CHALLENGES:
NUCLEAR POWER TODAY
AND
MEGAWATT SIZE REACTORS

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Challenges and Changes to U.S. Nuclear Fleet

> "Nuclear plants are under increasing economic pressure to close as a result of record low capacity prices…… Losing these plants has long-term implications both to the reliability of the system and on the nation's emission profile."
>
> Federal Energy Regulatory Commissioner Moeller, April 2015

- Current stresses on nuclear plants
  - Flat or even decreasing electricity demand
  - Very low natural gas prices
  - Renewable mandates
  - Renewable production tax credits
- Market failures have led to plant closings.
  - Vermont Yankee shut down December 2014
    - Fifth reactor to shut down recently.
  - Fitzpatrick, Pilgrim, Oyster Creek slated to close
  - Many other plants in difficult financial straits
- Nuclear will be essential in a low carbon future, but will we have the national capabilities when we need them?
- Discussions continue on how to value the benefits of nuclear energy in today's electricity markets.

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 (covered by previous speakers)

+Not discussed in this talk

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
    - Station blackout is particularly challenging event; special precautions in U.S.
    - 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 interest to DOE?

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 partners.
  - NuScale will file their Design Certification Application with the NRC in 2016
  - NuScale has filed 10s of topical reports with the NRC

- Site permitting and licensing activities are in progress:
  - U.S. Government Interagency Agreement with TVA to develop Early Site Permit for Clinch River Site, to be submitted May 2016, action expected 2019
  - Cooperative Agreement with NuScale to explore siting SMR at INL
    - Site Use agreement for INL signed between DOE and UAMPS – Feb 2016.

Key Regulatory Challenges for SMRs

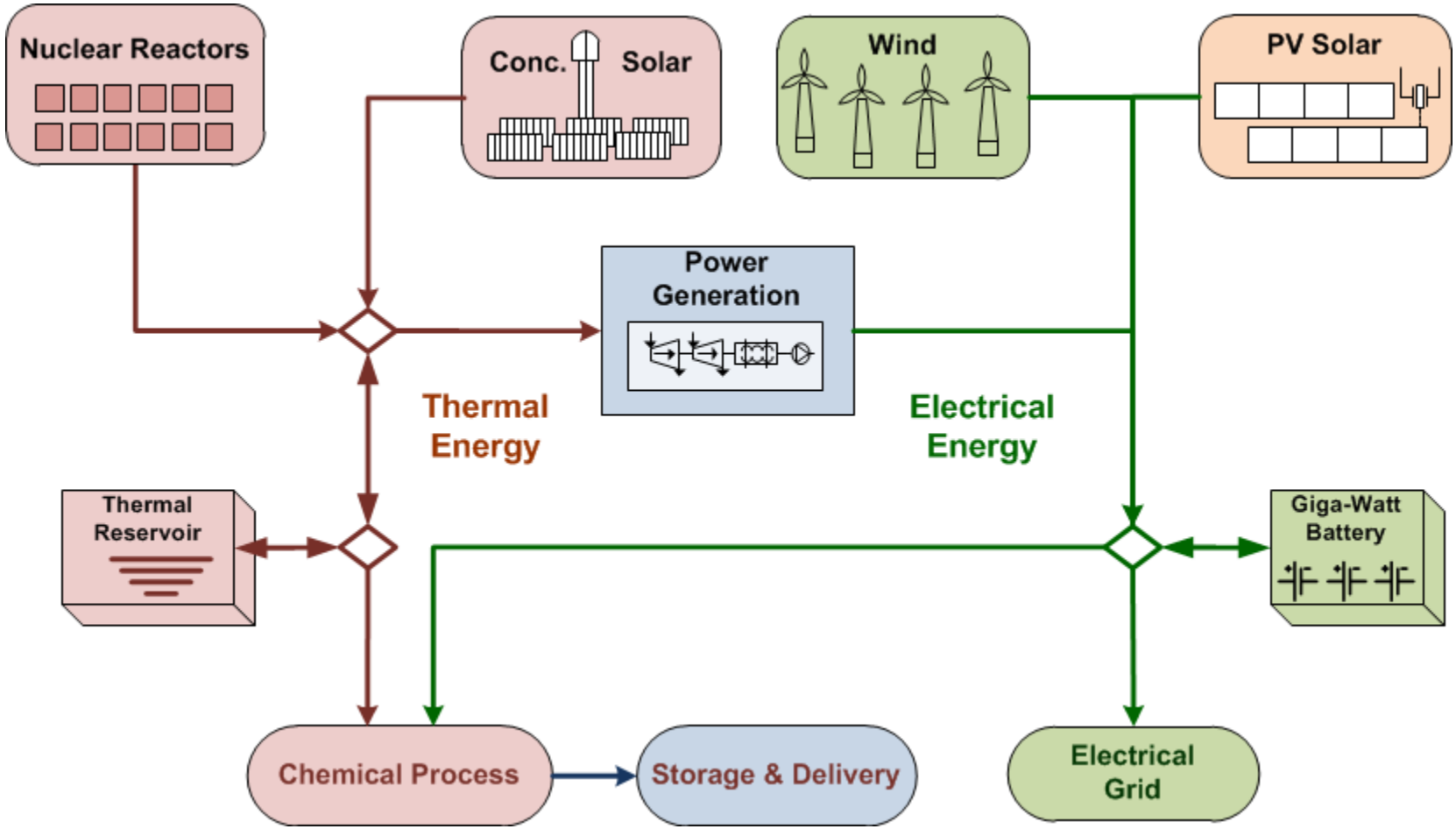
- Refinement of the Emergency Planning Zone
- Appropriate size of the control room staff
- Appropriate size of the security staff

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

- 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

Schematic of a Hybrid System



Potential Applications of Megawatt reactors

- Remote locations
  - Replace diesel generators
- Distributed generation
  - Address DOE mission to significantly reduce carbon emissions if deployed in large numbers
- Military applications
  - Appropriate only if funded by DoD, not ARPA-E

1. Regulatory and Policy Challenges for Mega-Watt Class Reactors

- Same regulatory challenges as SMRs, but highly accentuated
  - Definition of the EPZ
    - Applications may require a near-zero EPZ
  - Staffing of the control room
    - Distributed generation may require unattended operation
  - Staffing of security
    - Distributed generation may require unattended operation
  - ACRS/NRC will need convincing technical justifications for any decisions as well as test beds for new technologies.
  - Development of topical reports for the NRC in the near term would initiate NRC interactions and enable early discussion and possible resolution of key issues.

2. Regulatory and Policy Challenges for Mega-Watt Class Reactors

Additional policy and regulatory challenges

- Non-proliferation and security
  - In any credible scenario, can units provide nuclear material to terrorists for improvised weapons or dirty bombs?
  - What, if any, site security may be required for each application?
- Ability to withstand loss of external power (SBO) or grid disturbance and promptly restart (with operator (if any) intervention).
- If non-LW coolants or non-thermal spectra are planned, early work with the NRC will be essential to develop regulatory expertise.
  - The current interest in licensing of advanced reactors is highly relevant to this issue