



US Energy System and Innovation Needs

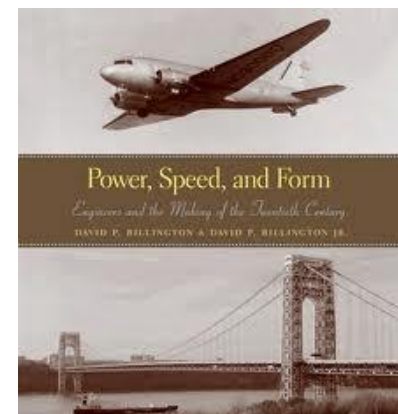
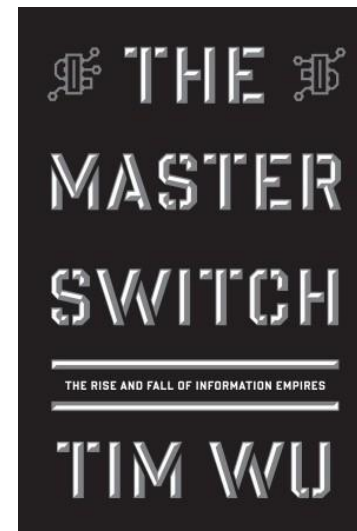
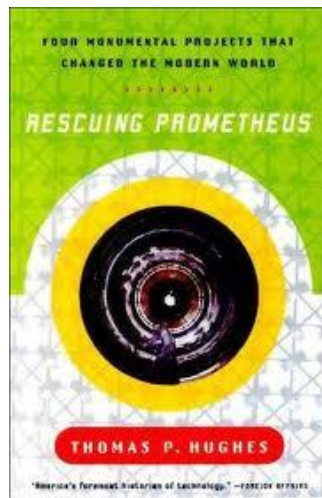
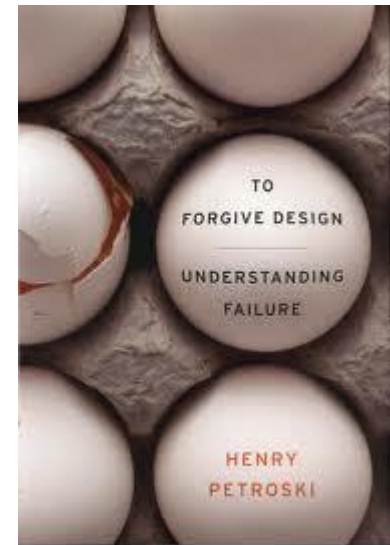
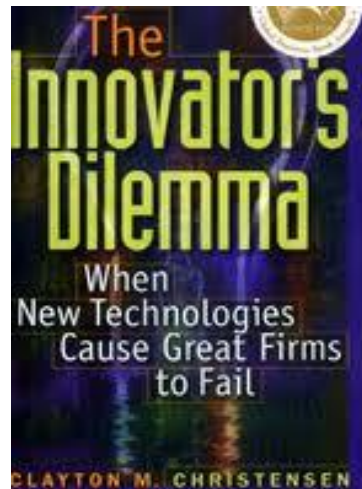
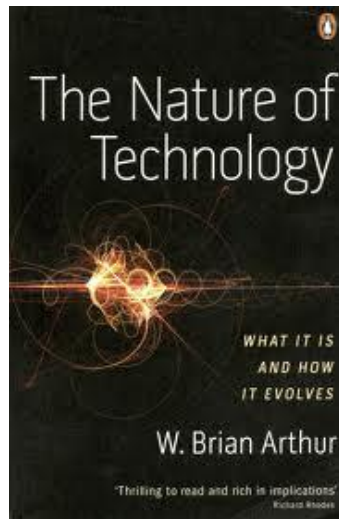
June 6, 2012

Sputnik, Climate and Energy: Are Small Modular Nuclear Reactors a “Game Changing” Innovation?



Victor H. Reis
Senior Advisor
U.S. Department of Energy

A few recently (related) read (or re-read) books





Secretary Chu

Is the Energy Race our new "Sputnik" Moment?



National Press Club
Washington, D.C.
29 November, 2010



President Obama State of the Union January 25, 2011



Newton

Lavoisier

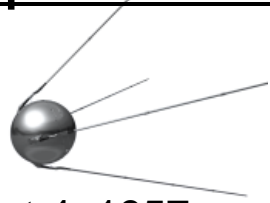
“Half a century ago, when the Soviets beat us into space with the launch of a satellite called Sputnik, we had no idea how we would beat them to the moon.

The science wasn't even there yet. NASA didn't exist. But after investing in better research and education, we didn't just surpass the Soviets; we unleashed a wave of innovation that created new industries and millions of new jobs. This is our generation's Sputnik moment.”

“Some folks want wind and solar. Others want nuclear, clean coal and natural gas. To meet this goal, we will need them all -- and I urge Democrats and Republicans to work together to make it happen.”

“We're telling America's scientists and engineers that if they assemble teams of the best minds in their fields, and focus on the hardest problems in clean energy, we'll fund the Apollo Projects of our time.”

Sputnik & Apollo: A Strategic Planning Perspective



Oct 4, 1957

President's
Vision



Юрий Гагарин
April 12, 1961

Bay of Pigs Invasion
April 17, 1961



A Cold War
Strategy



July 20 1969

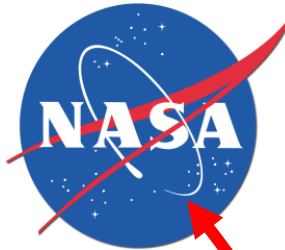
Timely
Goal



July 29, 1958



Feb 1958



Focus &
Align



May 25, 1961

First, I believe that this nation should commit itself to achieving the goal, before this decade is out, of landing a man on the moon and returning him safely to the earth.

Civil Nuclear Power Leadership: Small Modular Reactors

“We must harness the power of nuclear energy on behalf of our efforts to combat climate change, and to advance peace opportunity for all people.”

President's Vision



President Obama, Prague, April 2009



Miller Lyons
June 2010



Develop a story on how SMR “change game.”

National Energy & Nuclear Goals

- Climate/Clean Energy
- Energy Security
- Competiveness
- National Security
 - (Non- Proliferation)

Strategy

Align U.S. Electricity Sector Goals to National Goals

- Consumers
- Utilities
 - Generators
- Regulators
 - NRC
- Grid
- Industrial Base

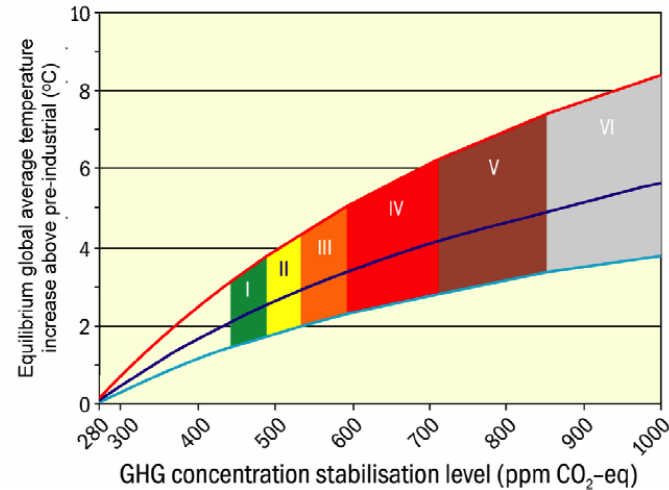
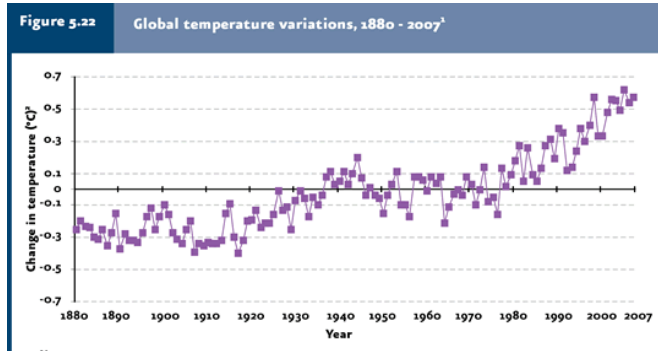
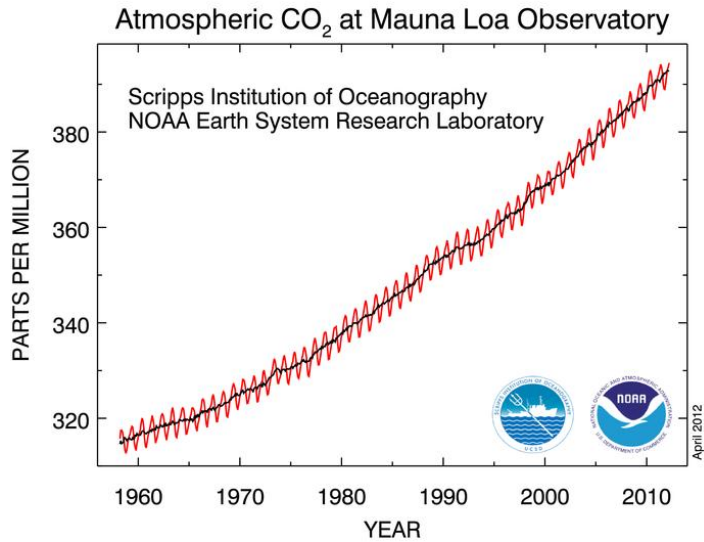
Timely Goal

“ **By 2035, 80 percent** of America’s electricity will come from clean energy sources”

2011
State of the Union



The Challenge of Climate Change

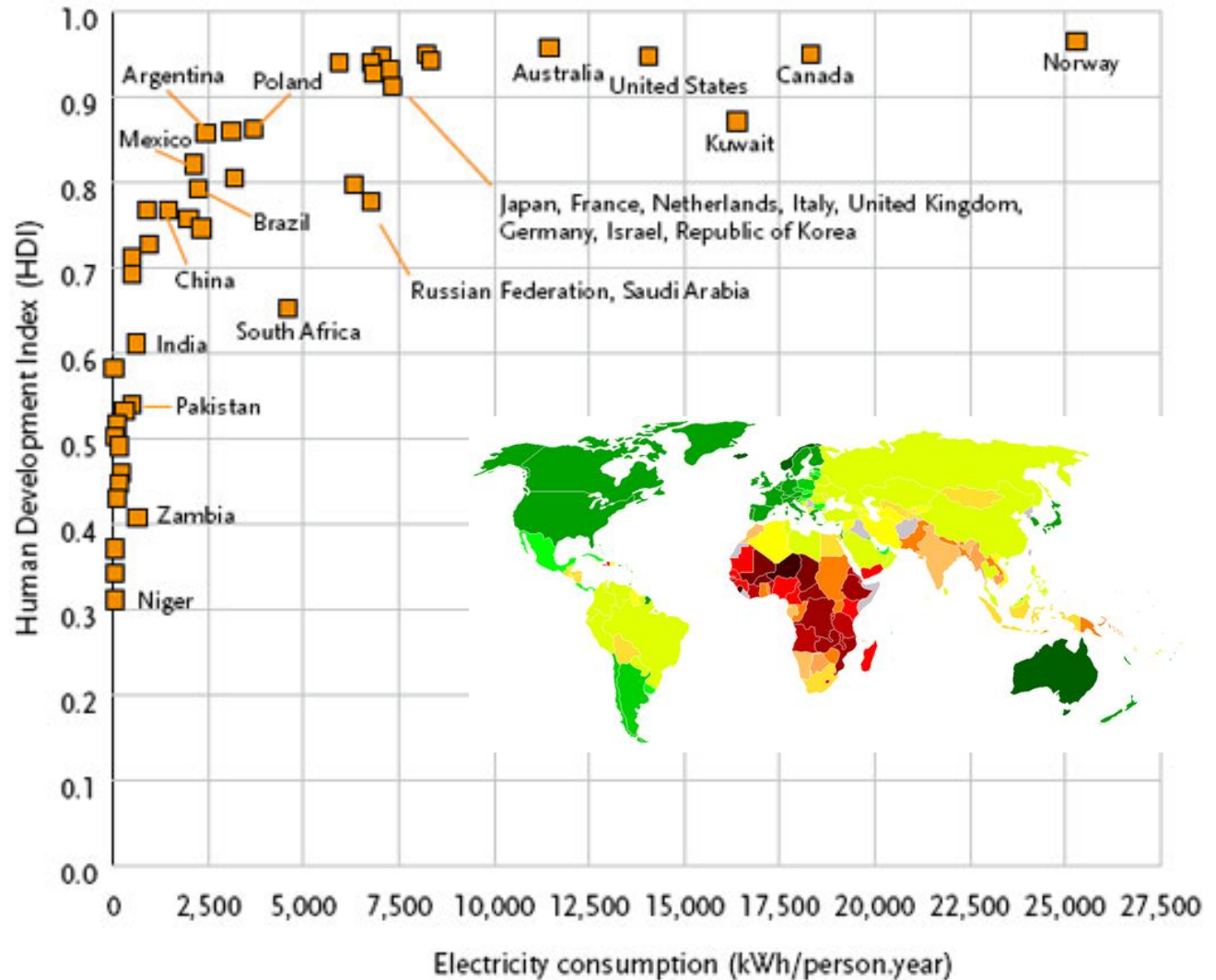


“And unless we free ourselves from a dependence on these fossil fuels and chart a new course on energy in this country, we are condemning future generations to global catastrophe.”
Senator Obama April 2006

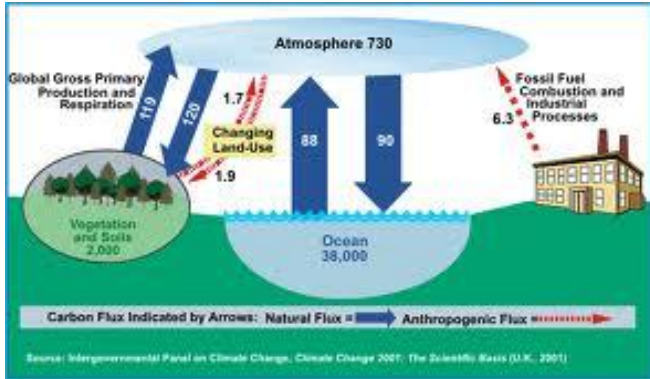


Energy (Electricity) is Fundamental to Development

The **Human Development Index (HDI)** is an index combining normalized measures of life expectancy, literacy, education and GDP per capita



A (very simple) look at Climate and CO₂




Net absorption of CO₂ ~ 14 Gt/year
 Total Population ~ 7 Billion



Net earth equilibrium CO₂ footprint ~ 2 Tons CO₂ /person/year

Electricity CO₂ footprint:

= Per capita electricity consumption x (1- clean energy fraction)x 1 kg/kWhr(coal)

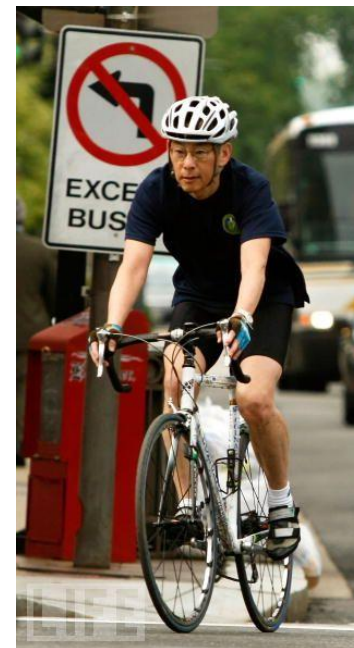
Country	Per capita Electricity kWhr/yr/p	Clean Energy (%)	Tons/year/p 
U.S.	12,500	42	7
China	2500	20	2
France	6900	93	0.5

Secretary Chu on Small Modular Reactors

•“one of the most promising areas is small modular reactors (SMRs). If we can **develop this technology in the U.S. and build these reactors with American workers, we will have a key competitive edge.** Small modular reactors would be less than one-third the size of current plants. They have compact designs and could be made in factories and transported to sites by truck or rail. SMRs would be ready to "plug and play" upon arrival.

•If commercially successful, SMRs would significantly expand the options for nuclear power and its applications. Their small size makes them suitable to small electric grids so they are a good option for locations that cannot accommodate large-scale plants. **The modular construction process would make them more affordable by reducing capital costs and construction times.**

•Their size would also **increase flexibility for** utilities since they could add units as demand changes, or use them for **on-site replacement of aging fossil fuel plants.** Some of the designs for SMRs use little or no water for cooling, which would reduce their environmental impact.”



*Steven Chu,
Wall Street Journal,
March 23, 2010*

- U.S. Competitiveness
- Affordability
- Flexibility
- Market
 - Retiring Coal Plants

Clean Energy

Recent (Strategic) Events

Sputnik ?
Moment ?

Climate?



2010 Election



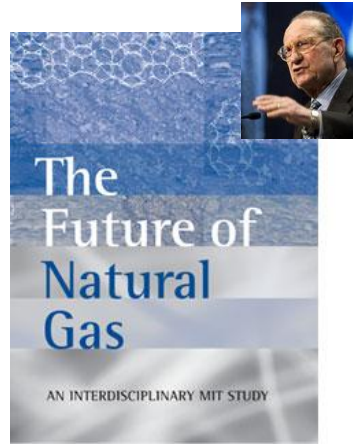
President Obama
November 3, 2010

“There's been discussion about how we can restart our nuclear industry as a means of reducing our dependence on foreign oil and reducing greenhouse gases. Is that an area where we can move forward?”



NATURAL GAS SUBCOMMITTEE OF THE
SECRETARY OF ENERGY ADVISORY BOARD
Safety of Shale Gas Development

Competition?



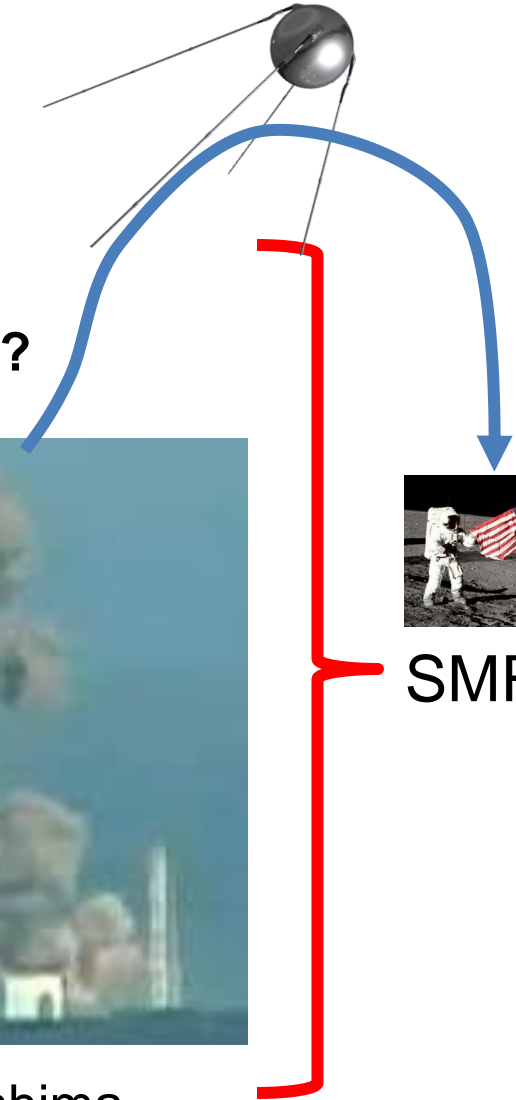
SAFETY?



Fukushima
March 11, 2011



SMR?



Meeting Administration's 2035 80% Clean Energy Standard

Assume: • Weighted Emission Standards:

Coal= 1, Gas = 0.5, CCS =0.1

- No New Coal Builds
- All Coal > 50 years phased out
- Renewable and CCS goals met

<u>Source</u>	Elect (TWhr)	CO ₂ (Gton)	Elect (TWhr)	CO ₂ (Gton)	Elect (TWhr)	CO ₂ (Gton)	
Coal	1800	1.85	2100	2.1	300	0.3	Replace Phased out Coal
Coal (CCS)	0	0	0	0	200	0.02	
Natural Gas	785	0.4	1030	0.5	1200	0.6	
Nuclear (Large)	800	0	870	0	800	0	
Nuclear (SMR)	0	0	0	0	1200	0	A lot ~150 GW Fast ~ 12 GW/yr
Hydro	250	0	250	0	250	0	LWR, LEU
Renewable	130	0	320	0	650	0	
Petroleum	40	0.04	0	0	0	0	
TOTAL	3800	2.3	4570	2.6	4600	0.92	

2010 U.S Electricity Consumption and CO₂ Emissions. *EIA*, **CE=42%**

EIA Reference Projections 2035
CE=43%

Assumed 2035 electricity production to meet “clean energy” standard, **CE=80%**

 ~ 2.5t/y/p

Align Civil Nuclear Sector with National Goals

“Nuclear is a Business – Not a Religion”

Currently: 104 Reactors 100 GW 800 TWhrs
Last Previous Ground Breaking - 1973



Talk to ANS
November 2011

John Rowe
Exelon

Current U.S. Utilities’ Strategy: A Culture of Prudence

- Maintain (extraordinary) High Performance
- Extend Lifetime of Current Reactors
- Buy New (Gen 3) Reactors when Licensed & Cost Competitive
 - Westinghouse (Toshiba) : 1150 MW
 - GE/Hitachi : 1350 MW, 1600 MW
 - AREVA: 1650 MW
 - Mitsubishi: 1540 MW

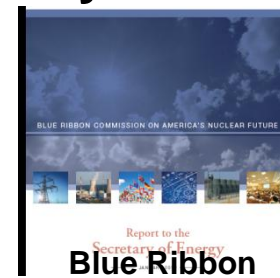
Passive
Safety

U.S. Government: Multiple Agencies – Mixed History

- Spent Fuel - DOE/NRC/EPA
- Safety/Security- NRC
- Environment - EPA
- Proliferation - DOE/NNSA



Yucca Mountain



Report to the
Secretary of Energy
**Blue Ribbon
Commission**

DOE Nuclear Power 2010

- Cost Share Design Certification & License (Completed)
- Loan Guarantees
- R&D on Advanced Concepts

DOE/SMR
Program



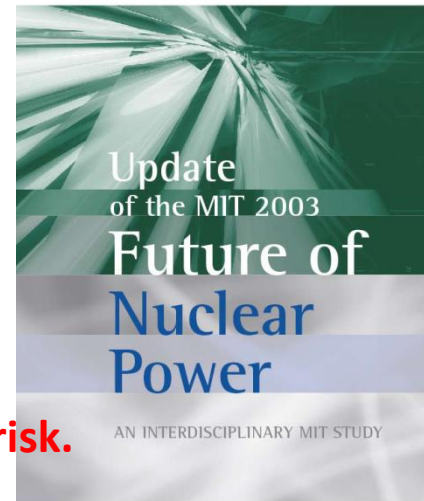
Align with Utilities' Strategy:

Affordable (Consumers), Reliable and Profitable

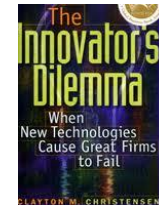
"Nuclear power can be economically competitive under appropriate market conditions"

Large Plant Investment
\$10B, >5yrs ???

SMR lower early utility capital costs (\$1-3B) reduce utility financial risk.



"Levelized Cost of Electricity"
Cost of Carbon



	Overnight Cost	Fuel Cost	Base Case	\$25/Ton CO ₂	= Cost of Capital
\$2007	\$/KW	\$/MBTU	¢ KWhr	¢ KWHR	¢ KWhr
Nuclear	4000	0.67	8.4		6.6
Coal	2300	2.6	6.2	8.3	
Gas	850	4/7/10	4.2/6.5/8.7	5.1/7.4/9.6	

Loan Guarantees for large plant "first movers"

Innovation in Small Modular Nuclear Reactors: LWR Examples



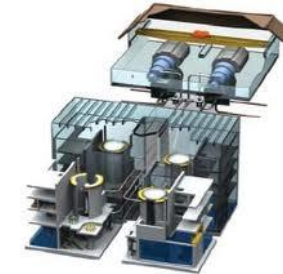
Jose Reyes



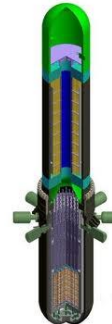
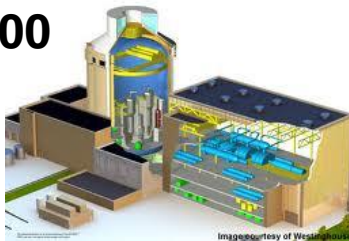
45 MW



180 MW



AP 1000



225 MW

All

- PWR Design
- Commercial LEU Fuel
- U.S. Industrial Base
- Affordable to more utilities

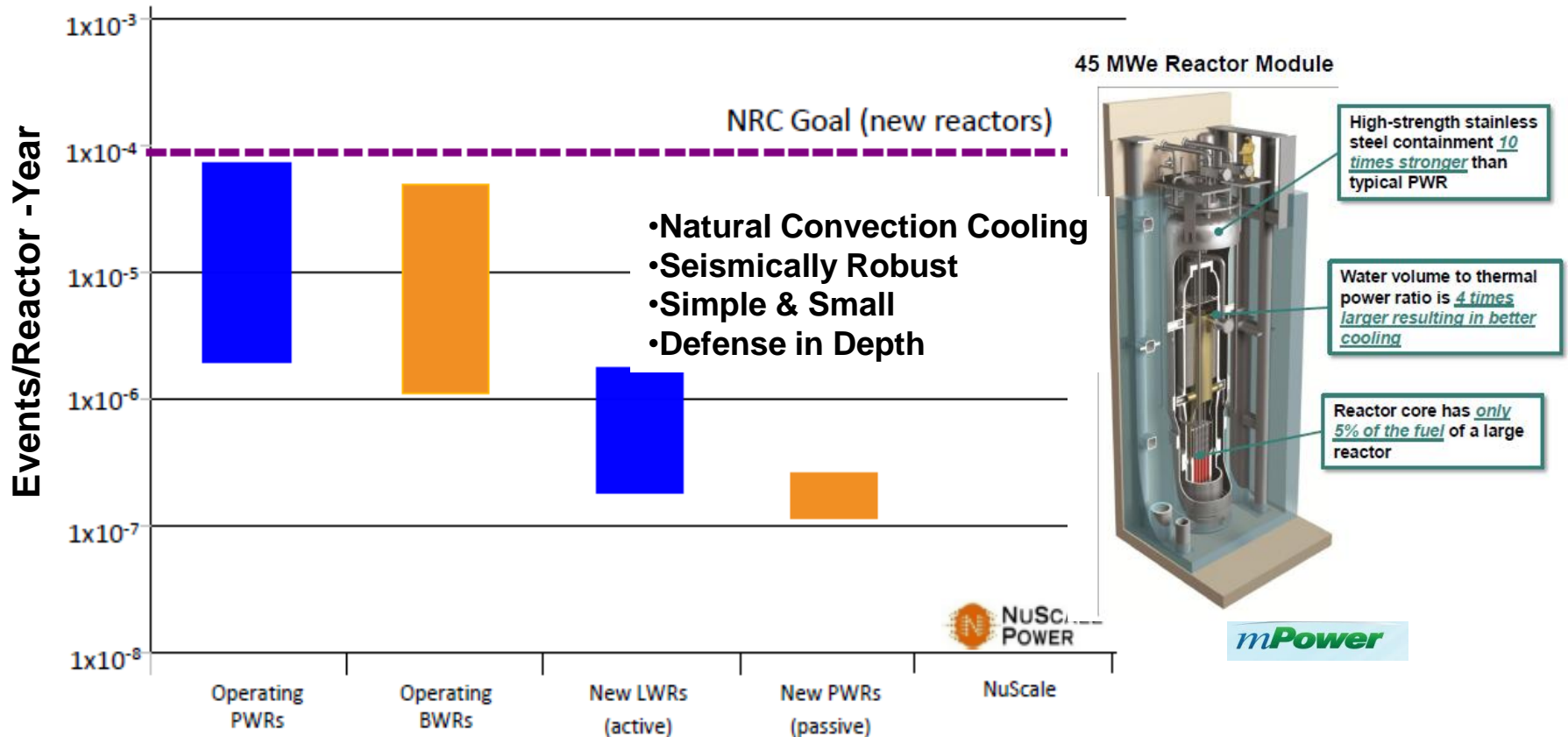


140 MW



Innovative Safety Case for SMR

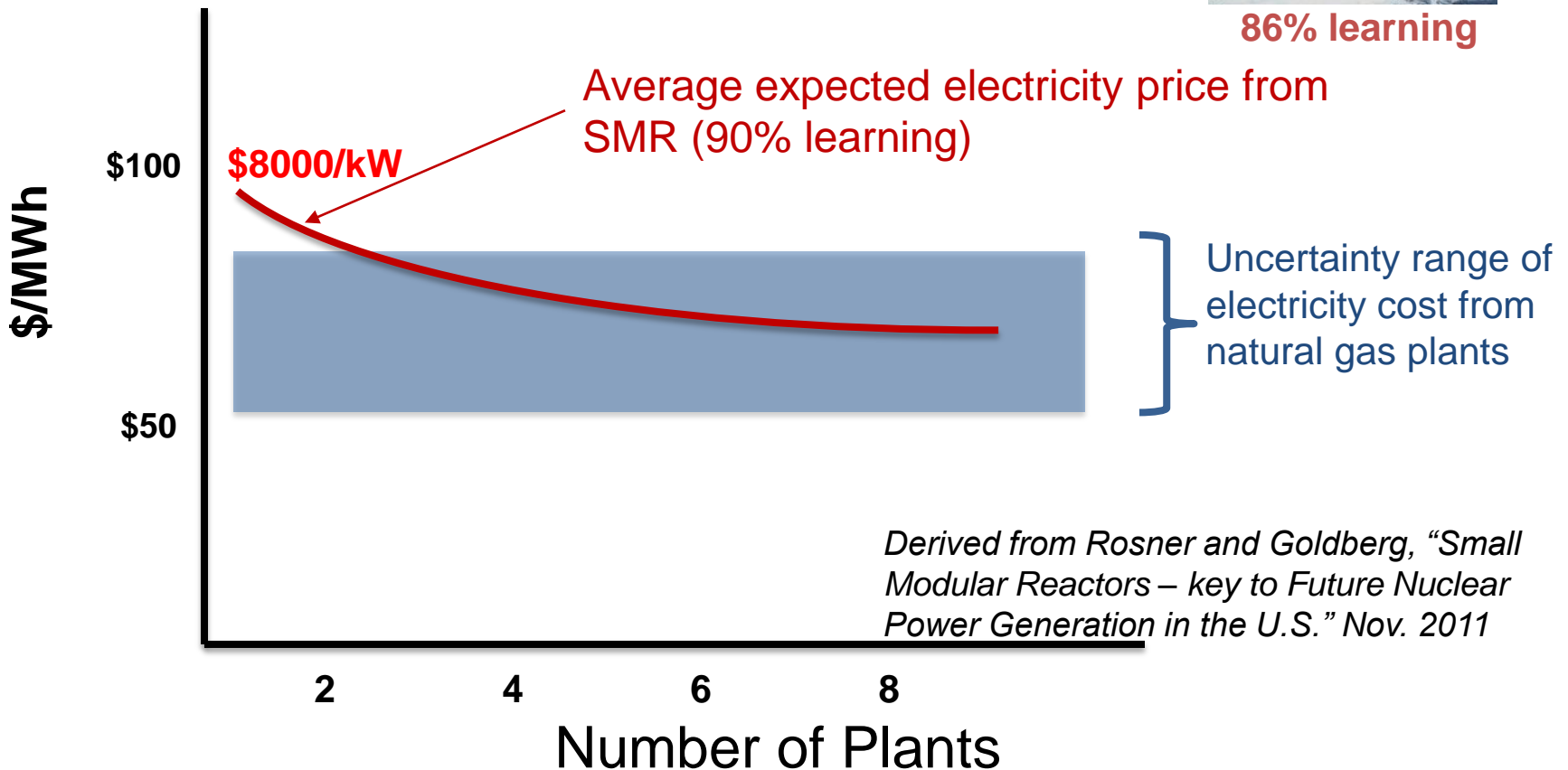
Probabilistic Risk Assessment (PRA) of Core Damage Frequency (CDF)



SMR Could Become Cost Competitive Through (Innovative) Manufacturing Learning



86% learning



Other Nations are “planning” Small Nuclear Reactors

- **Russia**



- **KLT-40S is a 35MWe barge mounted PWR - Available for commercial deployment**
- Other Russian SMR designs include **VBER-150/300**, VK-300, ABV and the SVBR-100

- **Korea**



- **SMART is a 90MWe PWR**
 - Plan to begin operation of a Demonstration plant in 2017
 - Plan to be used for electricity or desalination

- **China**



- **CAP100 /ACP100 is a 100-150MWe PWR**
 - Plan to begin construction of a 2 module plant in 2015
 - Plan to be used for electricity, heat or desalination
- HTR-PM is a High Temperature Gas-Cooled Reactor
 - Rebar in place, waiting on government approval to continue construction

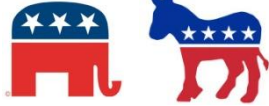
- **Argentina**



- **CAREM-25 is a 27MWe PWR**
 - Plan to complete construction of a prototype in 2016
 - Plan to be used for electricity, desalination or as a research reactor

Obama Administration & SMR

FY 2012 Budget



Small Modular Reactor Licensing Technical Support.

-The conference agreement includes **\$67,000,000** to provide licensing and first-of-a-kind engineering support for small modular reactor designs that can be deployed expeditiously, to be administered as specified in the budget request. The Department is directed to consider applications utilizing any small modular reactor technologies. The conferees expect the program to total **\$452,000,000** over five years.



3/26/2012

Hankuk Univ

“And with rising oil prices and a warming climate, nuclear energy will only become more important. That’s why, in the United States, we’ve restarted our nuclear industry as part of a comprehensive strategy to develop every energy source. We supported the first new nuclear power plant in three decades. **We’re investing in innovative technologies so we can build the next generation of safe, clean nuclear power plants.**”



“We can build the next-generation nuclear reactors that are **smaller** and safer, cleaner and cheaper.”

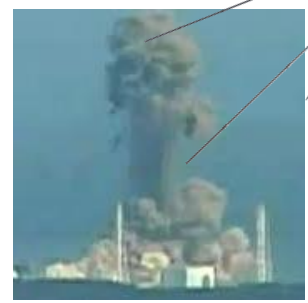
Ohio State Univ., March 22, 2012

Small Modular Reactors for Civil Nuclear Power Leadership

When we enhance nuclear security, we're in a stronger position to harness safe, clean nuclear energy. When we develop new, safer approaches to nuclear energy, we reduce the risk of nuclear terrorism and proliferation.



3/26/2012
Hankuk Univ



Fukushima

“ By 2035, 80 percent of America's electricity will come from clean energy sources”

President's Vision

National Energy & Nuclear Goals

- Climate/Clean Energy
- National Security
 - Non-proliferation
- Energy Security
- Competiveness

Strategy

Align U.S. Electricity Sector Goals to National Goals

- License 2 or more ultra-safe SMR designs
- Multiple Factory Manufacture
 - U.S. Navy Industrial Base
- Compete with Natural Gas to replace coal
 - Financial Incentives (?)
 - Government first user
- Global Market Leader

Timely Goal



2011
State of the Union