Safety Culture and the Future of Nuclear Energy

International Conference on Human and Organizational Aspects of Assuring Nuclear Safety
– Exploring 30 Years of Safety Culture
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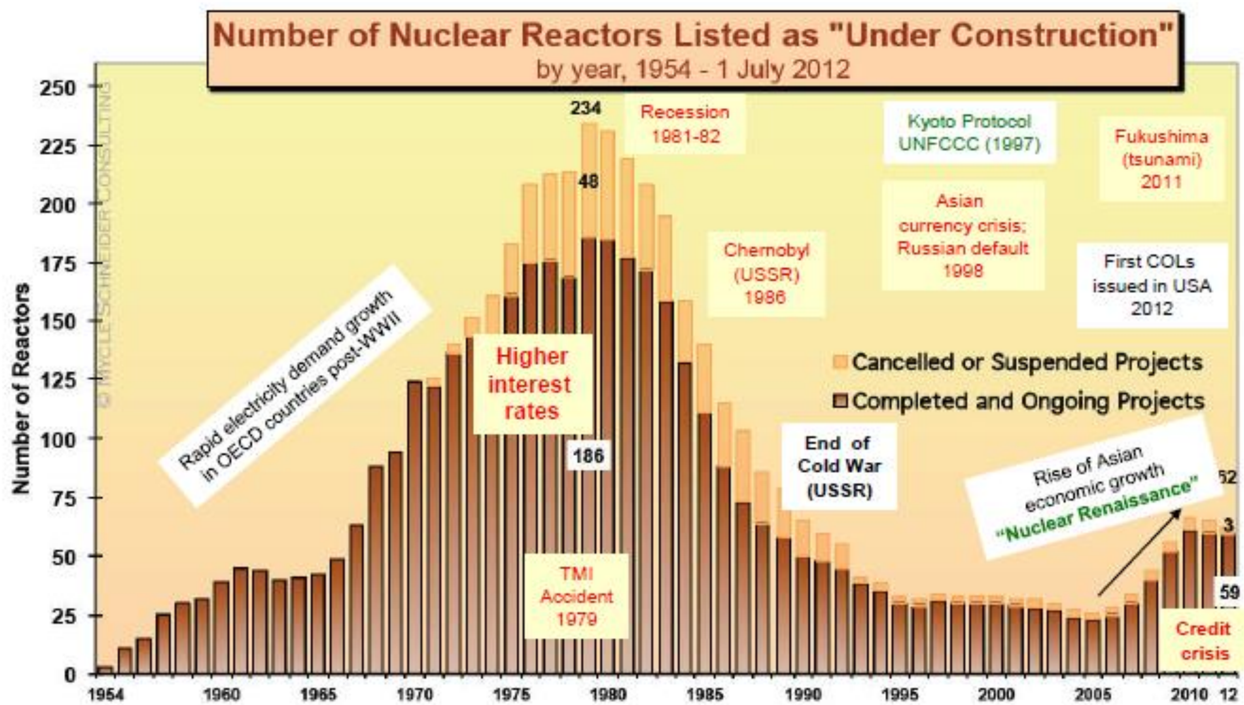
History of Nuclear Power

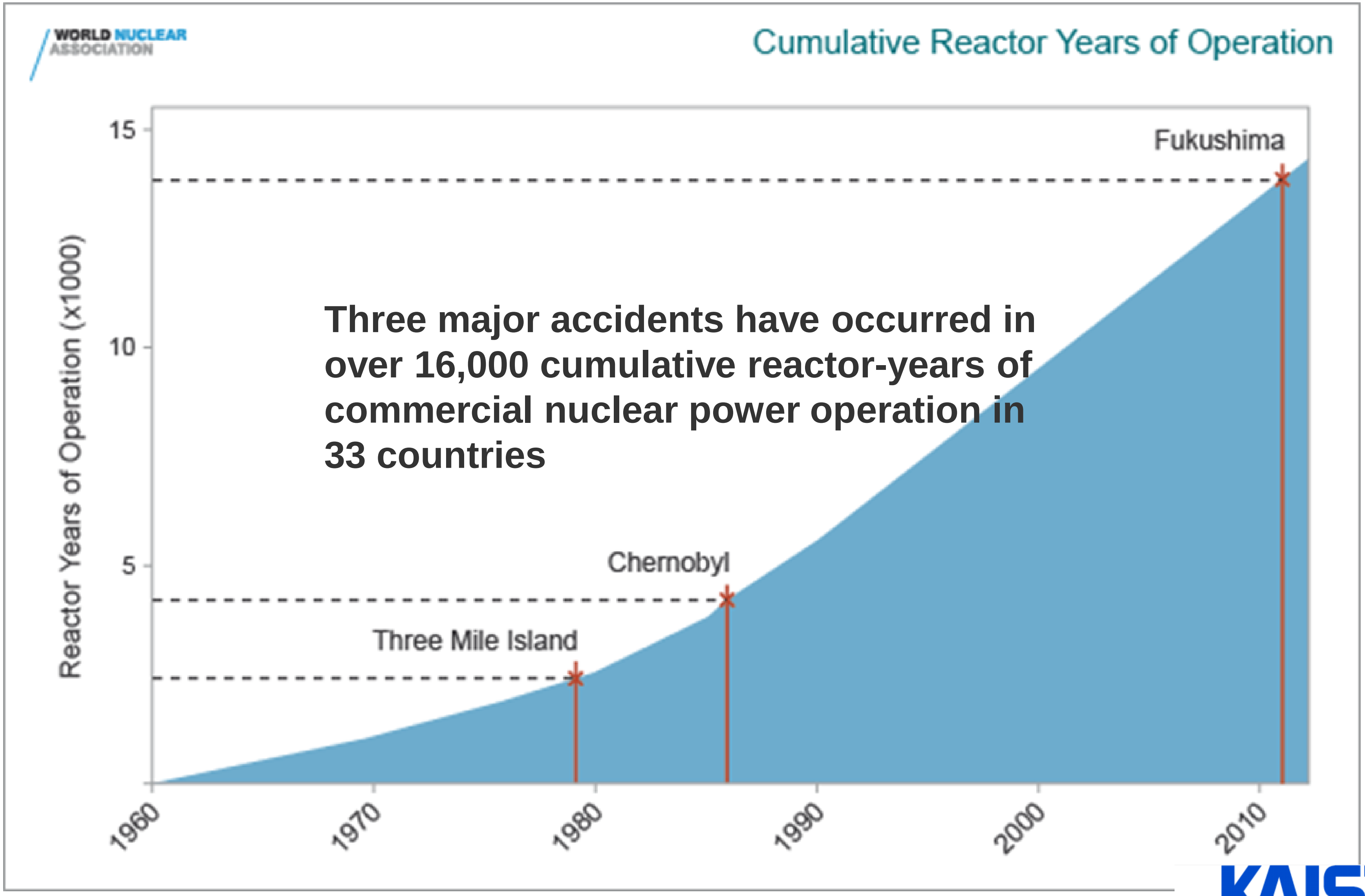
- Atoms for Peace
- TMI
- Chernobyl
- Nuclear Renaissance
- Fukushima



Evolution in Nuclear Safety

- Enrico Fermi’s nuclear reactor (1942)
- “Siting and Containment” (1940s)
- Use of engineered safeguards, under ***Defense-in-depth*** (1950s - 70s)
- Importance of human error and operator training (1980s)
- Importance of ***safety culture*** (1990s)
- Beyond Design Basis Accident and Severe Accident Management (2011 -)

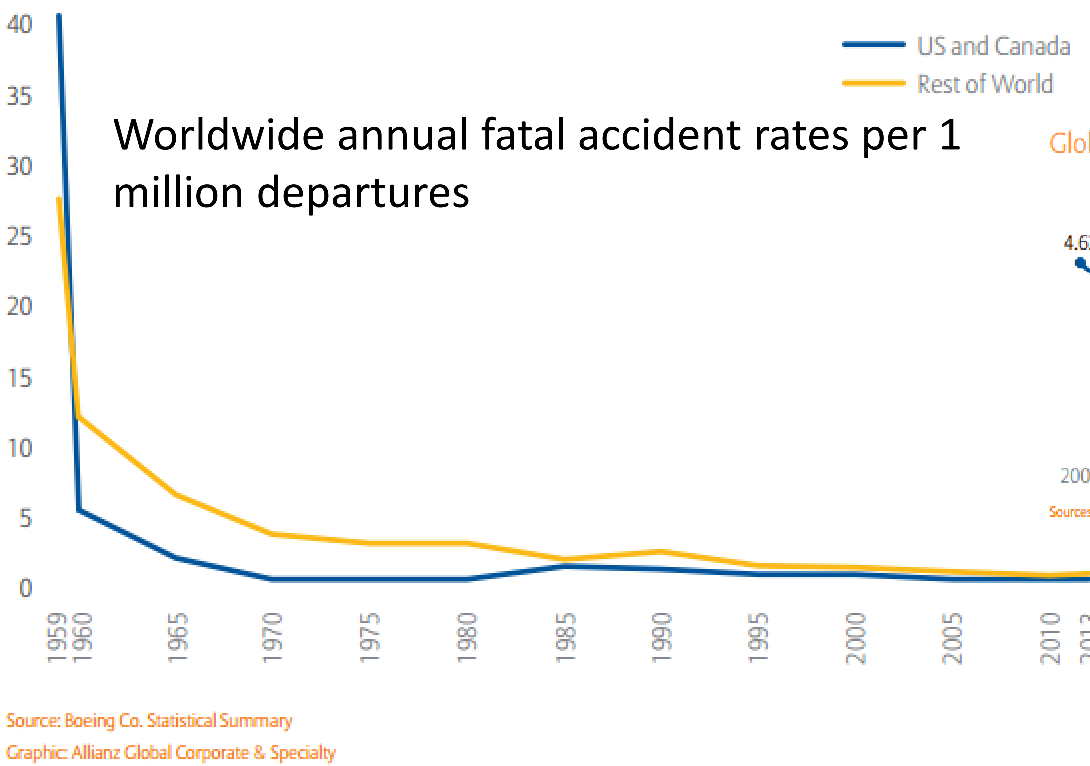
Another Major Nuclear Accident in the Future?

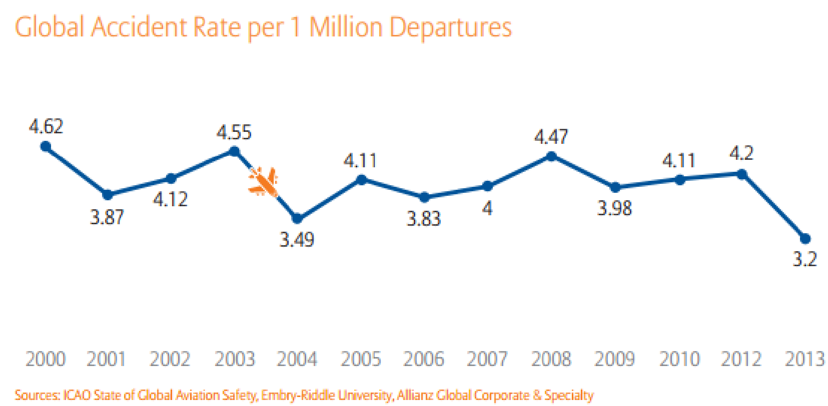


Lessons from the Aviation Industry

- In the 1950s and 60s, the commercial aviation industry was plagued with accidents. The projected fatalities with the growth of the industry were too big to sustain the industry. Did the projection continue into the future?
- Today, commercial airplanes are accepted by the public with no major safety concern. The rate of fatal accident in the industry has been reduced significantly.

Worldwide annual fatal accident rates per 1 million departures





How did they do it?

- Technological development
- Operation and maintenance
- Regulatory oversight
- Safety thinking

The phases of safety thinking

[Reason, 1993; Wilpert, et al., 1999]

1. Technical phase

   Technology as source of problem

2. Human error phase

   Individuals as source of problem

3. Socio-technical phase

   Interaction of subsystem as source of problem

4. Inter-organizational relationship phase

   Dysfunctional relations between organizations as source of problem

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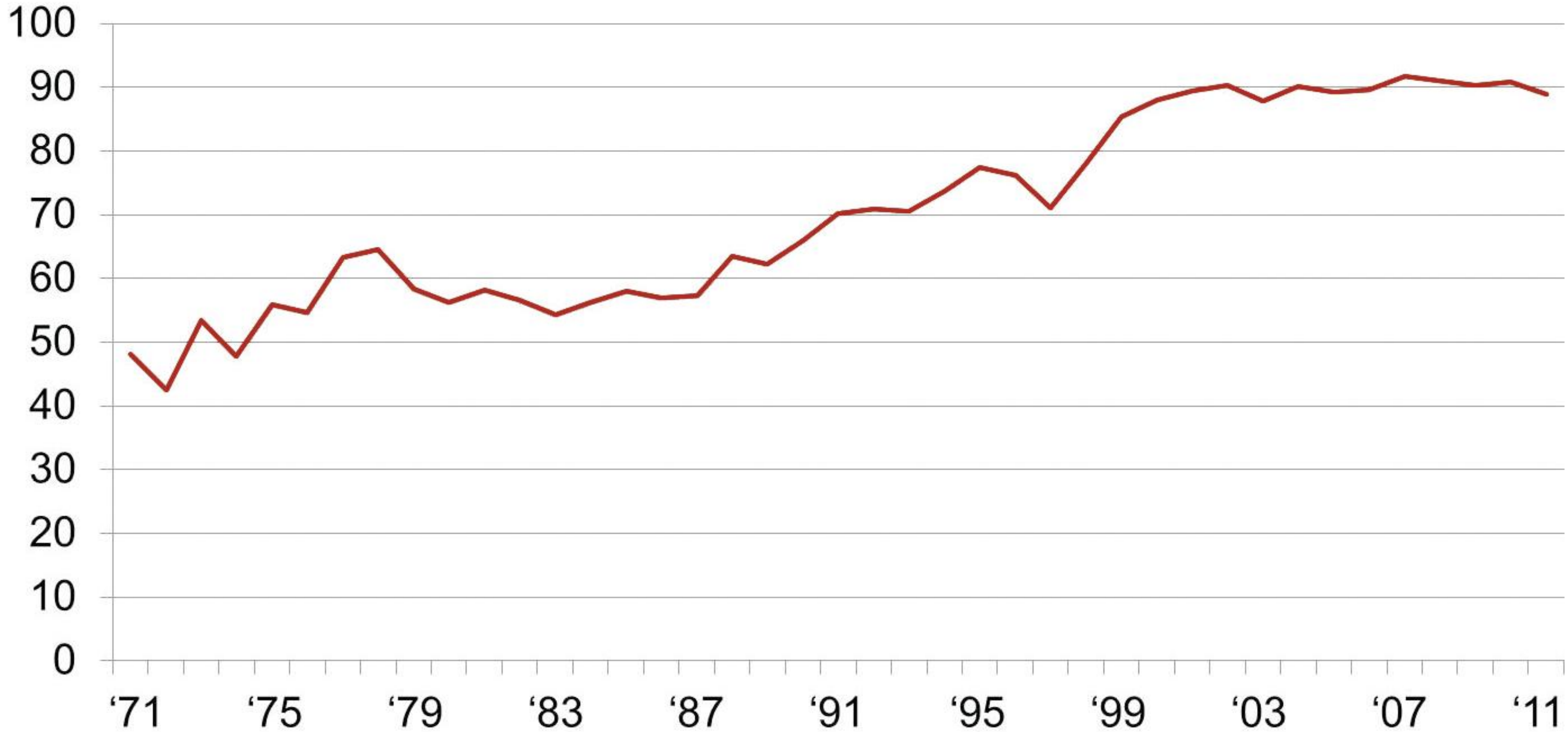
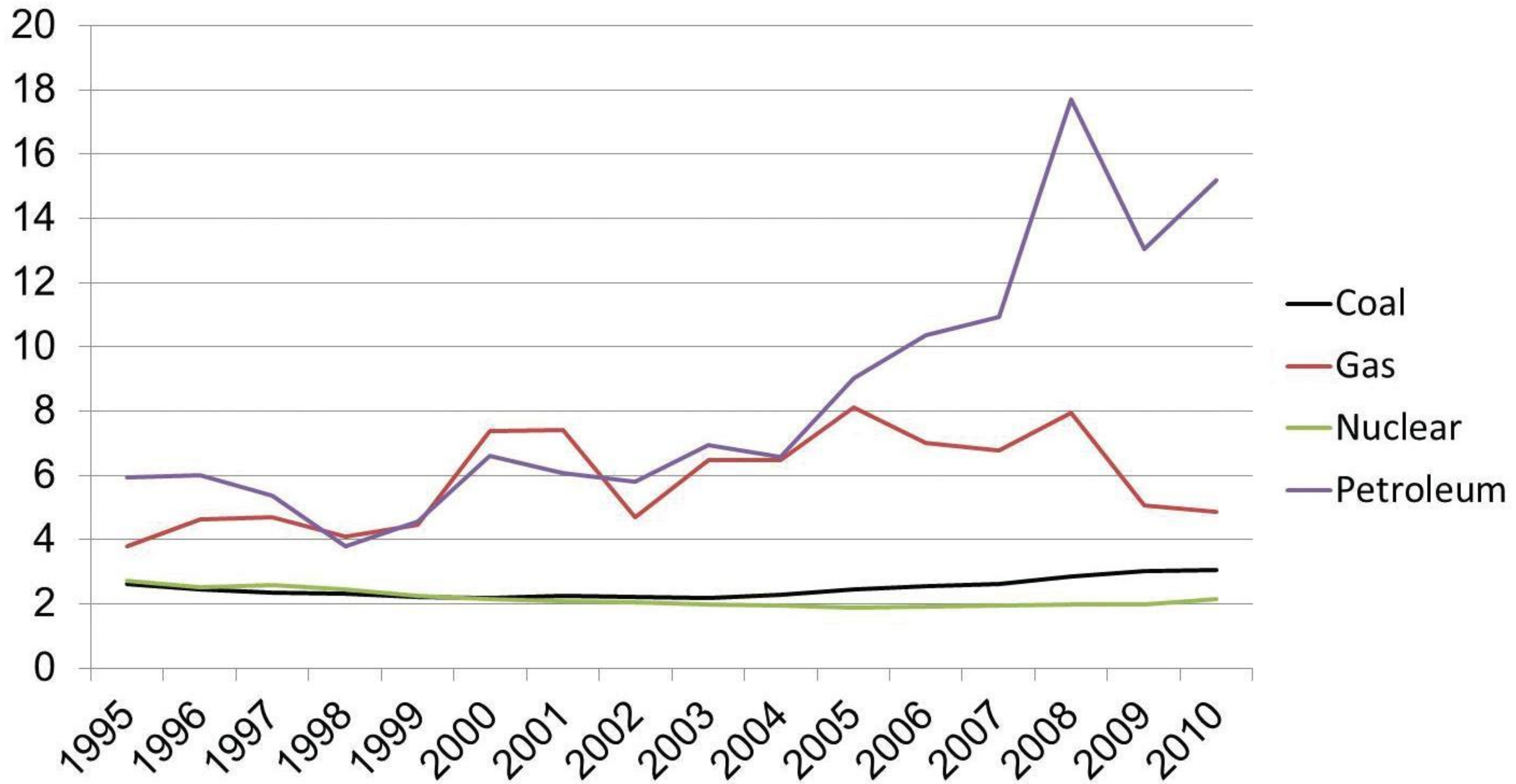
U.S. Nuclear Industry Capacity Factor 1971-2011



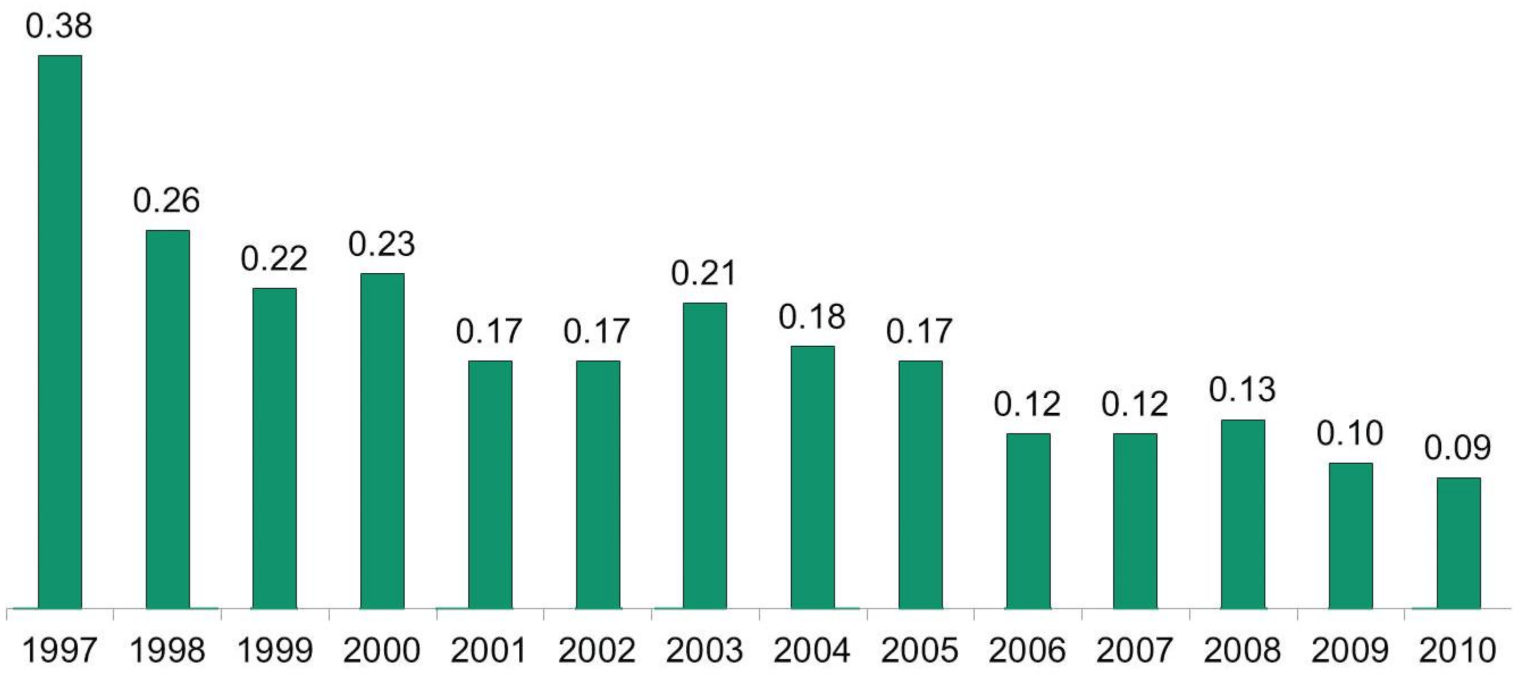
Source: Energy Information Administration, 2012.

U.S. Electricity Production Costs 1995-2010



U.S. electricity production costs, 1995–2010, in 2010 cents per kilowatt-hour.
Source: Nuclear Energy Institute, 2011.

U.S. Nuclear Industrial Safety Accident Rate 1997-2010



ISAR = Number of accidents resulting in lost work, restricted work, or fatalities per 200,000 worker hours.

Source: Nuclear News, 2011.

“Safety improves economics.”

The Future of Nuclear Power

- Despite the 2011 Fukushima accidents in Japan and the phase-out decisions by a few European countries, demand for nuclear power continues in the world.
- This development is, in part, related to current global consensus on greenhouse gas reduction effort.
  - Nuclear power used to be considered as just one of many alternative technologies to produce electricity.
  - Today, nuclear power is touted as one of the few options that we must use to fight the gravest challenge the world faces today.

Nuclear Power:
Expansion vs. Spread Post-Fukushima 2013

[Scott Sagan, NEREC Conference on Nuclear Nonproliferation, Seoul, Korea, July 31st, 2014]

	Americas	Western Europe	Eastern Europe	Central and South Asia	East Asia/ Oceania	Middle East	Africa
States with Nuclear Power Programs	Argentina Brazil Canada United States Mexico	Germany Switzerland Belgium Finland France Netherlands Spain United Kingdom Sweden	Armenia Bulgaria Czech Republic Hungary Slovakia Romania Russia Slovenia Ukraine	India Pakistan	Japan China South Korea Taiwan	Iran	South Africa
Aspiring Nuclear Power States	Peru Venezuela Uruguay Dominican Republic Haiti Bolivia Chile Jamaica El Salvador	Italy	Belarus Poland Lithuania Croatia Latvia Albania Estonia Greece	Bangladesh Kazakhstan Sri Lanka Mongolia Georgia	Thailand Singapore Myanmar Indonesia Malaysia Vietnam North Korea Philippines	Israel Egypt Jordan Turkey UAE Kuwait Qatar Saudi Arabia Bahrain Oman Syria Yemen	Senegal Nigeria Tanzania Tunisia Libya Kenya Algeria Namibia Niger Uganda Ghana Morocco Sudan

Red = Cancelling plans **Green = Continuing with plans**

Black = No evidence

Orange = Ongoing debates that have produced a delay or uncertainty about plans

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The Future of Nuclear Power

- Rapid expansion of nuclear power is called for to cope with current crisis in the global ecosystem.
- Nuclear power and renewable energy technologies are expected to cooperate to realize carbon-free energy generation.
- Construction of small and modular reactors (SMRs) is considered for smaller grid applications.
- Commercial marine applications of nuclear power is drawing interest.
- Presence of nuclear power plant in close proximity to humans or population is envisioned.
- For these developments to be realized, nuclear power must be accepted by the public/local communities.
- The future requires a new level of nuclear safety.

Challenges in Nuclear Safety

- Many of the nuclear power plants currently operating are approaching their initial operating license limits.
- The infrastructure to support safe operation of nuclear power plants may be weakening.
  - Nuclear work force is aging in many countries.
  - Nuclear work force is reduced with slowdown of nuclear development.
    - Number of highly qualified experts is on steady decline in most of the countries.
    - The number of graduates with training in nuclear technology has declined.
  - The amount of R&D funding to support nuclear safety has decreased.

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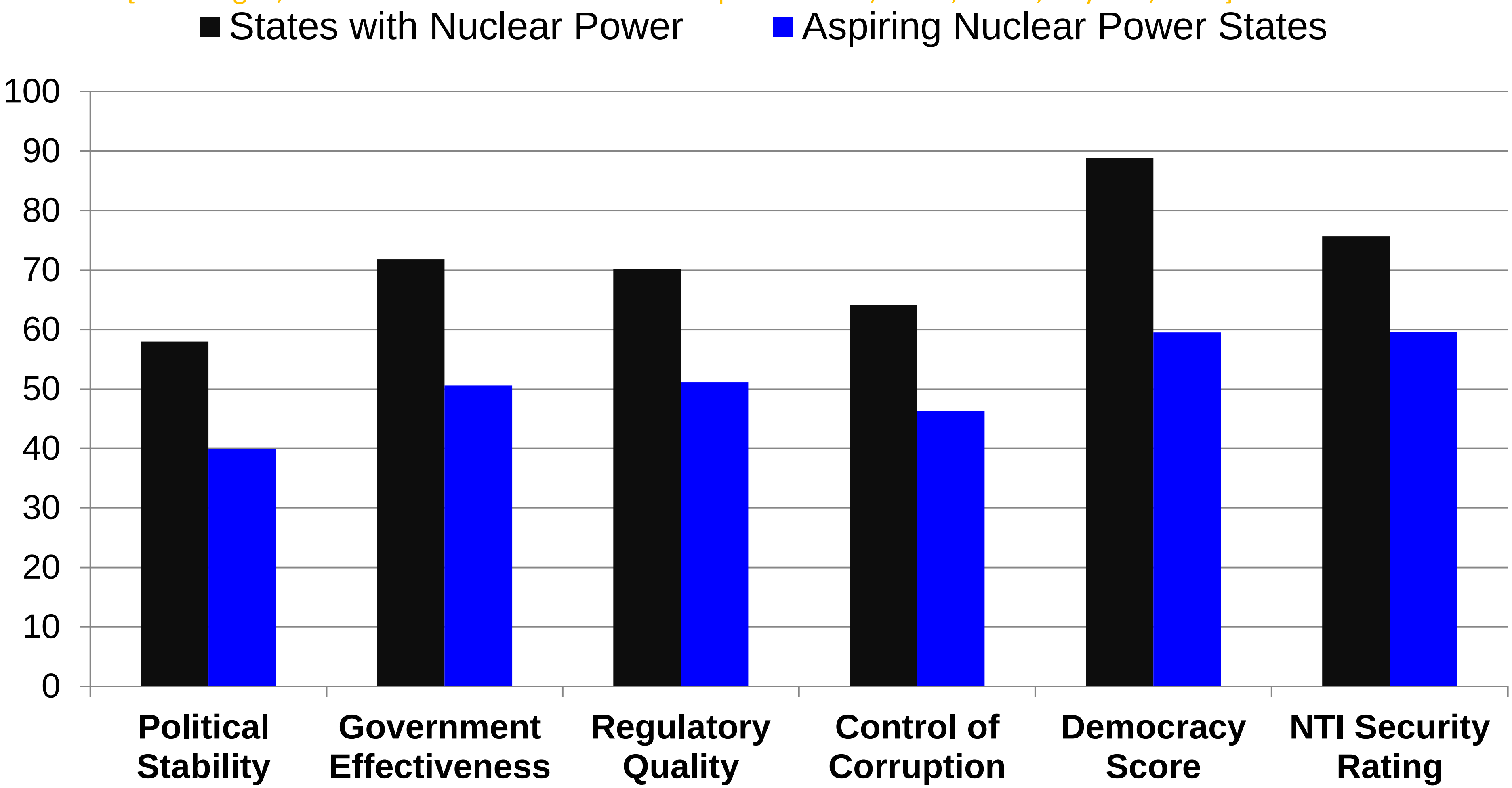
Challenges in Nuclear Safety

- As the number of newcomer states increases, countries without experience in the operation of nuclear power increase.
- Although IAEA provides technical guidance and support, the level of international cooperation to support safe operation of nuclear power plants is low.
- Many of the aspiring states do not have domestic "good governance" characteristics that will encourage proper nuclear operation and management.
  - low degrees of corruption
  - high degrees of political stability
  - governmental effectiveness
  - strong degree of regulatory competence
- Some of the newcomer countries may rely on foreign workforce to operate and maintain the plant (multicultural workforce issue).
- The 2011 Fukushima accidents demonstrated the need for integration of nuclear safety and nuclear security.

Governance, Corruption, and Regime Type 2013

[Scott Sagan, NEREC Conference on Nuclear Nonproliferation, Seoul, Korea, July 31st, 2014]

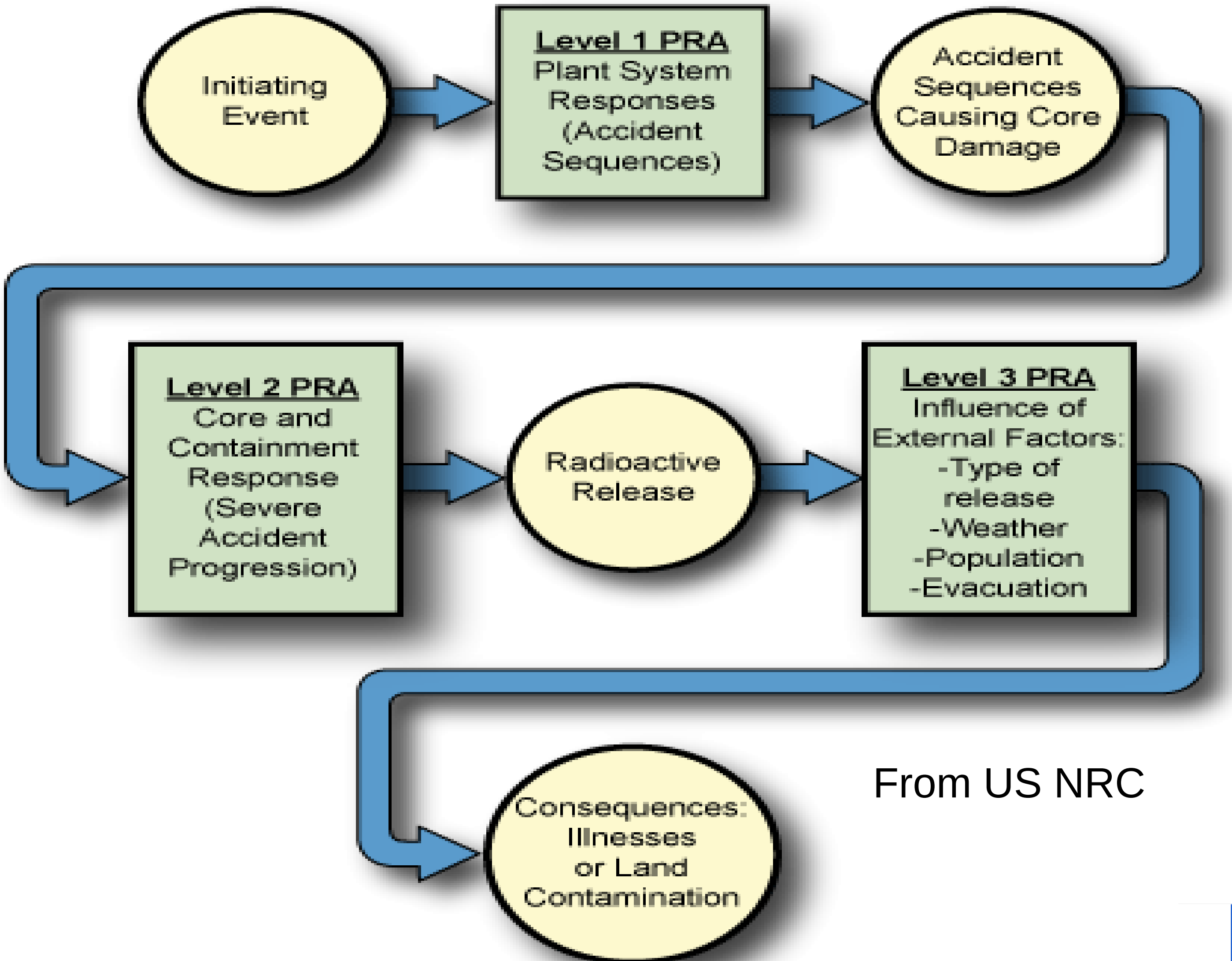


Sources: World Bank, *World Governance Indicators, 2011*, info.worldbank.org/governance/wgi/index/asp; Polity IV Project, *Political Regime Characteristics and Transitions, 1800-2007*, www.systemicpeace.org/inscr.htm; NTI Nuclear Materials Security Index, http://www.ntiindex.org/. * Measurement for Democracy/Autocracy Score is mean Polity IV 20-point score on a 100-point scale. Scores above 50 represent democracy; below 50 implies non-democracy.

Requirements for Nuclear Safety

- Consequence relevance
  - Technology for nuclear safety needs to be risk reduction driven.
- Cost-benefit relevance
  - Technology for nuclear safety needs to be cost effective.
- Core human performance relevance
  - Infrastructure for nuclear safety needs to support human performance.
- Cultural relevance
  - Nuclear power is accepted as part of the culture.

Probabilistic Risk Assessment



From US NRC

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For the Future of Nuclear Safety

- Higher level investment is needed.
- Higher level international cooperation is needed.
- Comprehensive coverage is needed.
  - The component level (to minimize the failure)
  - The system level (to minimize the release to the environment)
  - The post-accidental level (to mitigate the consequence and public's fear)
  - The social level (to gain trust)
- Repeated, consistent performance of safety is needed.
  - Supported by mature safety culture
- New mindsets among nuclear professionals are needed.
  - Understand that different types of people facing a similar societal problem react in different ways.
  - Understand that there are a variety of ethics underlying the public attitude.
  - Understand that what the public want is not so much the outcome of the decision itself but a justifiable decision-making process itself.
  - To earn trust from the public is the key.

Technical Rationality vs. Cultural Rationality

- Trust in scientific methods, explanations, evidence
- Appeal to authority and expertise and peer groups
- Boundaries of analysis are narrow
- Risks are depersonalized
- Emphasis on statistical variation and probability
- Appeal to consistency and universality
- Resolution of controversy follows status
- Those impacts that cannot be uttered are irrelevant

- Trust in political culture and democratic process
- Appeal to folk wisdom, traditions
- Boundaries of analysis are broad.
- Risks are personalized
- Emphasis on the impacts of risk on the family and community
- Focus on particularity: less concerned about consistency
- Popular responses to scientific differences do not follow the prestige principle
- Unanticipated/unarticulated risks are relevant.

Trust

- Trust is gained through repeated behaviors that demonstrate:
  - A belief that those with whom you interact will take your interest into account.
  - A sense of confidence that the party trusted is able to empathize with your interests and is competent to act on that knowledge.
- Trust is easily eroded or lost.
  - if an organization is unable or unwilling to respect the views of vulnerable parties
  - If an organization is unable or unwilling to fulfill promises.
  - If there is mismatch in the distribution of benefits and costs associated with the organization's mission.
  - If there is a long time lag between taking an action and discovering its success or failure, it is also difficult to maintain trust.
  - If the organization is not transparent in sharing information, it is also difficult to maintain trust.

Socially-trusted Nuclear Safety

- The final phase of nuclear safety.
- Nuclear safety in the perspectives of the public.
    - Efforts in nuclear safety address psychological factors related to public perception and acceptance.
    - Technology for nuclear safety is perceived by the public as something understandable and mitigating their fear.
- Nuclear safety through completion of safety culture.

Elements of a Change Process

- Create a sense of urgency
- Understand the range of choices
- Create a vision
- Create new networks of relationships
- Communicate the vision
- Develop and communicate short-term wins
- Institutionalize the changes
- Evaluate and affirm the changes

Nuclear Safety for the Future

- Nuclear safety is safety only if nuclear power serves the purpose.
- Safety:
  - Humans have a basic, innate desire for safety.
  - Its satisfaction requires security, stability, protection, structure, order, and freedom from fear and anxiety.
  - Even if the nuclear industry achieves the best level of safety with best available technology, if the people still experience fear and anxiety, it is not safe.
  - If the public does not trust the people who man the technology, nuclear power is not safe.

Final Words

- Challenges that the nuclear industry faces in the future have strong social connections.
  - Nuclear safety
  - Public acceptance
  - Economics (+ social cost)
  - Nuclear waste
  - Nuclear nonproliferation
  - Governance challenge
- Nuclear engineering professionals must be prepared to address these challenges along with the dedication to safe and responsible use of nuclear technology.

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