



RENAISSANCE OR RUIN? THE RISKS , BENEFITS, AND FUTURE OF NUCLEAR ENERGY

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OVERVIEW

Nuclear energy projections

The Fukushima effect-

Other Nuclear energy challenges

The Big Picture



DREAMS OF A RENAISSANCE

In early 2000s, nuclear power was on the decline

- Projected to decrease from 15% in 2006 to 10% in 2030 (IEA 2008)
- In U.S., no new reactors proposed since 1979
 - U.S.-25% of global nuclear energy generation capacity

Mid 2000s Revival of interest in nuclear build

- Continued growth in nuclear power in Japan, South Korea
- Surging demand for electricity in Asia's developing countries
 - Especially China and India
- Green: nuclear is a low-carbon energy source (vis coal)
- Secure: uranium supplies are from peaceful often developed ctys
 - Canada, Australia, (Kazakhstan)
- Balance-of-payments issues (Japan and Korea)
 - In place of importing expensive oil and gas
- Safe: no major accidents since Chernobyl (1986)

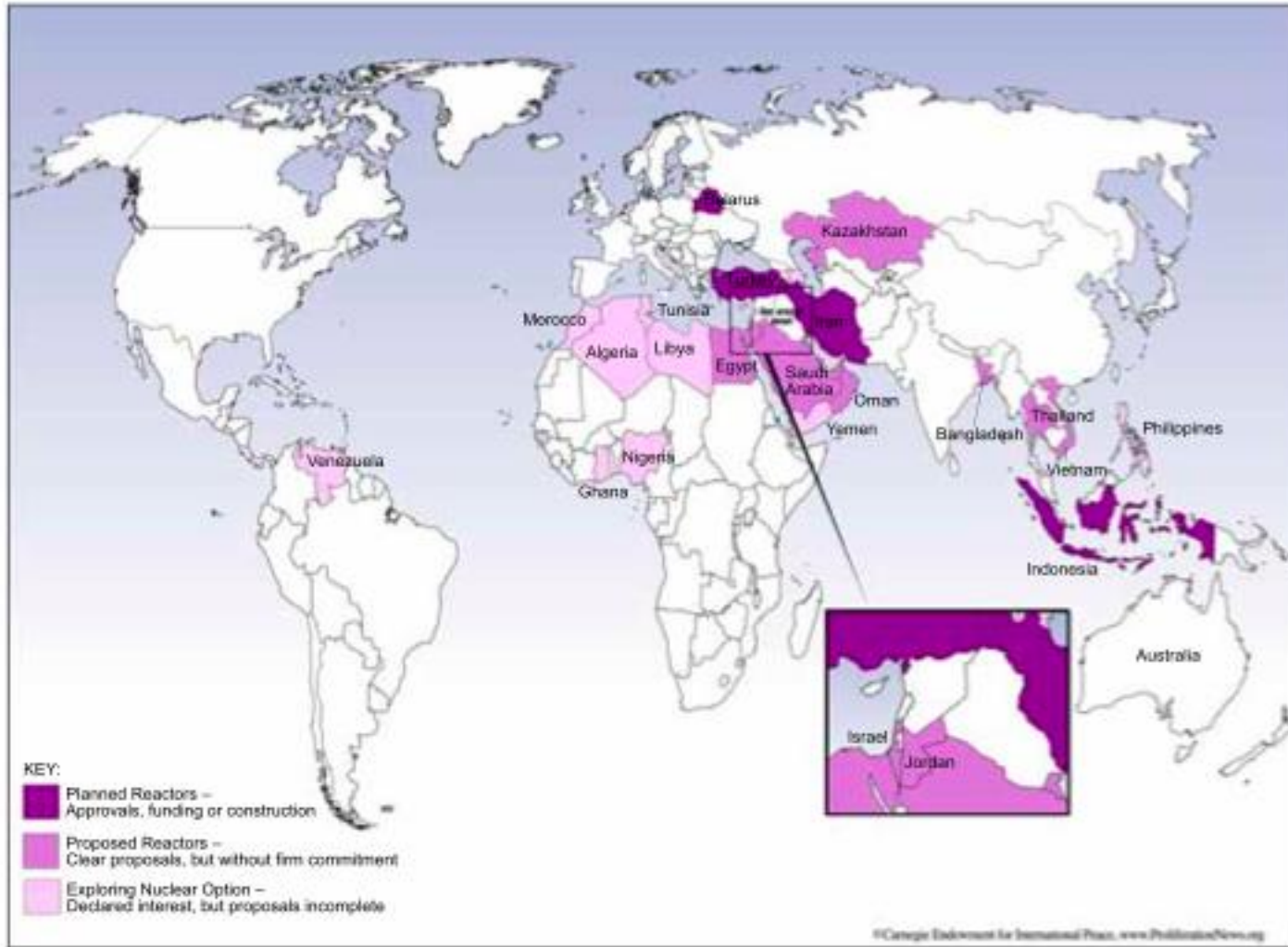
Many countries announced plans to build nuclear power plants

- Some interested in other parts of fuel cycle also
 - ROK Interest in pyro (re) processing, enrichment
 - Brazil, Jordan interest in enrichment



INTEREST IN NUCLEAR POWER

Proposed New Nuclear States, 2008

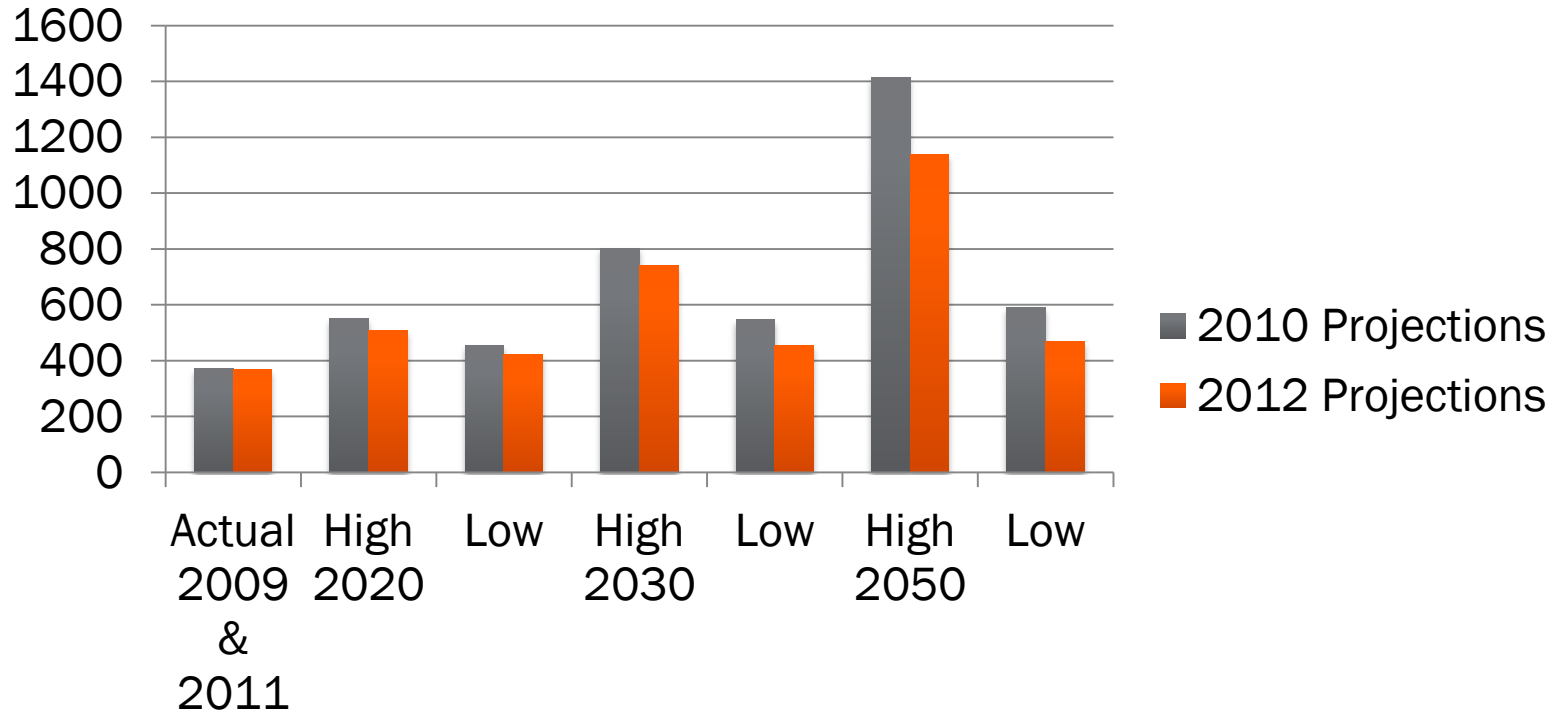


NUCLEAR ENERGY CAPACITY TODAY



As of end of 2011, 435 reactors in operation* with 368,791 MW(e) operational capacity (IAEA 2012)

IAEA PROJECTIONS: THE FUKUSHIMA EFFECT



A RENAISSANCE DEFERRED? SAFETY CONCERNS

2011 Fukushima accident put expansion on hold

- Public concerned about safety of operation
- Pressure from safety requirements on operational costs
- Stress Tests in Many Countries
- Need for independent regulator highlighted
 - If an advanced country like Japan has such problems, what can be expected from newcomers?

SAFETY IMPROVEMENTS SINCE FUKUSHIMA

IAEA Action Plan

- Approved by BG in September 2011
- Addressed at March 2012 experts mtg, 2012 GC

Calls for

- Enhanced IAEA safety standards, peer reviews
- Increased effectiveness of national regulators
- Enhanced protection against extreme events
 - Total station blackout loss of coolant-reactor/spent fuel pools
 - Including more robust instrumentation and
 - Improved emergency preparedness and response

AFTER FUKUSHIMA: WHO'S OUT AND WHO'S IN-GLOBAL

Startups, shutdowns, new build

- In 2011: 7 started up, 19 shut down, 4 new build
- Multiple certification, licensing, other delays

Construction cancellations

- At least 6 newcomers: Egypt, Italy, Jordan, Kuwait, Oman, Poland
- NPPs in Brazil, France, India, the U.S., Bulgaria, Japan, China
- Industry withdrew from key projects: Netherlands, U.S., U.K.

Nuclear phase out decisions

- 4 states: Belgium, Germany, Switzerland, Taiwan

Construction started up and continued

13 countries currently building 56 reactors

$\frac{3}{4}$ of those building in China, India, Russia

Belarus, UAE, Turkey, Vietnam, Saudi Arabia

Iran first to start NPP operations since Romania in '96

ROLE OF ASIA: OPERATING AND PLANNED REACTORS

NATION	No. of Operable Reactors	MWe (Nuclear)	No. Reactors Under Construction	On Order or Planned	Proposed
EAST ASIA TOTAL	95	83,028	38	66	124
Japan	50	44,396	3	10	3
North Korea (DPRK)	0	0	0	0	1
People's Republic of China	16	12,918	29	51	120
South Korea (ROK)	23	20,787	4	5	0
Taiwan	6	4,927	2	0	0
SOUTHEAST ASIA TOTAL	0	0	0	6	17
Indonesia	0	0	0	2	4
Malaysia	0	0	0	0	2
Philippines	1 (Never Completed)	621 (Estimated)	0	0	(600 M We by 2025; 1,800 M We by 2034)
Thailand	0	0	0	0	5
Vietnam	0	0	0	4	6
SOUTH ASIA TOTAL	23	5,110	9	20	41
Bangladesh	0	0	0	2	0
India	20	4,385	7	18	39
Pakistan	3	725	2	0	2
WORLD TOTAL	435	374,108	65	167	317
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*Graph assembled primarily from data found at "World Nuclear Power Reactors & Uranium Requirements," World Nuclear Association, 1 January 2013 [<http://www.world-nuclear.org/info/reactors.html>].

AFTER FUKUSHIMA: JAPAN'S NUCLEAR QUANDARY

Currently only two reactors in operation – Units 3 and 4 at Ohi Nuclear Power Plant in Fukui Prefecture

IAEA recently reclassified 47 reactors from “in operation” to “long term shutdown”

PM Abe


- July 2013 – Nuclear Energy Regulatory Authority lays out new standards
- Within three years – assess future of existing plants
- Within 10 years – transition to a “more stable energy mix”
 - Decrease n-power gradually and to greatest extent possible

AFTER FUKUSHIMA: CHINA

- After Fukushima (in 2011) completed review of safety at both operating reactors and those under construction.
- Massive construction program –more than two dozen reactors-- has continued since Fukushima but new approvals were held up for 1 ½ years
- On 24 October 2012 Chinese premier outlined a modified approach to nuclear power construction at a State Council meeting, signaling that approvals for new plants could recommence.
 - New reactors would only be safer Generation III reactors
 - Plans for inland plants would be put on hold until 2015.
 - The nuclear capacity target for 2020 is now 58 GWe.

A RENAISSANCE DEFERRED?: IT'S NOT JUST SAFETY

Other factors put a further damper

- General economic consideration of nuclear vs. other sources
 - Economic recession decreased energy demand
 - In U.S., some other ctys increased shale gas, oil supply altered calculus
 - Countries cautious about spent fuel accumulation
 - Proliferation implications, nuclear security
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ECONOMIC CONSIDERATIONS

High capital costs (60-70%) and relatively low operating, maintenance, and fuel costs (30-40%) over NPP lifetime

- Reactor costs: 5-9 billion
- Project completion time: 9-12 years
- Qualified personnel per reactor: 2,400 people
- Hard for many countries to afford
 - Russia just announced Bangladesh's inaugural nuclear plant (with two VVER-1000 reactors) will begin in January 2014, with actual construction slated to start in 2015.
 - Russia said it would provide a \$500 million loan to Bangladesh to finance initial works with perhaps an additional \$1.5 billion in additional funding later and a discounted price
 - Is this a viable business model?

Governments play a key role in nuclear by

- Underwriting private sector risks, subsidizing costs
- Incentivizing nuclear vis-à-vis other energy sources
- Supervising safety, security, spent fuel management

But, recession shifted spending patterns

- Immediate needs prioritized
- Public and private sector lending cautious
- Other energy sources more attractive

PROLIFERATION THREATS

More countries with nuclear knowledge & technology

- = More potential proliferation states
- = More interest in neighboring states

Spread to new or more dangerous regions

- Of facilities and E&R technology

Nuclear security problems in nearly all states

- Terrorist access



US NUCLEAR COOPERATION AGTS

Waiting for presidential decision on issue of review of “Gold Standard” vs “Case by Case”

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ROK-March 2014

- ROK wants advanced consent to enrichment and reprocessing (pyroprocessing) of U.S. origin fuel
- U.S. opposed

Taiwan– June 2014

- May Embrace “Gold Standard”
- U.S. has unique leverage

Vietnam

- Still negotiating
- Vietnam resisting gold standard
- Side Letters

Other agreements

- **China—renewal 2015**– not gold standard (NWS) but other issues?
- **Japan—Key juncture in 2018**
 - 30-year initial term ends , can be terminated with six months notice
 - Termination unlikely but issue of plutonium stocks could affect it.

SPENT NUCLEAR FUEL ISSUES

Poses political and proliferation challenges

- 1 GWe = 20 tons of spent fuel/year

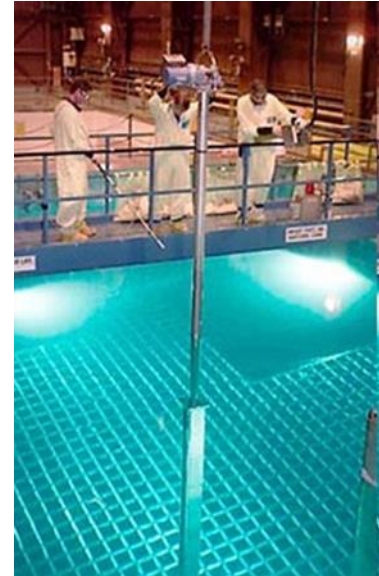
Spent fuel strategies politically difficult

- Countries tend to start nuclear program first, ask spent fuel questions later
 - Since have initial cooling period of 20 year or more of cooling after use
- Defer decisions on Interim storage, reprocessing, and geological repository
 - Sweden, Finland only ones really dealt with issue
- NIMBY prevents public acceptance of waste solutions
- Do regional solutions make sense in Asia?
 - Especially for countries with smaller nuclear fleets (SE Asia?)
- Russia leveraging willingness to take back used fuel it supplied to sell reactors
 - Bangladesh, Vietnam
- Without solutions or cradle to grave, states may resort to reprocessing as perceived “solution” to waste problem

Reprocessing dangers

“A 1 GW pressurized water reactor nuclear power unit... burns about 1 tonne of fuel per year, producing 250 kg of plutonium—roughly enough to make an implosion bomb every year.”

-Ian Jackson, Royal Society's *International Affairs*



JAPAN AND ROK REPROCESSING CONCERNS

Japan is only NPT NNWS with full fuel-cycle facilities

Despite shift in Japanese nuclear energy use, still plans to open massive Rokkasho reprocessing plant in October

- No facility yet to produce MOX fuel; No operating reactors using MOX
- Already has 9 tons of separated plutonium (enough for many hundreds of nuclear weapons) in Japan plus 35 tons overseas in France and UK
- Exacerbates concerns of neighbors already worried about Japan's virtual nuclear weapon state status
 - Should hold off on Rokkasho at least until future of Japanese nuclear energy is clearer
 - Look for ways to dispose of Pu, such as having UK burn pu there.
 - **When you're trying to get out of a hole, stop digging**

South Korea seems determined to follow poor example of Japan, DPRK

- Pushing for moving ahead with pyroprocessing without clear disposal pathway
 - Timeline for fast reactors comes after pyroprocessing would take place.
 - Needs a fuller discussion of a comprehensive spent fuel management approach
 - Including interim storage and disposal of spent fuel or high-level waste

PLUTONIUM: A NUCLEAR SECURITY CONCERN

“The smallest amount of plutonium –about the size of an apple- could kill hundreds of thousands and spark a global crisis. We simply can’t go on accumulating huge amounts of the very material, like separated plutonium, that we’re trying to keep from terrorists.”

– President Obama, Hankuk University, March 2012



OTHER NUCLEAR SECURITY CONCERNS

Sabotage is main concern at nuclear power plants

- Fukushima accident could offer roadmap
 - Take out both normal and emergency cooling

Dirty bomb threats—radiological security needs to be tightened

Dangers from theft of materials at fuel cycle facilities

- Enrichment, Reprocessing, Fuel fabrication facilities



THE BIG PICTURE

Future of the renaissance in Asia will be determined by

- Choices of developing countries w/ energy demand
 - China, India
- Lifetime of NPPs in more developed countries
 - –extensions to 60—even 80 years?
- Japan's choice on nuclear
- Price/availability of alternative energy sources

Challenges remain

- ENR Policy
- Spent Fuel Management
- Safety and Security