# The Role of Nuclear Energy in Clean Reliable Electricity

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Tulane Engineering Forum

*Panel on Energy Independence*

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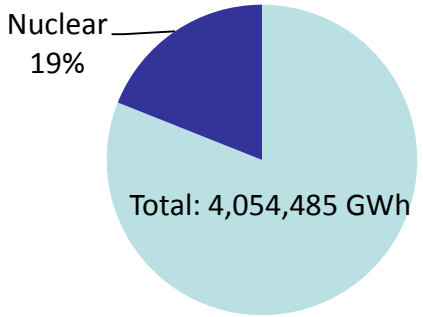
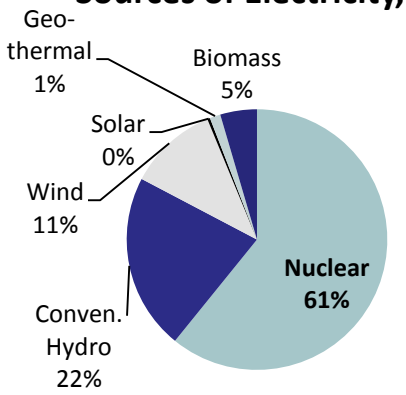
# Nuclear Energy
## *A Vital Component of U.S. Energy Supply*

- Nuclear power is a clean, reliable base load energy source
  - Provides 19% of U.S. electricity generation mix
  - Provides 61% of U.S. emission-free electricity
  - Avoids about 700 $MMTCO_2$ each year
  - Helps reduces overall NOx and SOx levels
- U.S. electricity demand projected to increase ~28% by 2040 from 2011 levels
- 100 GWe nuclear capacity - 99 operating plants
  - Fleet maintaining close to 90% average capacity factors
  - Most expected to apply for license renewal for 60 years of operation.

**Electricity Production, 2012**




**Net Non-Carbon Emitting Sources of Electricity, 2012**




*Source: Energy Information Administration*

# Important Attributes of Nuclear Power

- **Important Benefits of Nuclear Power**
  - 24/7 reliability in all weather conditions
    - Typically 18 months of fuel on site
  - Provides diversity of energy sources
  - Safe with an appropriate regulatory system
  - Long term, predictable costs
  - Provides clean, carbon-free energy
  - Provides an economic engine for high-tech jobs
  - Provides educational engine for advanced training
  - Well-matched to hybrid energy systems



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# U.S. electricity market is severely flawed

De-regulation has precluded long term considerations

- Focus is on short-term prices and profits

Market prices are low

- Low cost natural gas
- Flat demand in many parts of nation

Wind and solar are subsidized and frequently mandated.

- Electricity prices driven below zero at some times.

**Unique attributes of nuclear energy are not valued.**
**Six Nuclear Plants closed in recent years.**
**Many more Nuclear Plants are threatened with closure.**



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# Dr. Rush Holt - December 7, 2016 CEO of AAAS and Executive Publisher of *Science*

- "The preponderance of scientific evidence and our understanding of climate change is rigorous. Human activities are largely responsible, impacts are already underway, and the sooner we act, the lower the cost and risk will be. This has been well-established by many scientists working from many points of view and accepted by virtually every leading scientific organization in the world."
- Credible scientific investigation considers uncertainties, but "it is dangerous and counter to scientific methodology to completely deny the weight of evidence when it is revealed. "If a person jumped off a building because he said gravitation is only a theory, one would say he is delusional. So too, any policy maker who would base national policy on denial of climate science because there is 'debate' would be called dangerously irresponsible."

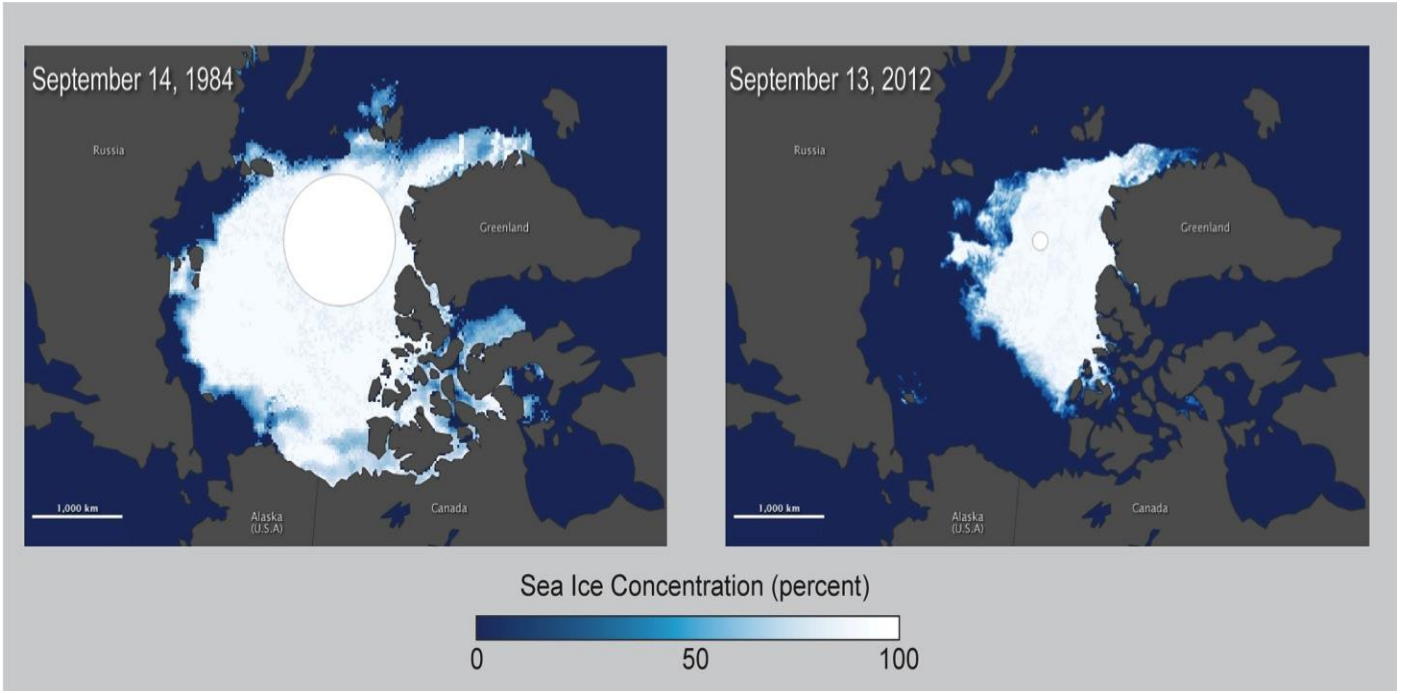
# Arctic Sea Ice Declined Dramatically

(pictures from Somerville, ANS Nov 2015)
and

**Washington Post, March 22, 2017:**

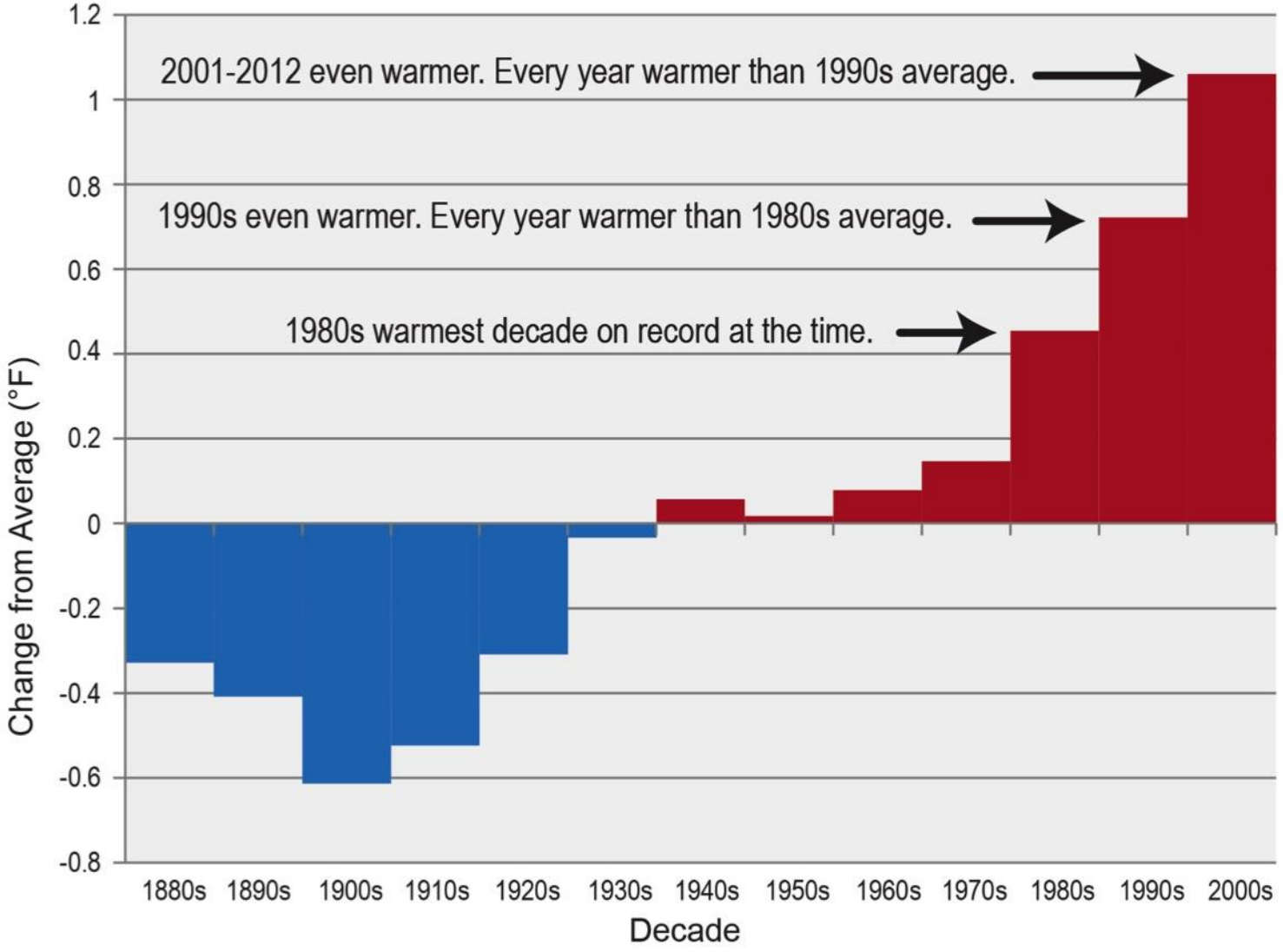
***The Arctic just set a Grim New Record for Low Levels of Sea Ice***

**"Smallest winter maximum extent ever observed in records dating to 1979."**



# Each New Decade is the Warmest

(Somerville, ANS Nov 2015)



# Pathways to a strong future for Nuclear Power

- Passive Safety
- Small Modular Reactors (SMR)
- Integration of renewable and nuclear power
- National path forward on nuclear waste
- Fukushima and nuclear safety
- Advanced reactors
- Strong university programs

# PASSIVE SAFETY

- ACTIVE SAFETY
  - All LWRS in the world today utilize active safety
  - Reactors require prompt operator actions in an upset condition
    - Correct actions typically needed in less than an hour
    - Frequent Drills with NRC in U.S. to assure operator readiness to respond
    - Fukushima was seriously compromised by failure to exercise prompt actions.

- PASSIVE SAFETY
  - Designed to avoid the need for prompt operator actions
  - Typically large quantities of stored coolant moved by gravity or convection
  - Some advanced reactors have inherent safety, no meltdown possible.
  - Passive safety can extend time for actions from hours to indefinite
  - Westinghouse AP1000 was first passively safe reactor certified
    - No operator actions needed for 3 days.

# Why are SMR technologies of U.S. interest?

**Working definition of SMRs:** reactor units with a nominal output of 300 MWe or less and ability to have large components or modules fabricated remotely and transported to the site for assembly of components and operation.

Safety Benefits

- Passive decay heat removal by natural circulation
- Smaller source term inventory
- Simplified design eliminates/mitigates several postulated accidents
- Below grade reactor siting
- Potential for reduction in Emergency Planning Zone

Economic Benefits

- Reduced financial risk
- Flexibility to add units
- Right size for replacement of old coal plants
- Use domestic forgings and manufacturing
- Job creation

# U.S. Small Modular Reactor (SMR) Licensing Technical Support Program

- In 2012, DOE initiated a 6-year/$452M program to provide financial assistance for design engineering, testing, certification and licensing of promising SMR technologies with high likelihood of being deployed at domestic sites in the mid-2020's.

- Commercial SMR development is being accelerated through public/private arrangements with 50% cost share provided by U.S. industry partner.

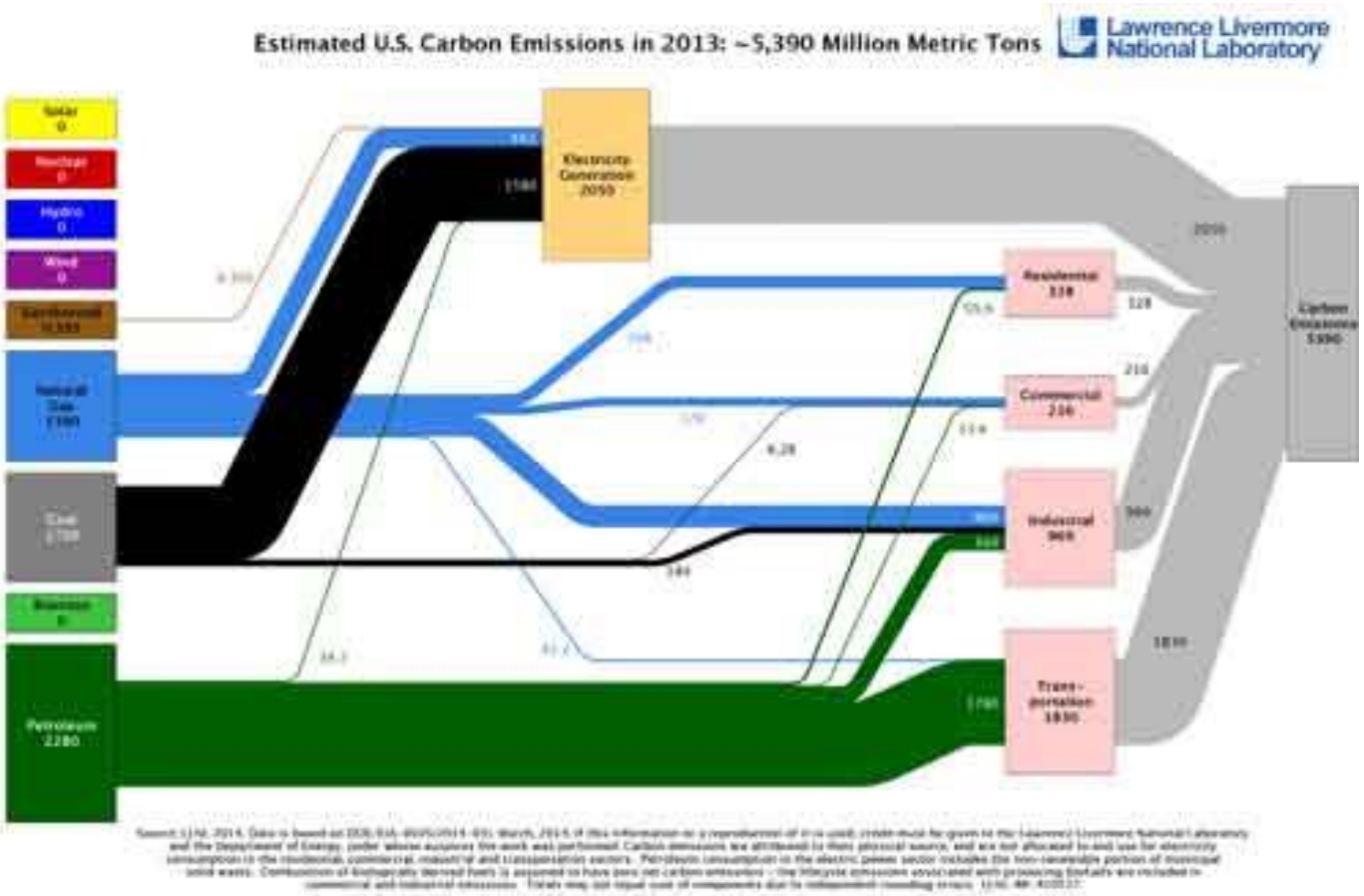
- Site permitting and licensing activities are in progress:
  - NuScale filed Design Certification application in January.
    - Docketed March 15, 2017
  - TVA filed Early Site Permit application for Clinch River – May 2016
  - NuScale partnering with UAMPS to explore siting SMR. Site Use permit with Idaho National Laboratory signed February 2016

# Integration of Renewable and Nuclear Power Leaders: NREL, INL, and MIT

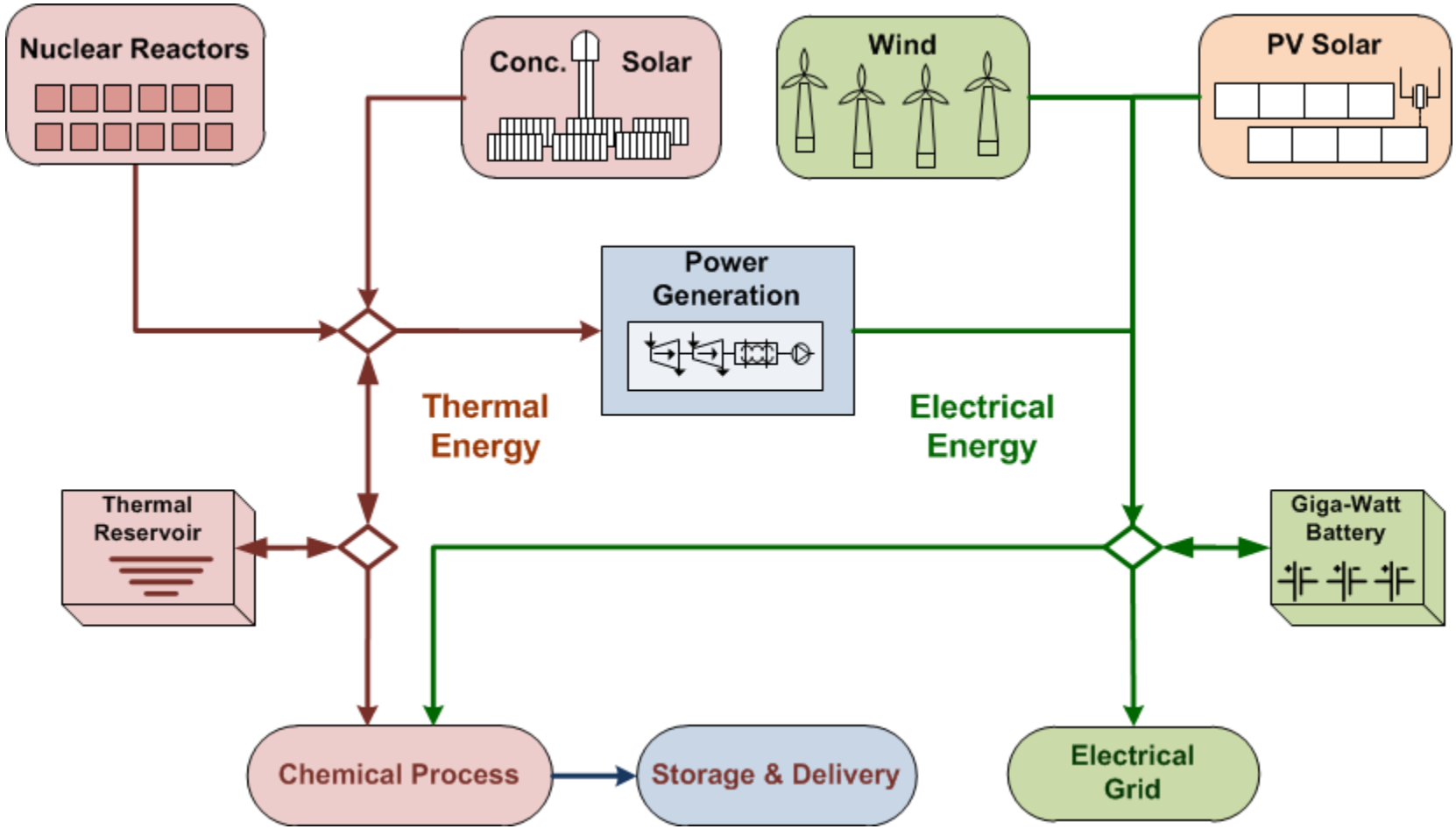
- Hybrid Energy Systems
  - Focus on recognition that only Renewables, Nuclear and Hydro are clean energy sources available today.
  - Hydro can not expand significantly in the U.S.
  - Emphasize integration of assets on a grid level
  - Recognize that a national grid must exhibit supply diversity and high levels of reliability
  - International workshop held at NREL on June 9-10, 2016

- Key Attribute
  - Designed to optimize contribution of both nuclear and renewable assets
  - Cleanly produce all needed electricity PLUS another asset in the industrial or transportation sector

# CARBON EMISSIONS IN THE U.S.

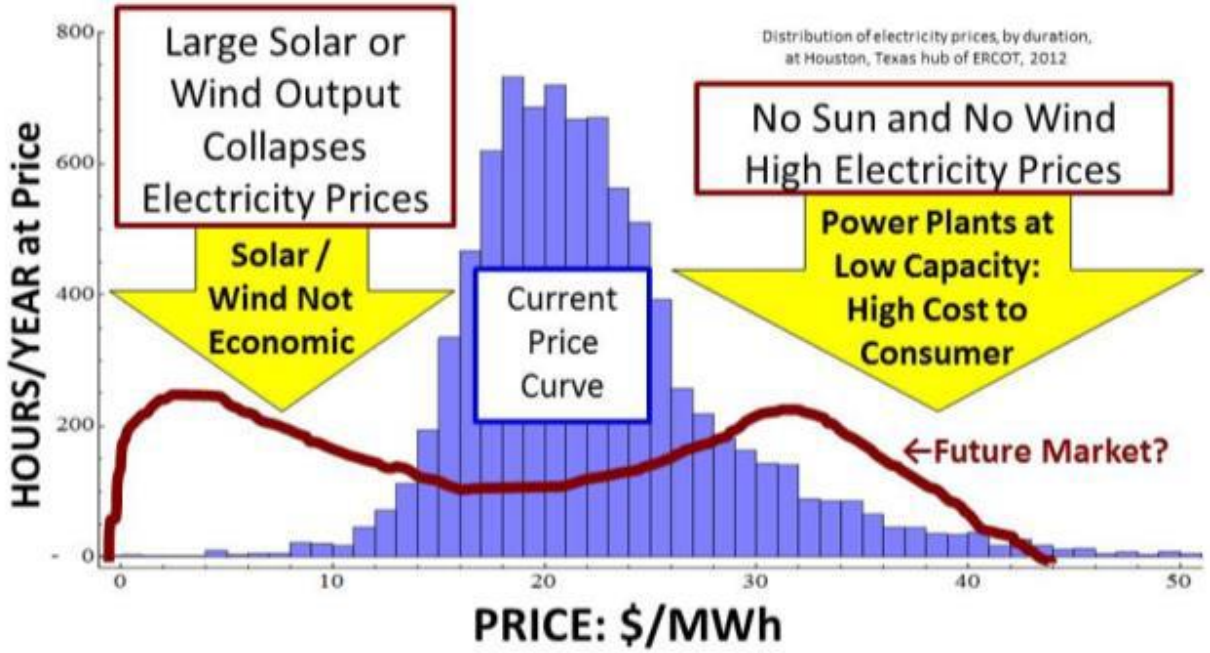


# Schematic of a Hybrid System



# Price Distribution in Current/Future Scenarios

(from Charles Forsberg, MIT, at ICAPP, 2016)

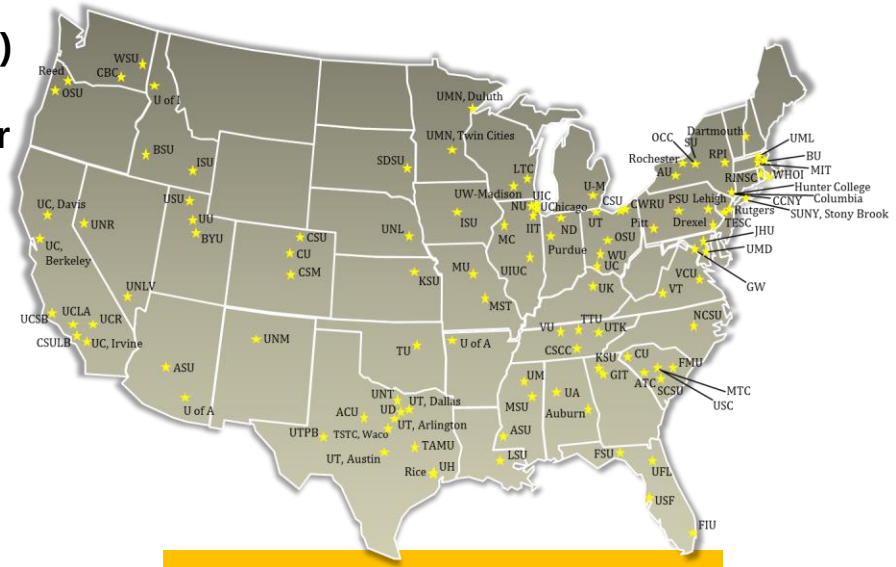


U.S. DEPARTMENT OF ENERGY

Nuclear Energy

# Nuclear Energy University Program / Integrated University Program

- **The Nuclear Energy University Program (NEUP) and the Integrated University Program (IUP) have a well established competitive process for awarding R&D, infrastructure and scholarships/fellowships.**
  - The Office of Science and Technology Innovation will continue implementing this competitive process and will expand to incorporate it into all competitive research
  - FY16 IUP awards: 57 scholarships and 33 fellowships, totaling $5M
  - FY16 R&D awards: 48 awards, totaling $35M
  - FY16 IRP awards: 4 awards, totaling $15M
  - FY16 Infrastructure awards: 17 awards, totaling $4.9M




Since FY09, NEUP and IUP have awarded $463.8M to 113 schools in 40 States and the District of Columbia.

- **The NE R&D Programs are the cognizant technical managers of these competitive R&D awards and therefore play an integral role in the success of each project.**
  - Universities, national laboratories, industry, and international research partners are strongly encouraged to actively engage and collaborate with the NE R&D programs.

# What does a weak nuclear energy industry mean for the United States?

- Loss of additional fuel diversity and ultra high reliability for our grid
- Potential loss of the nation's largest source of clean energy
- Loss of export markets –100s of plants will be built
- Loss of high tech jobs both in exports and operating plants
- Loss of control of the global nonproliferation and safety agendas
- Potential weakening of the world's best university system for nuclear engineering.

# Actions to Regain Global Leadership in Nuclear Power for the United States

- Launch a strong domestic building program
  - Regain strong, experienced, domestic vendors.
  - Regain a strong domestic supply chain.
  - Treat nuclear energy on a par with other clean energy sources.
  - Assure functioning electricity markets that value attributes of Nuclear Power.
  - May require government loans, PTCs, or PPAs initially.

- Regain a functioning ExIm Bank to support U.S. Exports
  - Lack of a quorum of directors limits loans now to $10M.

- Implement a credible domestic waste management program with options for international take back of used fuel.
  - Authorize and fund both interim storage and repository programs.
    - Use a consent-based program to assure state, tribal, local acceptability of new facilities.
  - Russia's BOO (Build, Own, Operate) program is highly attractive to new entrant nuclear energy countries.
    - Russia is today's largest exporter. China is very well positioned. South Korea is doing well.
  - U.S. reactor vendors can not effectively compete without a U.S. used fuel take-back program.

# Backup slides

# U.S. Capacity Factors*

- **2014**
  - **Nuclear** **91.7%**
  - **Hydropower** **37.3**
  - **Wind** **34.0**
  - **Solar PV** **25.9**
  - **Solar thermal** **19.8**
  - **Geothermal 74.0**
- **2015**
  - **Nuclear** **92.2**
  - **Hydropower** **35.9**
  - **Wind** **32.5**
  - **Solar PV** **28.6**
  - **Solar thermal 22.7**
  - **Geothermal** **71.7**

***from U.S. Energy Information Administration**



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# National Path Forward on Nuclear Waste

- Yucca Mountain required by Nuclear Waste Policy Act Amendments of 1987
  - Not chosen through a scientific or consent process
  - Opposed in Nevada and effectively blocked
- Obama Administration recognized need for alternative approaches
  - Blue Ribbon Commission formed
    - Emphasized consent-based processes and need for interim storage.
- Trump Administration budget proposes $120M to restart Yucca Mountain and develop interim storage

# Fukushima and Nuclear Safety

- Regulator and Industry strive to learn from past experiences like TMI and Fukushima

- TMI and 9/11 led to significant changes in U.S. reactor regulation.
  - Resident Inspectors post-TMI.
  - Positive control functions post-TMI
  - Requirement to address Station Blackout after 9/11.
    - Rationale and regulations were shared with Japanese regulator by NRC.

- Fukushima was a product of multiple factors
  - Japanese regulator was not independent of industry.
  - Safety culture in Japan was not adequate
  - At most basic level, Fukushima event was a Station Blackout

- Post Fukushima, NRC further strengthened regulatory requirements in U.S.
  - Station Blackout preparations further strengthened
  - Instrumentation for spent fuel pools required.

# Advanced Reactors

- SMRs and  reactors with non-LW coolants
- Many coolants under study
  - Sodium
  - Molten salt (with solid or dissolved fuel)
  - Lead
  - High pressure helium
- Generation IV International Forum brings international researchers together
- Several companies formed to promote new coolants
- NRC has focused primarily on LWR licensing
- Some designs will offer inherent safety and may enable lower cost construction and operation
- National study ongoing to define the next Test or Demo reactor for the nation.
  - Report was due in April 2016