International Perspective on the Future of Nuclear Power

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“Peaceful power from atomic energy is no dream of the future. That capability, already proved, is here – now – today.”

President Dwight D. Eisenhower, December 8, 1953, to the 470th Plenary Meeting of the United Nations General Assembly
Existing Nuclear Commercial Power Reactors (13.8% World Wide / 21.4% OECD)

Number of reactors

- 10+
- 1-9

Prior to Fukushima accident

~ Source: IAEA information & news reports
Drivers that Influenced the First Wave of Nuclear Power Deployment

**Encouraging drivers**
- Post World War II: Re-emerging economies required increased energy
- 1970s - Oil Crisis
- Strong Government Backing

**Neutral drivers**
- Acid Rain
- Air Pollution

**Discouraging drivers**
- High Interest Rates
- Fear of Radiation
- Fear of Nuclear Weapons
- Three Mile Island Accident
- Chernobyl Accident
- Waste Management Impasse
Today, Worldwide Interest in Nuclear Power is Strong

- **Energy security**
  - Nuclear shelters countries from importing costly fossil fuels
  - Replacement of retiring nuclear or coal power plants

- **Economic incentives**
  - Nations rich in fossil fuels would prefer to export those fuels and use nuclear for domestic electricity production

- **Environmental protection**
  - Replacing coal with nuclear can alleviate air pollution problems
  - Dry condenser cooling possible with SMRs when water usage is restricted

- **Climate change concerns**
  - Nuclear is the “Emission-free” base load generation technology
CO₂ Emissions and GDP per Capita (1980 – 2005)

Source: DOE EIA database (2008)

Global Nuclear Construction Plans

- 443 nuclear reactors operating in 30 countries (372 GWe capacity)
- 66 reactors currently under construction in 15 countries (23 in China)
- 164 reactors planned in 27 countries over next 8-10 years
- 317 reactors proposed in 37 countries over next 15 years

~ Source: IAEA information & news reports
China is Driving the Nuclear Renaissance

- Most of China's electricity is produced from fossil fuels
  - 2014 data shows 80% coal, 2% oil, 1% gas, 15% hydropower & 2% nuclear

- China has 26 nuclear power reactors in operation, 23 under construction, and more about to start construction

- Additional reactors are planned to increase nuclear capacity
  - Goal is for 58 GWe by 2020, 150 GWe by 2030, and much more by 2050

- China is largely self-sufficient in reactor design and construction, and other aspects of the fuel cycle, but is making full use of western technology to adapt and improve

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Gen III+ designs are a major evolutionary step in large reactor technology

First new reactors being built in U.S. in 30 years

Nuclear construction
- Watts Bar 2015
- Vogtle late 2017
- V.C. Summer 2018 - 2020

Challenges of nuclear deployment
- High capital cost
- Lower electricity demand
- Low natural gas prices
- Post – Fukushima safety concerns
- Waste Management
SMRs can be Game Changers

“Small Modular Reactors represent a new generation of safe, reliable, low-carbon nuclear energy technology and provide a strong opportunity for America to lead this emerging global industry.”

“We are committed to fostering the safe and secure contribution of nuclear power to the global energy mix.”

~ IAEA International Conference on Nuclear Security – July 1, 2013
SMR Technologies are of Great Interest

**Safety benefits**
- Passive decay heat removal by natural circulation
- Simplified design eliminates/mitigates several postulated accidents
- Below grade reactor sites
- Potential for reduction in Emergency Planning Zone

**Economic benefits**
- Reduced financial risk
- Flexibility to add units
- Right size for replacement of old coal and other plants
- Frees up hydrocarbons for export or reduce need for fuel imports
- Job and skill creation

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mPower and NuScale have been selected for the Department of Energy $452M SMR Licensing Technical Support Program
SMRs are being Developed Globally

Russia
- KLT-40S is a 35 MWe barge mounted PWR - Available for commercial deployment
- Other SMR designs: VBER-150/300, VK-300, ABV & SVBR-100 (lead-bismuth variant)

Korea
- SMART is a 90-100 MWe PWR
  - Plan to begin operation of a demonstration plant in 2017
  - Could be used for electricity and/or non-electric applications such as desalination

China
- ACP100 is a 100 MWe PWR
  - Plan to begin construction of a 2 module plant in 2015
  - Could be used for electricity, heat or desalination
- HTR-PM is a High Temperature Gas-Cooled Reactor
  - First nuclear concrete poured December 2012

Argentina
- CAREM-25 is a 25 MWe PWR
  - Plan to complete construction of a prototype in 2017
  - Could be used for electricity, desalination or as a research reactor
  - Full scale 200 MWe CAREM reactor to follow in early 2020’s
Generation IV Reactor Concepts

Sodium Fast Reactor

Lead Fast Reactor

Very High Temperature Reactor

Gas Cooled Fast Reactor

Supercritical Water Cooled Reactor

Molten Salt Cooled Reactor
Gen IV Systems Moving to Early Phase Demonstration

- **Very High Temperature Gas Reactor**
  - Chinese HTR-PM

- **Sodium Fast Reactor**
  - Operation of Chinese Experimental Fast Reactor
  - Start-up of BN-800 in Russia
  - Active design efforts in China, Korea, Japan, India, France, Russia, and U.S.

- **Lead Fast Reactor**
  - BREST and SVBR-100 in Russia

- **Molten Salt Cooled Reactor**
  - Demonstration reactor planned in China
Summary

Nuclear Energy

- **Strong international interest**
  - Energy Security
  - Climate & Environment concerns
  - Economic incentives

- **Current construction**
  - China is leading the nuclear renaissance
  - USA is making good progress in new builds

- **SMRs can be game changers**

- **Early Generation IV demonstration reactors are likely in the next decade**

"Investing in clean energy isn’t a decision that limits our economic potential; it’s an opportunity to lead the global clean technology markets that are forming right now."

~ Secretary Moniz at National Press Club, February 1, 2014