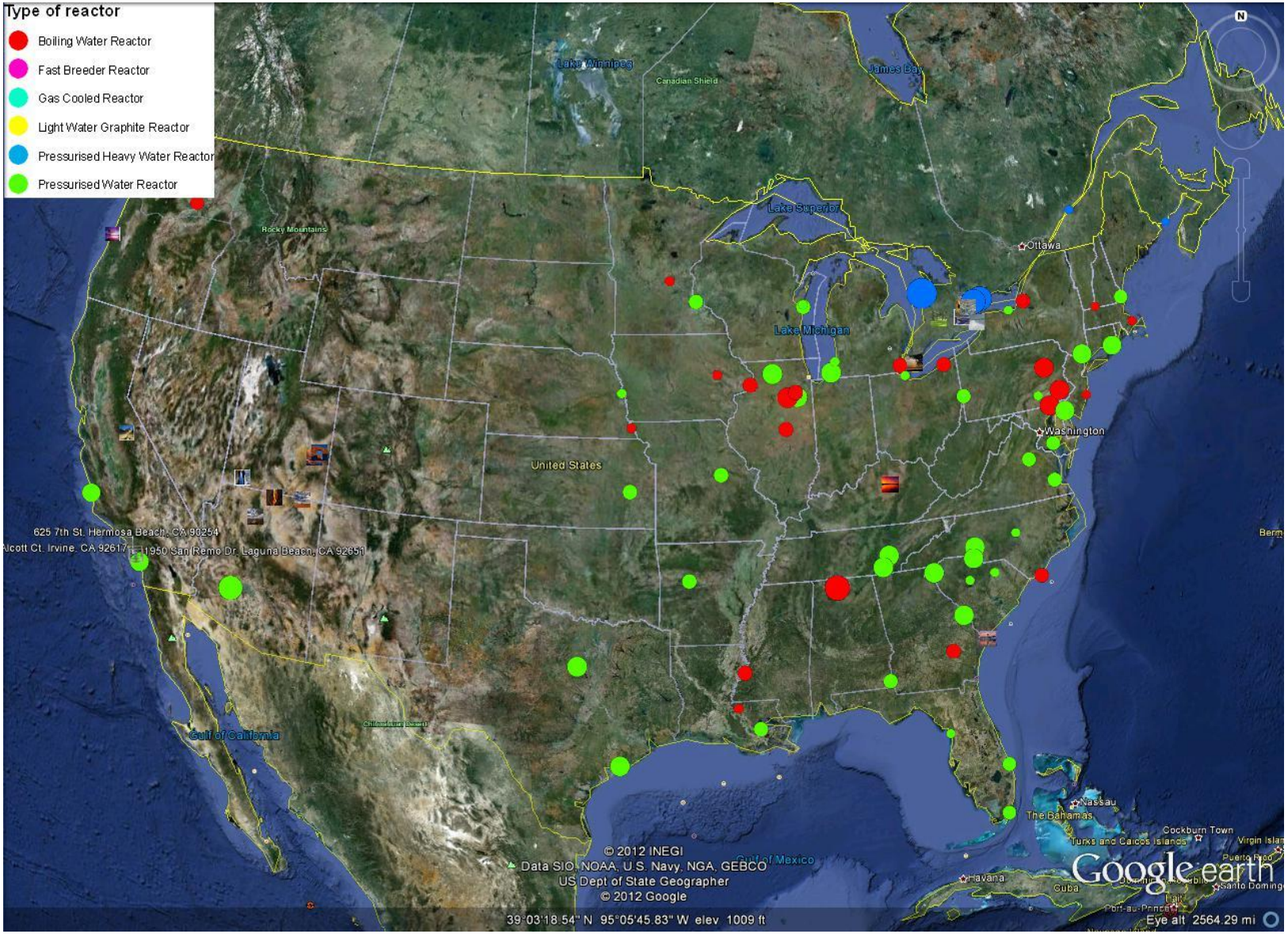
Mistakes at Fukushima

- Both Fukushima and the communities devastated by the tsunami did not use modern earthquake and tsunami assessments. A professor had informed the utility that the devastating quake and tsunami of 869 AD had gone many miles inland.
- The plant had its electronic circuitry under ground, where it was flooded.
- The backup pumps were not at a high level, where they would have been safe.
- The containment vessel vents could not be opened in such an emergency.
- The spent fuel pools, where radioactive fuel has to cool from 5 to 10 years, were elevated. One of the pool buildings is still in danger of collapse.

Response of the US Nuclear Regulatory Commission (NRC)

- US nuclear plants are to reassess natural hazards, and design plans to resist them by February, 2013. They are to complete the safety upgrades by December 2016.
- The California plant at San Onofre is subject to earthquakes and tsunamis, and the elevated plant at Diablo Canyon is has newly discovered nearby faults. The earthquake and tsunami risks are being reexamined by surveys. San Onofre is part way to getting approval from the PUC to spend $64 million of ratepayers funds on the survey. About half will be used by the Scripps Institute. Such a survey has not been done in 20 to 30 years in Southern California.
- The Indian Point plant, providing 30% of New York City power is now known to be on an earthquake fault, and Gov. Cuomo wants the reactors to be shut down in 2014 and 2016 when their licenses expire. They are 38 miles from Manhattan.
- Other plants on principal rivers are being evaluated for flooding protection.
- Some plants can be subject to tornadoes and hurricanes.

US and Canadian Reactors (App by Declan Butler)



NRC and Industry Response

- Industry has proposed its own plan called FLEX to respond sooner than NRC standards and time period.
- Each plant will add backup pumps and generators at various areas around the plant to keep them safe.
- There will be as many as a dozen regional facilities with even more backup equipment, that can be airlifted to a plant under stress.
- The NRC is requiring new plans and equipment to deal with plant blackouts where external sources of power are not available for extended lengths of time.
- The NRC is requiring new equipment to monitor spent fuel pools.
- The NRC is requiring that boiling water reactors have hardened containment vessel exhaust vents, so that low pressure water can be provided for reactor cooling. The vents have to be operable with emergency power, and also manually and remotely. The upgrade orders are to be carried out now.

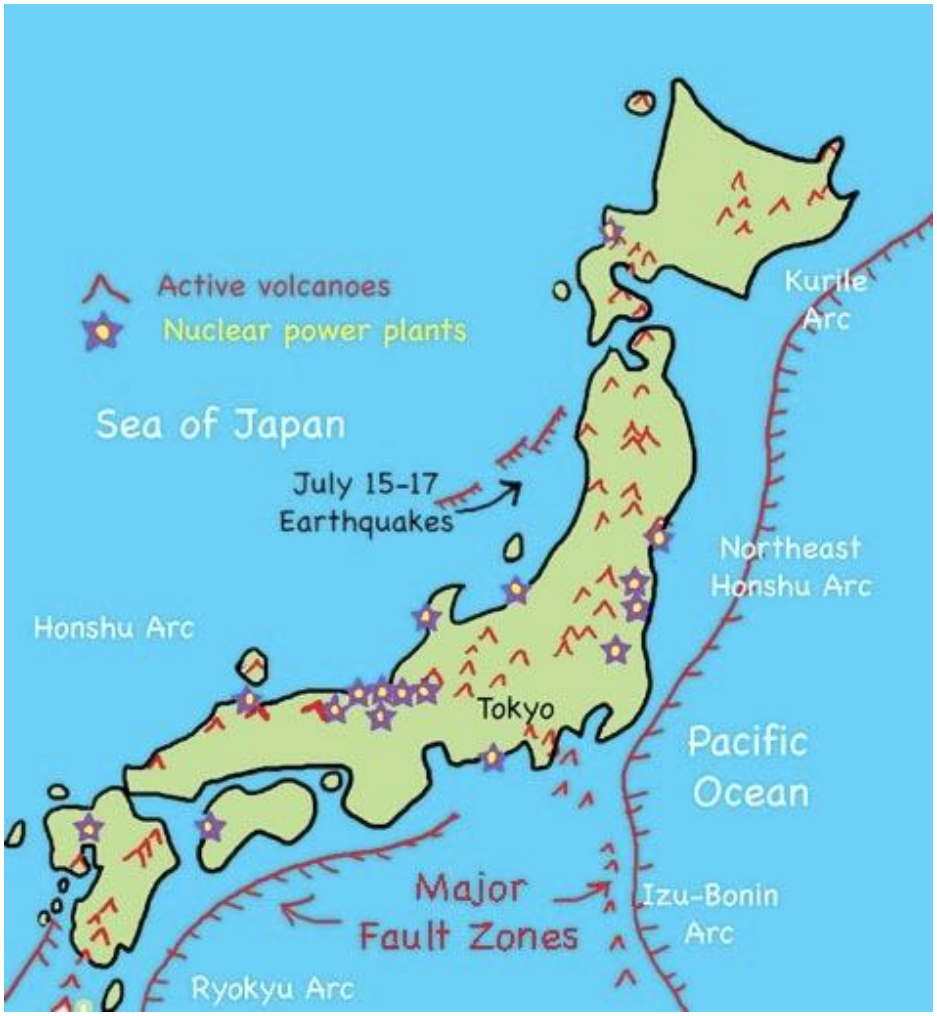
Public Responses in the US

- There are many anti-nuclear groups raising some real questions about reactor safety and the need for nuclear power.
- Some are focusing on local communities and specific reactors.
- The Union of Concerned Scientists is composed of scientists who have always called for greater reactor safety.
- The group Beyond Nuclear wants to de-license or at least improve the 23 US reactors of the GE Mark I design that was used in Fukushima.
- *Megawatts and Megatons* (2002) by Richard Garwin and Georges Charpak is a very authoritative book on nuclear weapons and on nuclear reactors.

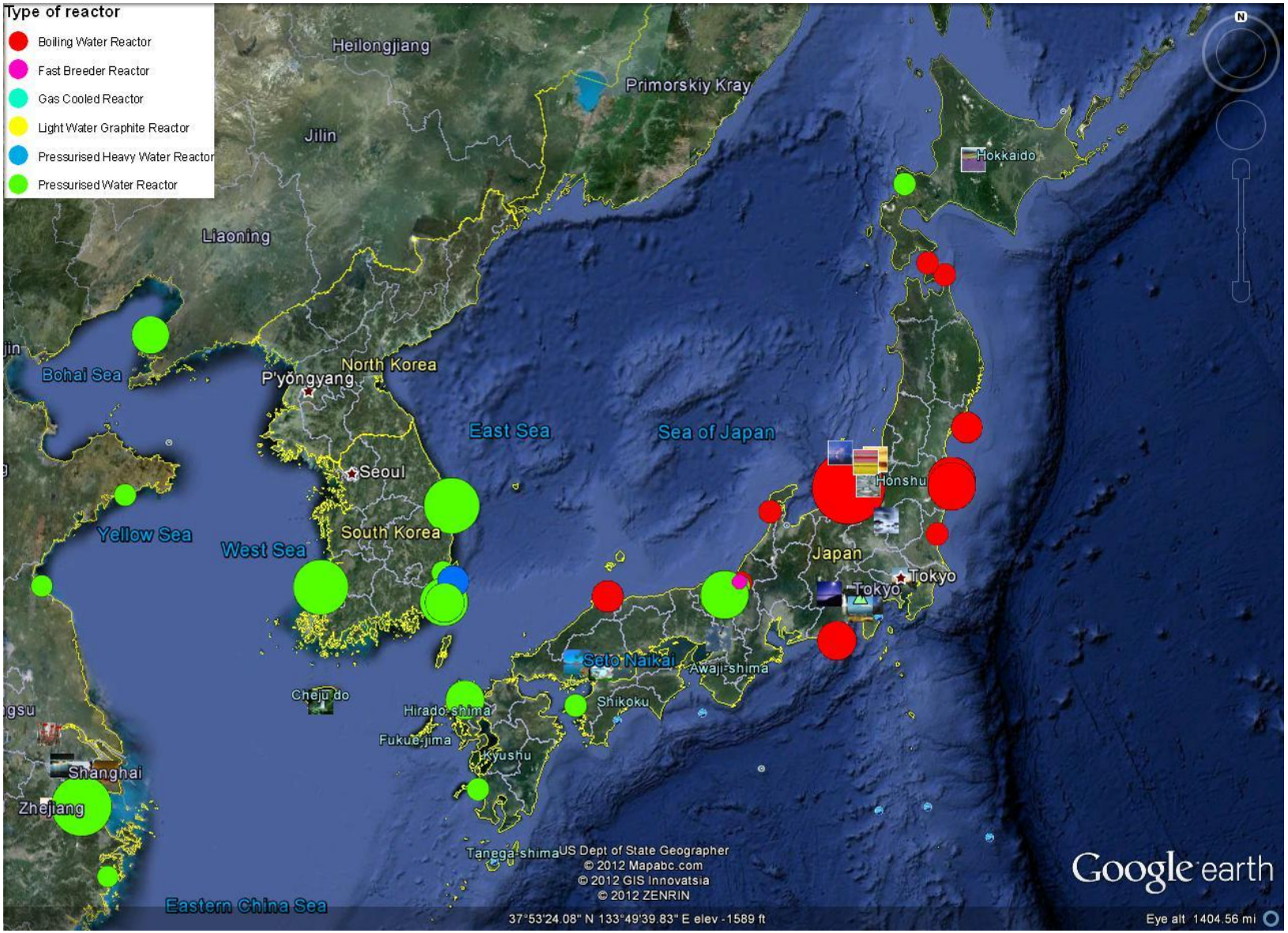
The Japanese Situation

- Local prefectures in Japan have the ability to shut down nuclear reactors. Of the 54 reactors, only one is still operating. A new energy plan is expected soon.
- Nuclear power supplied 30% of their electricity, and plans were to increase it to 60% by 2100.
- They have instituted energy conservation, rapid development of some renewable energy, and mainly use of oil and coal to power plants.
- About half of the plants are on the Eastern coast of Japan, subject to subduction faults at the meeting of the Asian and Pacific plates. These are mainly boiling water reactors. The West coast reactors are mainly pressurized water reactors.
- Near Tokyo is a triple fault junction, which had previously been considered the main focus.
- Reactors may be restarted on a case by case basis, especially if needed to overcome a possible summer heat wave.

Japanese Nuclear Plants and Earthquake Faults



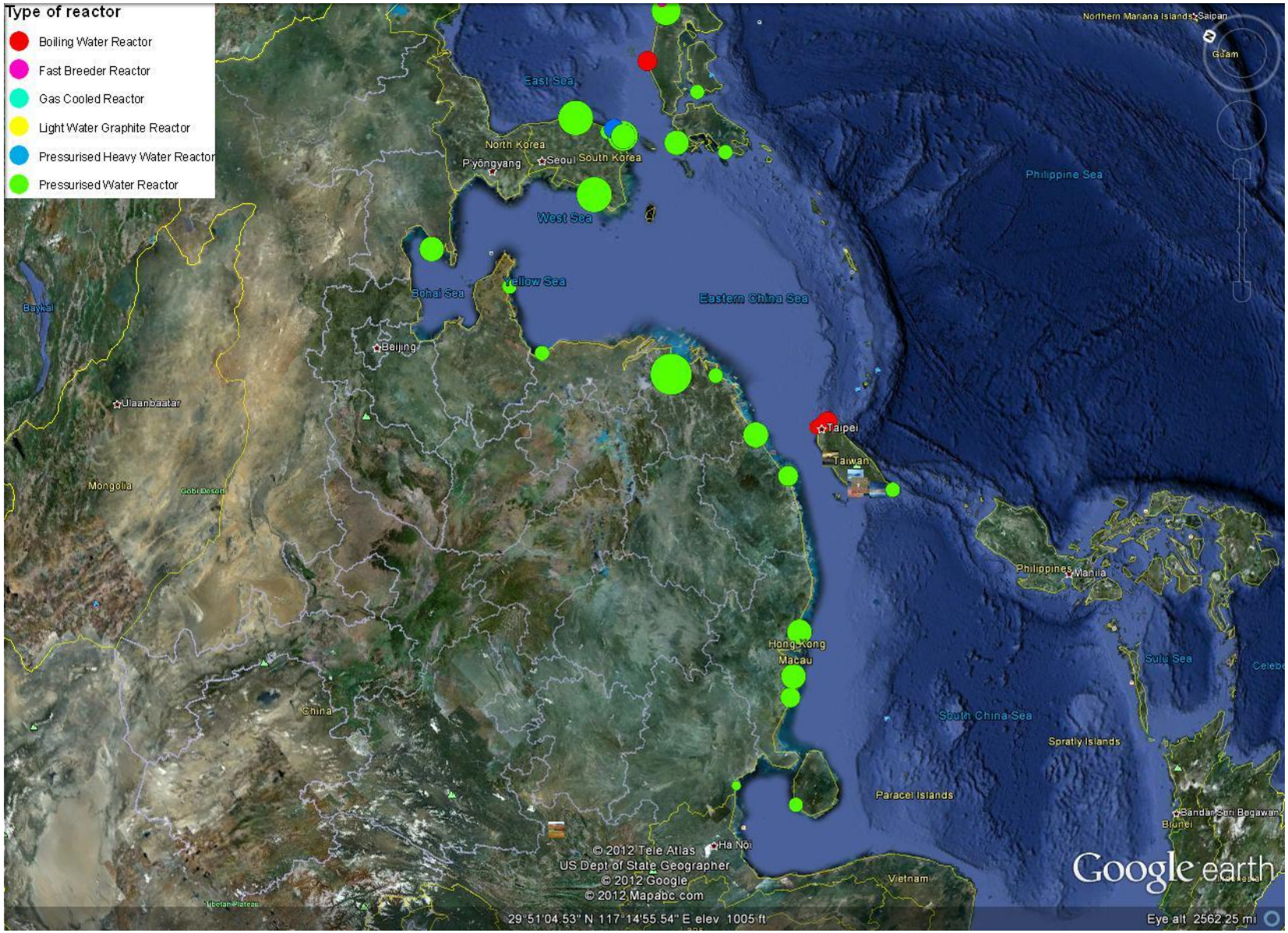
Japanese Reactors: Google Earth App by Declan Butler



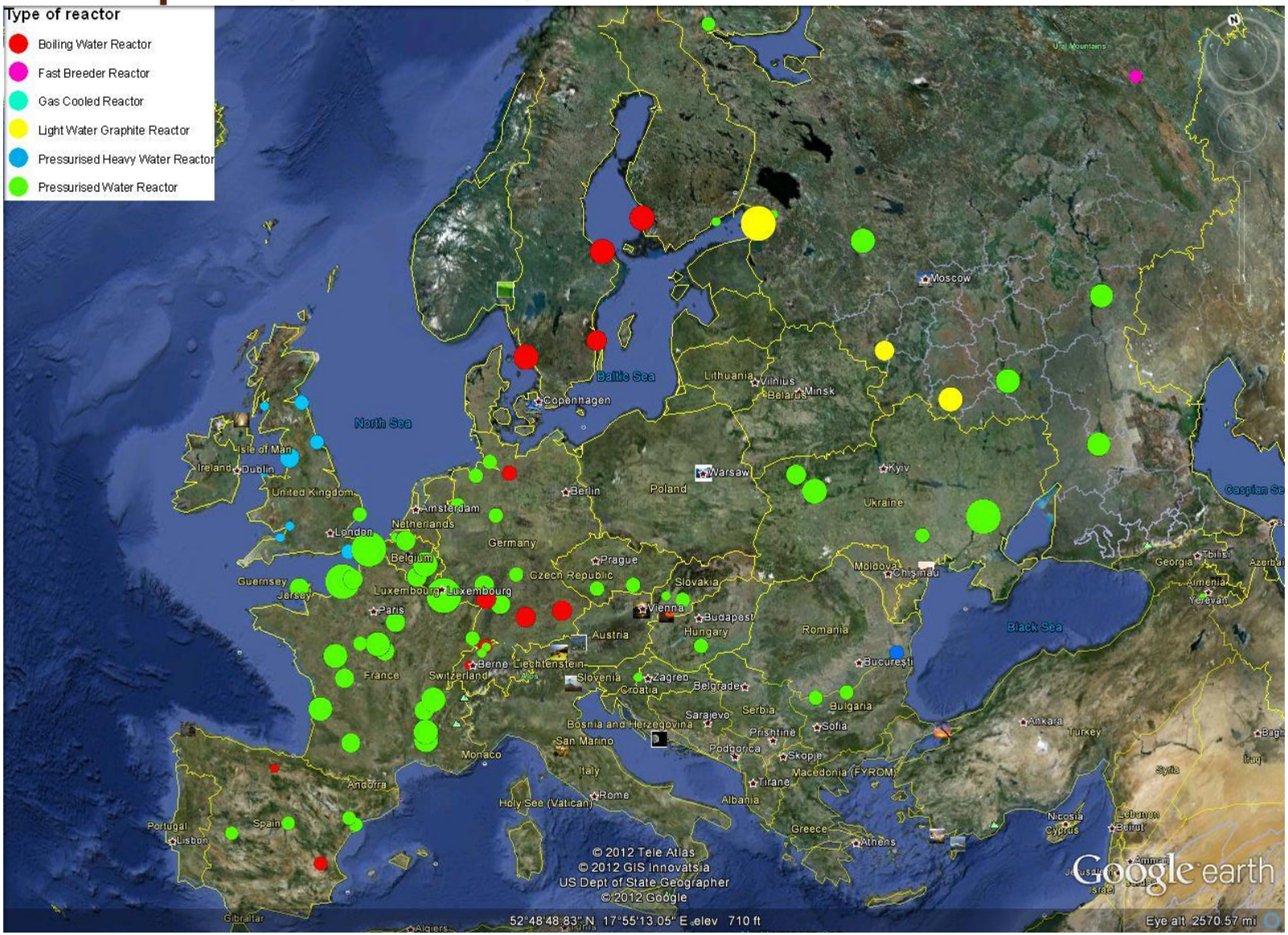
Japan, Continued

- Under new guidelines, some communities were warned about the possibility of 9.0 earthquakes, and tsunamis up to 100 feet.
- Several are considering moving their towns inland to higher ground.
- Despite preparation and training for tsunamis, many older people could not move to higher ground in the Tohoku tsunami.
- It may be that the boiling water reactor plants on the East coast with the severe earthquake threat would not be restarted.
- On the West coast there are fewer faults and less severe ones. Some of the reactors there are of the pressurized water design. A new energy plan is expected this year.
- Japan is expecting to pay 52 cents per kWh for solar, and 29 cents per kWh for wind. We currently pay about 13 cents per kWh as a base rate.
- Japan does not have homegrown fossil fuel sources and has to import its coal and oil.
- Taiwan is in a similar situation, and also next to a subduction fault.

Chinese and Korean Reactors



European, Russian, and Ukrainian Reactors



Other Countries

- Germany had already shut 8 of its 17 reactors, and now plans to shut the remaining 9 by 2022. Germany, however, does not have very severe earthquakes, but was strongly affected by Chernobyl. Nuclear power was 22% of Germany's electricity. They have had four serious nuclear accidents. They have wind power in the North, and very expensive solar power.
- Switzerland has 5 nuclear reactors, and will allow them to live out their lifetimes until 2034, but not replace them. They cancelled 3 new reactors.
- France is continuing its reactors, exporting their power, and still trying to sell its reactors as well. It is upgrading its reactors for safety against natural disasters.
- In China, plans seem to be stalled for 27 new reactors, in addition to the 14 that they already have. They have found 14 problems that they have up to three years to resolve. Their reactor site for Hong Kong has six large reactors that generate the same power as 16 US reactors. By 2030, China would have twice the nuclear power as the US.
- Russia is going to subject its reactors to stress tests for earthquakes beyond what they were designed for. They are planning 17 new reactors by 2020. They also continue to operate Chernobyl type reactors.

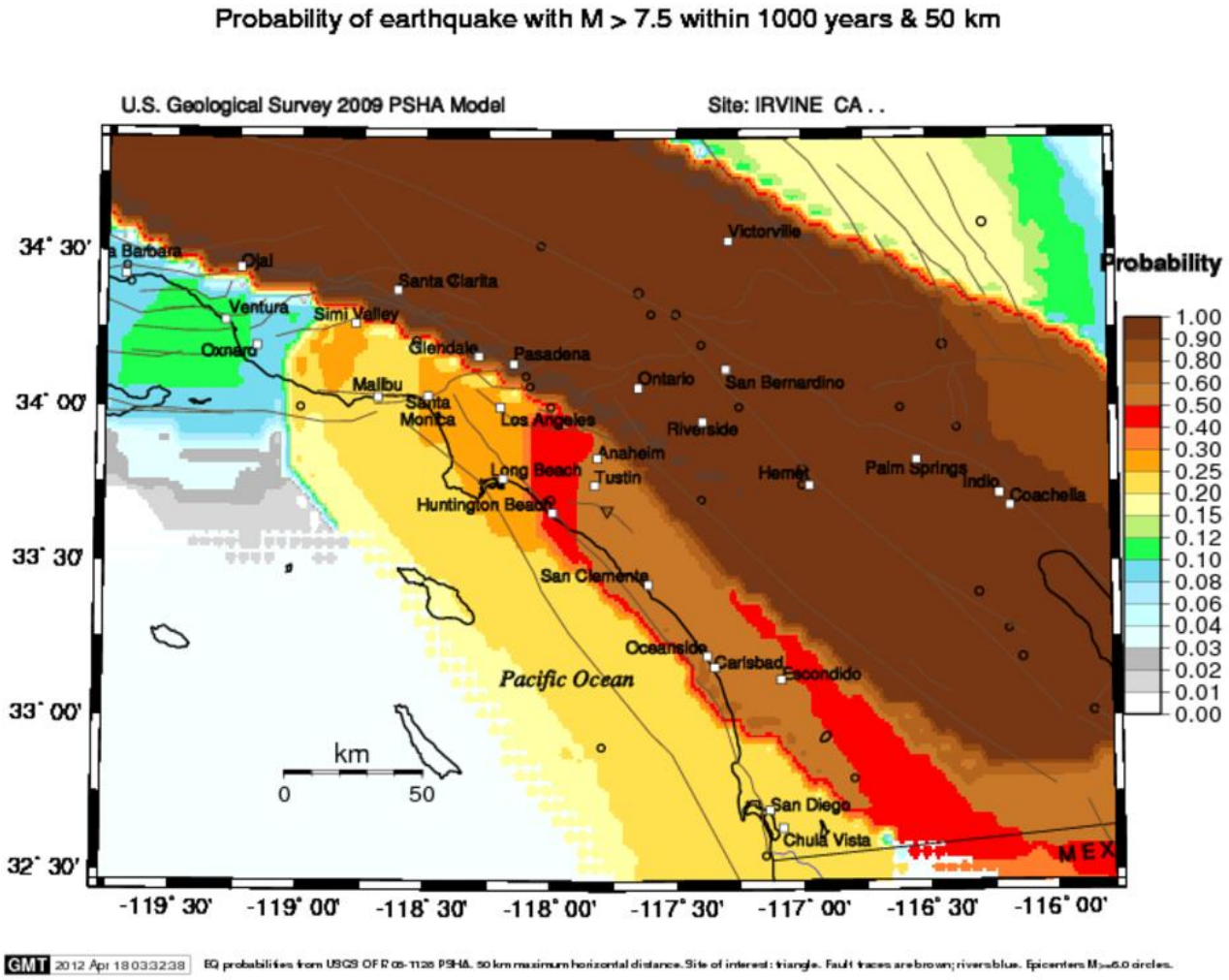
San Onofre Nuclear Generating Station (SONGS) Safety

- Caroline McAndrews has a Distinctive Voices talk at the Beckman Center on SONGS safety. Below is a summary of that talk.
- There is a current problem with the tubes in the newly replaced steam generators.
- The reactor is designed to resist a 7.0 earthquake on the Newport-Inglewood-Rose Canyon fault, or a 0.67 g acceleration.
- An 8.0 on the San Andreas would only produce a 0.2 g acceleration at SONGS, so they are prepared for that.
- Only a 6 foot tsunami is considered likely, reaching up to four feet below the top of the tsunami wall, even under the maximal tide and storm conditions.
- The battery backup power for cooling is 6 hours and it and the electrical connections are at the 50 foot level.
- There are spare backup generators for the pumps with a buried weeklong fuel supply.
- The plant is self sufficient for two weeks.
- The control room can be operated remotely.
- The spent fuel pond is enclosed and at ground level.
- After 7 to 10 years of radioactive decay, spent fuel is then encapsulated in steel and locked into concrete vaults.
- There is a large reservoir of backup cooling water.
- They still need new and modern earthquake and tsunami assessments.

My Concerns

- Before the reactor problems, 19,000 lives were lost to the tsunami.
- Protecting Lives: while worrying about the effects of large earthquakes and tsunamis on reactors, people forget that we need to have our communities prepared for the same.
- For example, in over 90% of the time for high tide and waves, each, San Onofre can stop an 18' tsunami at high tide, with its 30' height above low tide.
- But an 18' tsunami, even at low tide, would affect 42,000 in San Diego County, and 130,000 in Orange County, including 87,000 in Huntington Beach and 17,000 in Newport Beach.
- Fortunately, only a 6 foot tsunami is considered likely for San Onofre, and a 12' tsunami is a maximum on our coast from the Cascadia fault in Oregon
- We need a several hundred million dollar early warning system for the San Andreas fault, and an early warning system for locally caused tsunamis.
- We need backup power for our water systems in order to put out fires after an earthquake to avoid firestorms.
- We need to train our population for earthquakes and tsunamis.

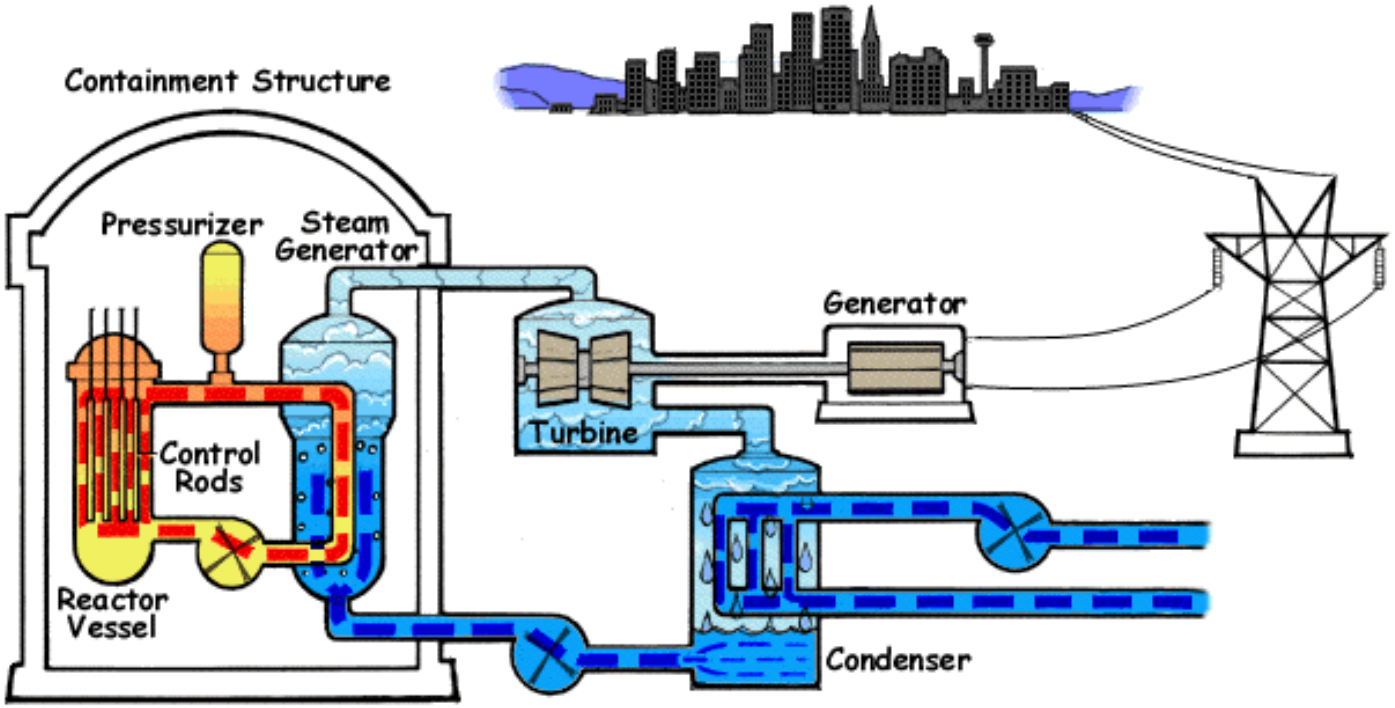
Long Beach – Newport – Rose Canyon Fault in Red Off-shore Magnitude 7.5 once every 2,000 years.



Risk and Consequences

- Considering the large area contamination that could be caused by a nuclear meltdown, it would not be worth chancing a small but definite risk to have reactors in a severe earthquake and tsunami zone.
- If the reactors are to be shut down, nobody has yet evaluated the costs for disposal, for replacement power, and for lost business and jobs in the recovery period.
- If both San Onofre and Diablo Canyon are shut down, that is a loss of 16% of California's power. Such base power cannot be replaced with fluctuating and part time solar and wind power.
- New reactors are already banned in California, and will probably never be considered again for a severe earthquake region.
- It seems very unlikely that the licenses in California will be extended after they expire in twelve years.
- The main things to consider now are a scientific evaluation of the risks of continued operation, the costs of a shutdown, and how to proceed with representative government to let the affected citizens decide, when the full facts are known.

Added Considerations Section



Things I wished that I had not learned by doing this research.

- Irvine between the freeways and West of Jeffrey is a liquefaction zone, extending down to Huntington beach.
- There is a UCI Campus fault running under the two bridges on the ring road.
- There is a San Joaquin Hills blind thrust fault beneath coastal hills like Top of the World, capable of a 7.0 magnitude quake, (but less often than once in 2,000 years). Local buildings are strengthened to a 7.0 or better.
- Catalina island was built up from subduction faults.

- There was an LA Times article labeling the Newport-Inglewood fault an 8.0, without considering that its likelihood of an 8.0 is less than once in a 100,000 years.
- For details, see my energy blog: sites.uci.edu/energyobserver/ or Google Dennis Silverman.
- People are allowed to say *anything* in city council meetings.
- Only one Irvine City Council member called for some scientific testimony.
- Only buildings have earthquake standards, not refineries or chemical plants.
- Extreme earthquakes seem to occur around the world in clumps in time.
- The NRC website does not have simply available current information.
- The SONGS and SC Edison do not appear at many public functions ready to defend the plant.

Nuclear Reactors Versus Pollution

- Nuclear power is around a million times more powerful per atom of fuel or waste than fossil fuel processes. However, the wastes are radioactive. But, the wastes are almost always contained.
- Fossil fuels cause pollution that causes asthma, eye watering, loss of work, hospital visits, acid rain, poisoning of forests, and harm to wildlife. Modern plants can contain some of the pollution. But none can contain CO2 pollution, that is spread all over the planet and causes climate change.
- In beautiful Southern California, we have by far the worst smog area in the US: Los Angeles-Riverside. We escape that in Irvine most of the time. We also have some of the most vulnerable areas to climate change that is going to be caused by the CO2. Our summer water supply depends on a snow pack in the Sierras and Rockies, that shrinks with earlier spring warming, and later winter freezing. Our local Huntington Beach, Newport Beach and Balboa Island are going to be most vulnerable to rising sea levels during storm surges.
- However, the immediate question is whether 6% of US reactors are at a serious earthquake risk, not whether all US reactors would have to be abandoned and lost to the cause of combating global warming.

Cumulative Industrial Risks

- The fact that there will be 400 operating reactors worldwide increases risks to the industry as a whole by that factor.
- The fact that a single reactor or plant fails is taken by many people and countries as a failure of the whole industry.
- This is not the case when a plane crashes, or a ship sinks, or a train, bus, or car crashes, or an earthquake knocks down buildings. In all these cases, we analyze, correct, and move on. The sinking of the Titanic led to many shipping innovations that made all shipping safer. The abject failure and pollution of the Deepwater Horizon oil well was followed by demands to restore similar projects as soon as possible.

Shedding Risk

- As an example, if the nuclear industry can guard against a meltdown at any reactor to the level of one chance in 4000 per year, the fact that there are 400 reactors means that there will be one meltdown every ten years, which is proving catastrophic for society, and for the industry as a whole. This could be called "cumulative industrial risk", that is, a risk to the industry as a whole. (To be fair to industry, I should state that their calculation of risk is one in 58,000 years for one reactor.)
- Given this cumulative industrial and societal risk, the industry as a whole should strive to remove those reactors that are most at risk of failure, either because of design, or hazards, or mismanagement of safety. It might even pay for the industry to accept the cost of shutting down the bad reactors themselves, and replacing them with newer, safer ones removed from hazards or nearby population. They certainly should demand that the regulatory agencies make sure that *all* plants maintain maximum safety across the board. This is just the opposite of the attitude that most companies regard their regulators with.