In order of discussion, the meeting included the following topics and presentations:

1) NRC Slides

2) Future of Nuclear Energy in a Carbon Constrained World (and potential insights to prioritize activities) – M Corradini (UWisc)

3) Consensus Codes and Standards – ASME Section III, Div 5

4) Fast Reactor Working Group, Metal Fuels Report – C Cochran (Oklo)

5) Licensing Modernization
Public Meeting on Possible Regulatory Process Improvements for Advanced Reactor Designs

September 13, 2018

Telephone Bridge
(888) 793-9929
Passcode: 2496308
Public Meeting

• Telephone Bridge
  (888) 793-9929
  Passcode: 2496308

• Opportunities for public comments and questions at designated times
Introductions

Status of Activities: NRC, NEI

Report on Future of Nuclear Energy in a Carbon-Constrained World and Potential Insights to Prioritize Activities (M. Corradini, UWisc)

Consensus Codes and Standards
  - ASME Section III, Division 5

Fast Reactor Technology Working Group
  (C. Cochran, Oklo)

## Implementation Action Plans

### Strategy 1
Knowledge, Skills and Capability
- ONRL Molten Salt Reactor Training
- Knowledge Management
- Competency Modeling

### Strategy 2
Computer Codes & Review Tools
- Identification & Assessment of Available Codes

### Strategy 3
Flexible Review Processes
- Regulatory Roadmap
- Prototype Guidance
- Non-LWR Design Criteria
- Environmental Reviews
- Licensing Modernization Project

### Strategy 4
Consensus Codes and Standards
- ASME BPVC Section III Division 5
- ANS Standards 20.1, 20.2, 30.2, 54.1
- Non-LWR PRA Standard

### Strategy 5
Policy and Key Technical Issues
- Siting near densely populated areas
- Insurance and Liability
- Consequence Based Security
- EP for SMRs and ONTs

### Strategy 6
Communication
- NRC DOE Workshops
- Periodic Stakeholder Meetings
- NRC DOE GAIN MOU
- International Coordination

### Potential First Movers
- Micro-Reactors

### Regulatory Roadmap
- Prototype Guidance

### Prototype Guidance
- Non-LWR PRA Standard

### Non-LWR PRA Standard
- ASME BPVC Section III Division 5
- ANS Standards 20.1, 20.2, 30.2, 54.1

### International Coordination
- EP for SMRs and ONTs
- Functional Containment

### NRC DOE GAIN MOU
- Periodic Stakeholder Meetings
- International Coordination
NRC Status

- Developing Additional Staff Training (HTGRs, LMFRs)
- Continuing Computer Code Assessments (Future Meeting Topic)
- Interactions with Licensing Modernization Project (DG 1353)
- Environmental Review Working Group
- ASME Div 5, ANS Design Standards, non-LWR PRA Standard
- Policy Issues
  - Siting, PAA, Security, EP, Functional Containment, RIPB Licensing
- “Micro-Reactors”
NEI / ARRTF Updates
Report on Future of Nuclear Energy in a Carbon-Constrained World and Potential Insights to Prioritize Activities

M. Corradini, University of Wisconsin

Report Slides
Licensing as Part of Overall Development Programs

From Dec 2017
Stakeholder Meeting
Break

Meeting/Webinar will begin shortly

Telephone Bridge
(888) 793-9929
Passcode: 2496308
Consensus Codes and Standards

- ASME Section III, Division 5

ASME Slides
Technology Working Groups

Fast Reactor Working Group

➤ C. Cochran, Oklo

FRWG Report
# Future Stakeholder Meetings

## Topics

<table>
<thead>
<tr>
<th>Date</th>
<th>TWG – Fast Reactors, Metallic Fuel</th>
<th>Prioritization of Issues Considering Capital Costs</th>
<th>Consensus Codes &amp; Standards (ASME §3, Div 5)</th>
<th>Licensing Modernization/DG 1353</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sept 13</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Wed Oct 24</td>
<td>TWG – HTGRs</td>
<td></td>
<td></td>
<td>Policy Table</td>
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<tr>
<td></td>
<td></td>
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<td></td>
<td>Licensing Modernization/DG 1353</td>
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<tr>
<td>Dec 13</td>
<td>TWG – ?</td>
<td></td>
<td></td>
<td>Seismic Isolation</td>
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<td></td>
<td></td>
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<td>Strategy 2 – Computer Codes</td>
</tr>
</tbody>
</table>
Public Comments / Questions
Lunch

Meeting/Webinar will begin at 1:00pm

Telephone Bridge
(888) 793-9929
Passcode: 2496308
Licensing Modernization Project

DG 1353

Policy Paper
Break

*Meeting/Webinar will begin shortly*

Telephone Bridge

(888) 793-9929
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The Future of Nuclear Energy in a Carbon-Constrained World

AN INTERDISCIPLINARY MIT STUDY

David Petti
Executive Director, INL

Jacopo Buongiorno
Co-Director, MIT

Michael Corradini
Co-Director, U-Wisconsin

John Parsons
Co-Director, MIT
Key Questions Analyzed in the Study

For the period present-2050:

• Do we need nuclear to de-carbonize the power sector?
• What is the cost of new nuclear and how to reduce it?
• What is the value proposition of advanced nuclear technologies?
• What is the appropriate role for the government in the development and demonstration of new nuclear technologies?
TAKE-AWAY MESSAGES

• Nuclear is an important option to keep average electricity costs reasonably low in a decarbonized economy

• The bulk of capital costs of new nuclear is in civil works, structures and buildings and indirect costs

• Innovative design/build approaches (not necessarily new reactor designs) have potential to reduce cost of nuclear

• Advanced reactors offer enhanced safety and are positioned to take advantage of the innovative approaches

• New government policies that level the playing field for all low-carbon energy technologies are needed
Five Major Themes

1. Opportunities
2. Cost
3. Advanced Reactor Evaluation
4. Policy and Business Models
5. Regulatory Assessment
What is *not* in the study
- Fuel Cycle -

Results from the MIT 2009 study on the future of the nuclear fuel cycle remain valid today:

- Fuel utilization is not a significant cost issue given current resources,
- Technically viable options exist for the HLW disposal challenge, but must be implemented in a socially and politically acceptable manners, which has not happened in most countries with few exceptions (Finland, Sweden),
- There are approaches (e.g. centralized spent fuel repositories) that can make civilian fuel cycle an unattractive path to proliferation.

Solutions to these political problems will be found if society will decide that nuclear technology is essential. If the value of nuclear as a central contributor to deep decarbonization is not recognized, waste and proliferation will continue to be issues used to reject nuclear energy.
The big picture
The World needs a lot more energy

World’s electricity consumption is projected to grow by 45% by 2040
The key dilemma is how to increase energy generation while limiting global warming.

CO₂ emissions are actually rising... we are NOT winning!
Should nuclear play a role in decarbonizing the power sector?
Nuclear electricity can be deployed as quickly as coal or gas at a time of need.
The economic argument

Excluding nuclear energy drives up the cost of electricity in low-carbon scenarios (U.S., Europe and China)

New England ISO
Nominal – 5500 $/kWe  Low – 4100 $/kWe

Nominal – 2800 $/kWe  Low – 2100 $/kWe

Simulation of optimal generation mix in power markets
MIT tool: hourly electricity demand + hourly weather patterns + capital, O&M and fuel costs of power plants, backup and storage + ramp up rates
The economic argument (2)

**New England ISO**
Nominal – 5500 $/kWe  Low – 4100 $/kWe

**Tianjin-Beijing-Tangshan**
Nominal – 2800 $/kWe  Low – 2100 $/kWe

**Capital cost matters!**
*(markets can expand for nuclear even at modest decarbonization)*
ERCOT and Europe Results are similar

By contrast, installed capacity is relatively constant with nuclear allowed.

To meet constraint w/o nuclear requires major build-out of renewables.
ERCOT Dispatchable Generation Competition

- Coal with CCS is never selected
- NG with CCS is selected over nuclear until 10 g/kWhr
- <10 g/kWhr, nuclear is chosen over NG with CCS
- Renewables add 10% to energy generated
T-B-T Province Results

- To meet constraint w/o nuclear requires significant build-out of renewables

- By contrast, installed capacity is relatively constant with nuclear allowed
T-B-T Dispatchable Generation Competition

- NG with CCS is only selected in Tianjin between 10 g/kWh and 1 g/kWh
- Nuclear is always selected at 100 g/kWh and below
- Renewables add ~5% to energy generated
The cost issue
An increased focus on using proven project management practices will increase the probability of success in execution/delivery of new nuclear NPPs

- Complete design before starting construction,
- Develop proven NSSS supply chain and skilled labor workforce,
- Include fabricators and constructors in the design team,
- Appoint a single primary contract manager,
- Establish a successful contracting structure,
- Adopt a flexible contract administrative processes to adjust to unanticipated changes,
- Operate in a flexible regulatory environment that can accommodate changes in design and construction in a timely fashion.
Civil works, site preparation, installation and indirect costs (engineering oversight and owner’s costs) dominate.
Why are nuclear construction projects in the West particularly expensive?

Construction labor productivity has decreased in the West
Why are nuclear construction projects in the West particularly expensive? (2)

Construction and engineering wages are much higher in the US than China and Korea.

Estimated effect of construction labor on OCC (wrt US):
- $900/kWe (China)
- $400/kWe (Korea)

Source: Bob Varrin, Dominion Engineering Inc.
### What innovations could make a difference?

**Emphasis should be put on cross-cutting technologies that can reduce the indirect costs**

<table>
<thead>
<tr>
<th>Reduce Capital Cost</th>
<th>Reduce O&amp;M and Fuel Costs</th>
<th>Boost Revenues</th>
<th>Boost Efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Modular Construction</td>
<td>Advanced Concrete</td>
<td>Robotics</td>
<td>Energy Storage</td>
</tr>
<tr>
<td>Seismic Isolation, Embeddment</td>
<td>Accident Tolerant Fuels</td>
<td>Advanced Informatics and I&amp;C (AI, machine learning)</td>
<td>Brayton Cycles</td>
</tr>
<tr>
<td>3D Printing</td>
<td>Advanced Decommissioning</td>
<td>Oxide Dispersion-Strengthened Alloys</td>
<td>Chemicals Production</td>
</tr>
</tbody>
</table>

**Must focus:**

- **Shift labor from site to factories** ⇒ reduce installation cost
- **Relentless push towards standardization** ⇒ reduce licensing and engineering costs
- **Shorten construction schedule** ⇒ reduce owner’s costs
A shift away from primarily field construction of highly site-dependent plants to more serial manufacturing of standardized plants (True for all plants and technologies. Without this, inherent technological features will NOT produce the level of cost reduction necessary)

**Standardization on multi-unit sites**

**Seismic Isolation**

**Advanced Concrete Solutions**

<table>
<thead>
<tr>
<th>Work Structure</th>
<th>Rebar arrangement</th>
<th>Form work (assembling)</th>
<th>Placing concrete</th>
<th>Form work (removal)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>RC</strong></td>
<td></td>
<td>Wooden form</td>
<td></td>
<td></td>
</tr>
<tr>
<td>28days</td>
<td>3 days</td>
<td>7 days</td>
<td>4 days</td>
<td>4 days</td>
</tr>
<tr>
<td><strong>SC</strong></td>
<td></td>
<td>Steel plate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14days</td>
<td>—</td>
<td>10 days</td>
<td>4 days</td>
<td>—</td>
</tr>
</tbody>
</table>

**Modular Construction Techniques and Factory Fabrication**
Advanced reactors
Advanced Reactors (Generation-IV)

High Temperature Gas-Cooled Reactors

Sodium Fast Reactors
- Rotatable Plug
- Electromagnetic (EM) Pump (4x)
- Vessel Liner
- Reactor Vessel
- Core
- In-Vessel Transfer Machine (IVTM)
- Intermediate Heat Exchanger (IHX) (2x)
- Control Rod Drives
- Used Fuel Storage

Fluoride High Temperature Reactors

Gas-Cooled Fast Reactors

Lead-Cooled Fast Reactors

Molten Salt Reactors
Leading Gen-IV systems exploit inherent and passive safety features to reduce the probability of accidents and their offsite consequences. Their economic attractiveness is still uncertain.

We judge that advanced LWR-based SMRs (e.g. NuScale), and mature Generation-IV concepts (e.g., high-temperature gas-cooled reactors and sodium-cooled fast reactors are now ready for commercial deployment.
<table>
<thead>
<tr>
<th>Cost ($/kWe)</th>
<th>HTGR</th>
<th>SFR</th>
<th>FHR (Large)</th>
<th>FHR (Small)</th>
<th>MSR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Machine Size</td>
<td>4 x 600 MWth</td>
<td>4 x 840 MWth</td>
<td>3400 MWth</td>
<td>12 x 242 MWth</td>
<td>2275 MWth</td>
</tr>
<tr>
<td>Design Stage</td>
<td>Conceptual approaching Preliminary</td>
<td>Conceptual approaching Preliminary</td>
<td>Early conceptual</td>
<td>Early conceptual</td>
<td>Early conceptual</td>
</tr>
<tr>
<td>Direct Cost</td>
<td>2400</td>
<td>2500</td>
<td>2100</td>
<td>2300</td>
<td>2500</td>
</tr>
<tr>
<td>Indirect Cost</td>
<td>1400</td>
<td>1600</td>
<td>1400</td>
<td>1300</td>
<td>1700</td>
</tr>
<tr>
<td>Contingency</td>
<td>800</td>
<td>800</td>
<td>1100</td>
<td>1100</td>
<td>1200</td>
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<tr>
<td>Total Overnight Cost</td>
<td>4600</td>
<td>4900</td>
<td>4600</td>
<td>4700</td>
<td>5400</td>
</tr>
<tr>
<td>Interest During Construction</td>
<td>600</td>
<td>700</td>
<td>600</td>
<td>700</td>
<td>700</td>
</tr>
<tr>
<td>Total Capital Invested</td>
<td>5200</td>
<td>5600</td>
<td>5200</td>
<td>5400</td>
<td>6100</td>
</tr>
</tbody>
</table>

Independent cost estimates for advanced reactors confirm importance of civil works (buildings and structures) and indirect costs, and do not suggest significant cost reduction with respect to LWRs.
Uncertainty in cost estimates for large, complex projects

Conventional View

Reality

Early-stage cost estimates are unreliable predictors of the eventual cost of mega-projects. This is valid across large non-nuclear mega-projects and also for all nuclear technologies.
What is the value proposition for advanced reactors? (3)

There exists a small (but not insignificant) potential market for nuclear heat

<table>
<thead>
<tr>
<th>Industry</th>
<th>U.S. Capacity (MW\textsubscript{th} Installed) (%)</th>
<th>Global Capacity (MW\textsubscript{th} Installed) (%)</th>
<th>300 MW\textsubscript{th} Reactor</th>
<th>150 MW\textsubscript{th} Reactor</th>
<th>Worldwide Capacity (MW\textsubscript{th} Installed) (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Co-Generation Facilities</td>
<td>82,800 (61.7%)</td>
<td>340,800 (59.8%)</td>
<td>86,250 (57.5%)</td>
<td>355,050 (55.7%)</td>
<td></td>
</tr>
<tr>
<td>Refineries</td>
<td>15,600 (10.4%)</td>
<td>76,800 (12.1%)</td>
<td>17,250 (11.5%)</td>
<td>84,750 (13.3%)</td>
<td></td>
</tr>
<tr>
<td>Chemicals</td>
<td>7,800 (5.2%)</td>
<td>36,600 (5.7%)</td>
<td>7,050 (4.7%)</td>
<td>34,200 (5.4%)</td>
<td></td>
</tr>
<tr>
<td>Minerals</td>
<td>2,100 (1.4%)</td>
<td>8,700 (1.4%)</td>
<td>2,100 (1.4%)</td>
<td>8,700 (1.4%)</td>
<td></td>
</tr>
<tr>
<td>Pulp and Paper</td>
<td>12,600 (8.4%)</td>
<td>51,900 (8.1%)</td>
<td>21,300 (14.2%)</td>
<td>87,750 (13.8%)</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td>13,200 (8.8%)</td>
<td>55,200 (8.7%)</td>
<td>16,050 (10.7%)</td>
<td>66,450 (10.4%)</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>134,100 (100%)</td>
<td>570,000 (100%)</td>
<td>150,000 (100%)</td>
<td>636,900 (100%)</td>
<td></td>
</tr>
</tbody>
</table>

Methodology:
- EPA database for US sites emitting 25,000 ton-CO\textsubscript{2}/year or more
- Site must need at least 150 MW\textsubscript{th} of heat
- Nuclear heat delivered at max 650°C (with HTGR technology)
- At least two reactors per site for assured reliability
- Heat from waste stream not accessible
- Costs not evaluated
Can we accelerate commercialization of the less mature advanced reactors?

Timeline

**Traditional Approach**
- **5 - 8 Years**
  - Research and Development
  - Develop Design
  - Establish Supply Chain

- **10 - 12 Years**
  - Design, License, Build and Operate Engineering Demonstration

- **10 - 12 Years**
  - Design, License, Build and Operate Performance Demonstration

- **Subsequent Commercial Offerings**

**Proposed New Paradigm**
- **5 - 8 Years**
  - Research and Development
  - Develop Design
  - Establish Supply Chain
  - Develop Integrated Computational Models

- **10 - 12 Years**
  - Design, License, Build and Operate Performance Demonstration at Remote DOE Site Using NRC Prototype Rule

- **Subsequent Commercial Offerings**

*Aggressive use of M&S in early stages, to be confirmed by demonstration machine (jet engines and automobiles “model”)*

By combining the engineering demonstration machine (traditionally a small-scale machine) with the at-scale performance demonstration machine, and using the NRC prototype rule at a “forgiving” site, it may be possible to accelerate the commercial deployment of the less mature advanced reactors (i.e. molten salt-cooled and lead-cooled designs) by over 10 years.
**Finding:** Regulatory agencies in other nations have similar basic principles as described in IAEA policies and as embodied in NRC regulations, but vary widely in the detailed application of these policies and principles.

**Finding:** Advanced reactor concepts should consider NRC prototype option (10CFR50.43(e)) to license less mature designs to accelerate these concepts toward commercialization.

**Finding:** Current NRC regulatory structure is flexible and can be adapted to accommodate licensing of (mature) advanced reactors (such as SFRs and HTGRs), without a new regulatory paradigm. NRC has sufficient and diverse tools at hand to provide a stepwise process with intermediate licensing decisions without unnecessary delays, given required design information.

Adapted from *Advanced Demonstration and Test Reactor Options Study*, Chapter 7, INL
Government role
Preserve the existing fleet

An essential bridge to the future to:

- Avoid emission increases:
  - Keeping current NPPs is the lowest cost form of constraining carbon emissions
  - A $12-17/MWh credit would be enough to keep US nuclear power plants open
  - *Zero Emission Credits* are doing the job in NY, IL and NJ

- Retain key technical expertise needed to operate the nuclear systems of the future
US Electricity Markets

- **Nuclear Plant Operating Cost**

- **Nuclear Plant Market Revenue**

- **Fossil Plant Market Revenue**

- **Social Cost of Carbon**

- **Missing Low Carbon Value**
Global Nuclear Market

- Growth in electricity demand is primarily in the non-OECD.

- Plenty of choice of vendors.
  - Korea has been successful.
  - Russia is extremely active globally.
  - China has built a domestic foundation to become an exporter.

- US success as a nuclear innovator must be won in this new context.
New Reactor Designs

Electricity sector remains the major energy product

- Bigger than ever on a global scale, and
- with electrification of transportation and other energy services in the offering

Cost is the driver

- That means cutting the capital cost of the entire plant.
- $5,500 overnight is only competitive when carbon constraints are very tight
- $2,000 overnight is required without carbon constraints
How can the government help to deploy new nuclear technologies?

**Improve the design of competitive electricity markets**

- Decarbonization policies should create a level playing field that allows all low-carbon generation technologies to compete on their merits.
- Ensure technology neutrality in capacity markets.
- Enable investors to earn a profit based on full value of their product (include reducing CO2 emissions).
- Would enable current plants to compete in the market.

- Focus government research spending on innovations that lower capital cost of NPPs vs. fuel cycle innovations, reductions in waste streams and recycling.
- Develop a durable political solution for spent fuel disposal to spur private investment.
How can the government help to deploy new nuclear technologies? (2)

Governments should establish reactor sites where companies can deploy prototype reactors for testing and operation oriented to regulatory licensing.

- Government provides site security, cooling, oversight, PIE facilities, etc.
- Government provides targeted objectives, e.g. production of low-cost power or industrial heat, for which it is willing to provide production payments as an incentive
- Government takes responsibility for waste disposal
- Companies using the sites pay appropriate fees for site use and common site services
- Supply high assay LEU and other specialized fuels to enable tests of advanced reactors
How can the government help to deploy new nuclear technologies? (3)

- Cost sharing for Research and Development
- Licensing support cost sharing for a demonstration reactor
- Commercial contracts to support construction of demonstration reactors that have key attribute
  - milestone payments (similar to NASA COTS program)
- Supplemental production for generated electricity

<table>
<thead>
<tr>
<th></th>
<th>Higher Maturity Technology</th>
<th>Lower Maturity Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Government Funding Program</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rate for R&amp;D cost sharing</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Rate for Licensing cost sharing</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Rate for Milestones</td>
<td>20%</td>
<td>31%</td>
</tr>
<tr>
<td>Production Credit, $/MWh</td>
<td>27</td>
<td>27</td>
</tr>
</tbody>
</table>
How can the government help to deploy new nuclear technologies? (4)

High upfront costs and long time to see return on investment (more so for less mature technologies, e.g. FHR, MSR, LFR, GFR, than more mature technologies, i.e. HTGR, SFR)
Take-away messages

- The opportunity is carbon emissions
- The major issue is cost
- There are ways to reduce cost
- Adv. Reactors: enhance safety, reduce cost
- Government help needed to make it happen
Acknowledgements

This study is supported by generous grants and donations from

DISCLAIMER: MIT is committed to conducting research work that is unbiased and independent of any relationships with corporations, lobbying entities or special interest groups, as well as business arrangements, such as contracts with sponsors.
BACKUP SLIDES
A nuclear build-up (at historically feasible rate) can completely decarbonize the World’s power sector within 30 years.

Source: Staffan Qvist, 2018
Opportunities for Nuclear Energy
Opportunities for Nuclear Energy

Objective: Analyze need for nuclear given goal of deep decarbonization

Approach: For time periods from present to beyond 2050:
- What is the current status and the plan for nuclear energy development internationally (e.g., China, India, Korea...)?
- What are the long-term prospects for decarbonization with different energy technology scenarios for nuclear electricity? Does nuclear have a role and under what conditions?
- What are the energy markets to which nuclear energy can contribute to (e.g., process heat, desalination..)?

Findings [Market Dependent]:
- Without a decarbonization constraint, new nuclear is not cost competitive today because of the low cost of fossil fuels without CCS.
- Given a low-carbon emissions constraint, nuclear technology, when part of the electrical generation system mix, produces the least expensive option.
- Average cost of electricity may escalate dramatically when nuclear is excluded from low-carbon scenarios
Opportunities (long term view)

What are the long-term prospects for decarbonization with different energy scenarios with and without nuclear? What role does nuclear energy have and under what conditions?

- Determine the electricity system mix of technologies for various scenarios in US (e.g. ERCOT, ISO-NE) and international (e.g., China and Europe).
- For 2050 timeframe pick a constraint on CO2 release (e.g., 50 gm/kWhr)
- Use cost-minimization simulation tool (GenX benchmarked by JuiceBox)
- Minimize overall electricity system cost for an optimal technology mix

Simulation of optimal capacity mix in each specific market:
- Capital costs, O&M costs and fuel costs for each power plants, energy storage + startup-ramp rates + hourly electricity demand + hourly weather patterns: limited by the CO2 emissions target
## Modeling: Technology Choices

<table>
<thead>
<tr>
<th>Pathway 1: “With Nuclear”</th>
<th>Pathway 2: “Without Nuclear”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Carbon “Free” Options</strong></td>
<td><strong>Carbon “Free” Options</strong></td>
</tr>
<tr>
<td>• Photovoltaic Solar</td>
<td>• Photovoltaic Solar</td>
</tr>
<tr>
<td>• On-Shore Wind</td>
<td>• On-Shore Wind</td>
</tr>
<tr>
<td>• LWR Nuclear</td>
<td><strong>LWR Nuclear</strong></td>
</tr>
<tr>
<td>• Coal (IGCC) with CCS (90% Efficient)</td>
<td>• Coal (IGCC) with CCS (90% Efficient)</td>
</tr>
<tr>
<td>• Natural Gas with CCS (90% Efficient)</td>
<td>• Natural Gas with CCS (90% Efficient)</td>
</tr>
<tr>
<td><strong>Carbon Options</strong></td>
<td><strong>Carbon Options</strong></td>
</tr>
<tr>
<td>• OCGT and CCGT Natural Gas</td>
<td>• OCGT and CCGT Natural Gas</td>
</tr>
<tr>
<td>• Coal (current technology)</td>
<td>• Coal (current technology)</td>
</tr>
<tr>
<td><strong>Storage Options</strong></td>
<td><strong>Storage Options</strong></td>
</tr>
<tr>
<td>• Battery Storage</td>
<td>• Battery Storage</td>
</tr>
<tr>
<td>• Hydro-electric Storage (fixed &amp; small)</td>
<td>• Hydro-electric Storage (fixed &amp; small)</td>
</tr>
</tbody>
</table>
# US Overnight Cost Assumptions

<table>
<thead>
<tr>
<th>Resource</th>
<th>Low Cost</th>
<th>Nominal Cost</th>
<th>High Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCGT &lt;sup&gt;A&lt;/sup&gt;</td>
<td></td>
<td>$805/kW</td>
<td></td>
</tr>
<tr>
<td>CCGT &lt;sup&gt;A&lt;/sup&gt;</td>
<td></td>
<td>$948/kW</td>
<td></td>
</tr>
<tr>
<td>Coal &lt;sup&gt;A&lt;/sup&gt;</td>
<td></td>
<td>$3,515/kW</td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td>$4,100&lt;sup&gt;C&lt;/sup&gt;/kW</td>
<td>$5,500&lt;sup&gt;A&lt;/sup&gt;/kW</td>
<td>$6,900/kW</td>
</tr>
<tr>
<td>Wind &lt;sup&gt;A&lt;/sup&gt;</td>
<td>$1,369/kW</td>
<td>$1,553/kW</td>
<td>$1,714/kW</td>
</tr>
<tr>
<td>Solar &lt;sup&gt;A&lt;/sup&gt;</td>
<td>$551/kW</td>
<td>$917/kW</td>
<td>$1,898/kW</td>
</tr>
<tr>
<td>Battery Storage &lt;sup&gt;B&lt;/sup&gt;</td>
<td>$429/kW ($215/kWh)</td>
<td>$715/kW ($)358/kWh)</td>
<td>$1,430/kW ($715/kWh)</td>
</tr>
<tr>
<td>Coal IGCC+CCS &lt;sup&gt;A&lt;/sup&gt;</td>
<td></td>
<td>$5,876/kW</td>
<td></td>
</tr>
<tr>
<td>Gas CCGT+CCS &lt;sup&gt;A&lt;/sup&gt;</td>
<td></td>
<td>$1,720/kW</td>
<td>$2,115/kW</td>
</tr>
</tbody>
</table>

<sup>A</sup> NREL-ATB report (2016)  
<sup>B</sup> Lazard.com report (2015)  
<sup>C</sup> OECD (2015)
GenX Results

Simulated Texas-ERCOT and NE-ISO with GenX; similar analyses for China (Tianjin, Zhejiang province) and UK and France with a range of carbon constraints (500-nominal, 100, 50, 10, 1 gm-CO2/kWh)

Performed a range of sensitivity studies on:

- Renewables plus battery storage cost (hi-nominal-low)
- Nuclear capital cost (nominal – low with improvements)
- Natural gas price (hi-nominal-low)
- CCS Cost and Efficiency (nominal-hi; 90% and 99%)
- Demand-Side Response (with and without)
- Extreme Weather (clouds/low-wind for a time period)
Simulation of optimal generation mix in power markets

MIT tool: hourly electricity demand + hourly weather patterns + capital, O&M and fuel costs of power plants, backup and storage + ramp up rates

Similar results were found for Europe (U.K. and France)
Texas - ERCOT Results

Nuclear option makes a difference btw 50 g/kWhr and 10 g/kWhr for nominal cost case

Nuclear always part of the system mix for lower cost nuclear with improvements due to enabling technologies

Extremely Low Nuclear Cost is Advanced Reactor Stretch Goal - $2500/kWe ONC
To meet constraint w/o nuclear requires major build-out of renewables

In contrast, installed capacity is relatively constant w nuclear allowed
GenX Sensitivity Nomenclature

• No nuclear case: All costs at nominal conditions w/o nuclear
• Nuclear-nominal: Nuclear included w nominal conditions
• Nuclear-low cost: Lower cost w improved enabling technology
• Renewable/Battery Low cost: Nominal w low cost renewables
• Renewable/Battery High cost: Nominal w hi cost renewables
• High Nat.Gas cost: Nominal w high natural gas fuel cost
• Low Nat.Gas cost: Nominal w low natural gas fuel cost
• 99% CCS: Nominal costs with 99% Carbon-capture efficiency
• Demand-side response allowed (DSM + DR)
• Extreme weather year: Nominal w 1wk-Low-Renew Cap.Fac.
Opportunity Cost = [Systems cost w/o Nuclear – Systems cost w Nuclear]

At a high renewables and battery storage cost, opportunity cost is much larger
At a low renewables and battery storage cost, nuclear is not selected until 1 g/kWhr
ERCOT Electrical Energy Generation

- Coal with CCS is never selected.
- NG with CCS is selected over nuclear until 10 g/kWhr.
- <10 g/kWhr, nuclear is chosen over NG with CCS.

---

**ERCOT Generation by Technology:**

- **Total Generation (TWh):**
  - Nuclear - None
  - Nuclear - High Cost
  - Nuclear - Nominal Cost
  - Nuclear - Low Cost
  - Nuclear - Extremely Low Cost

- **Total Generation %:**
  - Natural Gas (OCGT and CCGT)
  - Coal (IGCC)
  - Nuclear
  - Renewables (Wind and Solar)
  - Storage (Pumped Hydro and Battery)
  - CCS (CCGT and IGCC) Technologies

**Legend:**
- Blue: Natural Gas (OCGT and CCGT)
- Orange: Coal (IGCC)
- Gray: Nuclear
- Yellow: Renewables (Wind and Solar)
- Cyan: Storage (Pumped Hydro and Battery)
- Green: CCS (CCGT and IGCC) Technologies

**Total Generation (TWh):**

| 500 | 100 | 50 | 10 | 1 | 500 | 100 | 50 | 10 | 1 | 500 | 100 | 50 | 10 | 1 | 500 | 100 | 50 | 10 | 1 | 500 | 100 | 50 | 10 | 1 |
|-----|-----|----|----|---|-----|-----|----|----|---|---|-----|-----|----|----|---|-----|-----|----|----|---|---|-----|-----|----|----|---|---|
## China Overnight Cost Assumptions

<table>
<thead>
<tr>
<th>Resource</th>
<th>Low Cost</th>
<th>Base Cost</th>
<th>High Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>OCGT</td>
<td>$421/kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CCGT</td>
<td>$496/kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal</td>
<td>$1,160/kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Nuclear</td>
<td>$2,084/kW</td>
<td>$2,796/kW</td>
<td></td>
</tr>
<tr>
<td>Wind</td>
<td>$1,117/kW</td>
<td>$1,267/kW</td>
<td>$1,398/kW</td>
</tr>
<tr>
<td>Solar</td>
<td>$404/kW</td>
<td>$671/kW</td>
<td>$1,389/kW</td>
</tr>
<tr>
<td>Battery Storage</td>
<td>$429/kW ($215/kWh)</td>
<td>$715/kW ($358/kWh)</td>
<td>$1,430/kW ($715/kWh)</td>
</tr>
<tr>
<td>Coal IGCC+CCS</td>
<td>$1,940/kW</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas CCGT+CCS</td>
<td>$900/kW</td>
<td></td>
<td>$1,159/kW</td>
</tr>
</tbody>
</table>

**NOTE:** Study used the relative costs for each technology from the 2015 OECD Report with NREL U.S. cost values used as cost basis for scaling to other countries.
T-B-T Province Results

Due to its low relative cost, having nuclear as an option always decreases overall system cost.

This decrease in system cost is dramatic for low carbon scenarios.
T-B-T Province Results

To meet constraint w/o nuclear requires significant build-out of renewables

In contrast, installed capacity is relatively constant w nuclear allowed
Even with low renewables/storage cost, nuclear is still chosen for all constraints.
T-B-T Electrical Energy Generation

- Fossil (Coal & NG) selected for > 10g/kWhr
- NG with CCS is only selected in Tianjin between 10 g/kWh and 1g/kWh
- Nuclear is always selected at 100 g/kWh and below
Advanced Reactor Stakeholder Meeting:
NRC Endorsement of ASME BPVC Section III, Division 5

Andrew Yeshnik
September 13, 2018
Background – FY16-17

Implementation Action Plans (July 2017) to support NRC Vision and Strategy (December 2016)

1. Acquire/develop sufficient staff knowledge, tech. skills, capacity to perform non LWR regulatory reviews
2. Acquire/develop sufficient computer codes/tools to perform non-LWR regulatory reviews
3. Establish a more flexible, RIPB non-LWR review process within the bounds of existing regulations, incl. CDAs, staged reviews
4. Facilitate industry codes & standards development needed to support the non-LWR lifecycle, including fuels & materials
5. Identify & resolve tech-inclusive non-LWR policy issues
6. Develop a structured, integrated communications strategy for internal and external stakeholders with non-LWR interests)
NRC Endorsement of ASME BPVC Section III, Division 5

• Current nuclear power designs operate within a thermal range of 275°C to 315°C.

• Advanced reactor designs have operating thermal ranges that vary widely between 480°C and 1000°C.

• There is no NRC-endorsed code of construction for nuclear reactors operating above 425°C (800°F).

• American Society of Mechanical Engineers Boiler and Pressure Vessel Code (ASME BPVC) Section III, Division 5 provides design, construction, certification, and quality assurance rules for metallic components operating in excess of 800°F, graphite core structures, and ceramic-composite components.

• A letter dated June 21, 2018 from ASME (ML18184A065) requested that the NRC review and endorse the 2017 Edition of ASME BPVC Section III, Division 5 (NRC Response Letter: ML18211A571)
Review and Endorsement Process

• NRO-Lead with support from RES/DE and NRR/DE

• **Objective:** Official NRC Endorsement of the 2017 Edition of ASME BPVC Section III, Division 5

• **Anticipated Product (August 2020):** A draft regulatory guide for public comment that includes the 2017 ASME BPV Code Section III, Division 5 as an endorsed method of constructing Advanced Reactor Designs, subject to any conditions the staff deems necessary.

• The NRC is participating on two ASME/NRC task groups:
  – Metallic Materials
  – Graphite and Ceramics

• Contractors: PNNL, ORNL, ANL, Commercial

• Stakeholder engagement throughout the review
Review and Endorsement Process

Current Status:
• The endorsement team has started Task A, Project Planning
  – Establishing the scope, schedule, and NRC points of contact
• Process:

- Project Planning (Task A)
  - Review of Low Temperature and General Requirements (QA) Rules (Task B)
  - Review of High Temperature Metal Rules (Task C)
  - Review of Graphite Rules (Task D)
  - Review of Code Cases (Task E)

- Draft RG (Task F)
Metallic Fuel Experience in Sodium Cooled Fast Reactors

FRWG
September 13, 2018
Presentation Overview

• Presentation Purpose
• Metallic Fuel Experience
• Steady State Performance
• Transient Behavior
• EBR-II
• Notes on QA and legacy data work at Argonne and interest to other reactor types
• Summary
Presentation Purpose

• Familiarize the NRC and stakeholders with information on metallic fuel
Metallic Fuel Experience
Metallic Fuel History

• Over 30 years of irradiation experience

• EBR-I, Fermi-1, EBR-II, FFTF

• U-Fs*, U-Mo, U-Pu-Fs*, U-Zr, U-Pu-Zr, others

• EBR-II
  • > 40,000 U-Fs* pins, > **16,000 U-Zr pins** & > 600 U-Pu-Zr pins irradiated, clad in 316 stainless steel, D9 & **HT9**

• FFTF
  • > **1000 U-Zr pins**, mostly in HT9
  • Vast experience with HT9 cladding

*Fs – Simulated Fission Products
Sources of Metallic Fuel Data

- Metallic Fuels Data
  - TREAT
    - Metal Fuel Experiments
  - FFTF
    - IFR Experiments
  - EBR-II
    - IFR Experiments
  - Outpile Experiments
  - Metallic Fuels Handbook
Metallic Fuel Experimental Database (Steady State)

• EBR-II experiments to look at parameters and phenomena of interest to fuel performance
  • Prototype fuel behavior
  • RBCB* and failure mode
  • Fuel swelling and restructuring
  • Lead IFR** fuel test
  • Fabrication
  • Design parameters
  • High clad temperature
  • Large fuel diameter
  • Blanket safety
  • Fuel qualification
  • Fuel impurities

• FFTF experiments to look at
  • Fuel column length effects
  • Lead metal fuel tests
  • Metal fuel prototype
  • Metal fuel qualification

* RBCB – Run Beyond Cladding Breach
** IFR – Integral Fast Reactor
Metallic Fuel Experimental Database (Transient)

• In-Pile
  • Run Beyond Cladding Breach (RBCB) experiments:
    6 RBCB tests U-Fs & U-Pu-Zr/U-Zr
  • 6 TREAT tests:
    U-Fs in 316SS & U-Zr/U-Pu-Zr in D9/HT9

• Out-Pile
  • Whole Pin Furnace Tests (WPF)
  • Fuel Behavior Test Apparatus (FBTA)
  • Diffusion compatibility tests
Typical Metallic Fuel Design

Typical EBR-II Metallic Fuel Pin
(Pahl, et al., 1990)
### Design Parameters (nominal) of EBR-II Fuel

<table>
<thead>
<tr>
<th>Item</th>
<th>Mark-IA</th>
<th>Mark-II</th>
<th>Mark-IIC</th>
<th>Mark-IICS</th>
<th>Mark-III</th>
<th>Mark-IIIa</th>
<th>Mark-IV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel alloy, wt %</td>
<td>U-5Fs</td>
<td>U-5Fs</td>
<td>U-10Zr</td>
<td>U-10Zr</td>
<td>U-10Zr</td>
<td>U-10Zr</td>
<td>U-10Zr</td>
</tr>
<tr>
<td>Enrichment weight, % $^{235}$U</td>
<td>52</td>
<td>67</td>
<td>78</td>
<td>78</td>
<td>66.9</td>
<td>66.9</td>
<td>69.6</td>
</tr>
<tr>
<td>Fuel-slug mass, g</td>
<td>64</td>
<td>52</td>
<td>47</td>
<td>47</td>
<td>83</td>
<td>83</td>
<td>78</td>
</tr>
<tr>
<td>Fuel smeared density, %</td>
<td>85</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
<td>75</td>
</tr>
<tr>
<td>Cladding-wall thickness, cm</td>
<td>0.023</td>
<td>0.030</td>
<td>0.030</td>
<td>0.030</td>
<td>0.038</td>
<td>0.038</td>
<td>0.046</td>
</tr>
<tr>
<td>Cladding-wall OD, cm</td>
<td>0.442</td>
<td>0.442</td>
<td>0.442</td>
<td>0.442</td>
<td>0.584</td>
<td>0.584</td>
<td>0.584</td>
</tr>
<tr>
<td>Length, cm</td>
<td>46.0</td>
<td>61.2</td>
<td>63.0</td>
<td>53.6</td>
<td>74.9</td>
<td>74.9</td>
<td>74.9</td>
</tr>
<tr>
<td>Cladding material</td>
<td>304L</td>
<td>316</td>
<td>316</td>
<td>316</td>
<td>CW19</td>
<td>CW316</td>
<td>HT9</td>
</tr>
<tr>
<td>Spacer-wire diameter, cm</td>
<td>0.124</td>
<td>0.124</td>
<td>0.124</td>
<td>0.124</td>
<td>0.107</td>
<td>0.107</td>
<td>0.107</td>
</tr>
</tbody>
</table>

## Historical Fuel Design Parameters

<table>
<thead>
<tr>
<th>Key Parameter</th>
<th>EBR-II/FFTF</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peak Burnup, $10^4$MWd/t</td>
<td>5.0 – 20</td>
</tr>
<tr>
<td>Max. linear power, kW/m</td>
<td>33 – 50</td>
</tr>
<tr>
<td>Cladding hotspot temp., °C</td>
<td>650</td>
</tr>
<tr>
<td>Peak center line temp., °C</td>
<td>&lt;700</td>
</tr>
<tr>
<td>Peak radial fuel temp. difference, °C</td>
<td>100 - 250</td>
</tr>
<tr>
<td>Cladding fast fluence, n/cm²</td>
<td>up to $4 \times 10^{23}$</td>
</tr>
<tr>
<td>Cladding outer diameter, mm</td>
<td>4.4 - 6.9</td>
</tr>
<tr>
<td>Cladding thickness, mm</td>
<td>0.38 – 0.56</td>
</tr>
<tr>
<td>Fuel slug diameter, mm</td>
<td>3.33 – 4.98</td>
</tr>
<tr>
<td>Fuel length, m</td>
<td>0.3 (0.9 in FFTF)</td>
</tr>
<tr>
<td>Plenum/fuel volume ratio</td>
<td>0.84 to 1.45</td>
</tr>
<tr>
<td>Fuel residence time, years</td>
<td>1 - 3</td>
</tr>
<tr>
<td>Smeared density, %</td>
<td>75</td>
</tr>
</tbody>
</table>
Steady State Metallic Fuel Performance
Steady State Performance Topics

• Fission Gas Release (FGR)
• Fuel Swelling
• Constituent Redistribution and Zone Formation
• Fuel-Cladding Chemical Interaction (FCCI) & Rare Earth Migration
• Fuel-Cladding Mechanical Interaction (FCMI)
• Cladding Material Performance
Fission Gas Release (FGR)

- Insoluble fission gases, Xe and Kr, accumulate in fuel until inter-linkage of porosity at sufficient burnup leads to release of large fraction of gas.
- The fission gases accumulate in plenum region and constitute the primary clad loading mechanism.

FGR vs. Burnup (Hofman & Walter, 1994): U-5Fs slightly lower because of beneficial effect of Si inclusion
FGR vs. Fuel Swelling (Hofman & Walter, 1994): Independent of metal-fuel type
Fuel Swelling

- Driven by nucleation and growth of immobile fission-gas bubbles
- Low fuel smeared density (~75%) combined with high swelling rate allow rapid swelling to ~33 vol% at ~2 at.% burnup where inter-linkage of porosity results in large gas release fraction which decreases the driving force for continued swelling

EBR-II fuel length increase in various metallic fuels as a function of burnup where closed symbols correspond to FFTF data (ANL-AFCI-211)
Constituent Redistribution & Zone Formation

• Fuel melting temp. decrease in Zr-depleted region (this zone happens off the fuel center).
• Local fission rate change.
• Changes in swelling characteristics.
• Reliable predictive model has been developed.

Metallographic cross section with superimposed radial microprobe scans at top of U-10Zr pin DP-81, experiment X447 (Hofman, et al., 1995)

U-Zr Phase Diagram
Fuel Cladding Chemical Interaction (FCCI) & Fission Product Migration

- At steady state FCCI is characterized by solid state interdiffusion
- Interdiffusion forms U/Fe alloys with lower eutectic temperature
- Decarburized zone at fuel-clad interface is expected in HT-9 cladding
- RE fission products (La, Ce, Pr, Nd) form a cladding brittle layer
- Penetration depth data are available from in and out-of-pile measurements
Transient Behavior
Metallic Fuel Characteristics

• Excellent transient capabilities
  • Does not impose restrictions on transient operations capabilities
  • Sample history of a typical driver fuel irradiated during the EBR-II inherent passive safety tests conducted in 1986;

  - 40 start-ups and shutdowns
  - 5 15% overpower transients
  - 3 60% overpower transients
  - 45 loss-of-flow (LOF) and loss-of-heat-sink tests including a LOF test from 100% without scram

  - No fuel failures

Unprotected loss-of-flow test in EBR-II demonstrated the benign behavior predicted (Mohr, et al., 1987)
Transient Tests

- In-pile TREAT (Transient Reactor Test Facility) tests evaluated transient overpower margin to failure, pre-failure axial fuel expansion, and post-failure fuel and coolant behavior.

- Hot cell furnace testing of pin segments (Fuel Pin Test Apparatus), and full length pins (Whole Pin Furnace) showed significant safety margin for particular transient conditions.

  - Penetration depth data were measured and provided the basis for penetration depth correlations.

Effective cladding penetration rates from FBTA tests for specimens tested for 1.0 hour (Tsai, et al., 2007)
Eutectic Formation Temperature between Fuel and Clad

- Critical parameter for metal fuel design
- Onset of eutectic formation occurs between 650 – 725 °C
- Rapid eutectic penetration at a much higher temperatures
- Places limits on the coolant outlet temperature to provide adequate margin to onset of eutectic formation

The Iron-Uranium Phase Diagram (Okamoto, 1990)
EBR-II shutdown heat removal tests (SHRT)

- Performed on the same day (April 3rd, 1986)
- Two types of unprotected loss-of-cooling accidents
  - Loss of Flow Without Scram
  - Loss of Heat Sink Without Scram
- Performed on the actual, operating reactor at full power!
EBR-II Loss of Flow Without Scram

- Primary coolant pumps turned off while operating at full power
- Reactor shut down due to fuel thermal expansion feedbacks
More EBRII LOFWS plots
EBR-II Loss of Heat Sink Without Scram

• Intermediate coolant pumps turned off while operating at full power.

• Again, reactor shuts down without scram due to thermal expansion feedbacks.
EBRII passive safety

- Benign transient behavior enabled by lower stored Doppler reactivity of metal fuel
- Result of operating at lower nominal fuel temp (relative to oxide)
EBR-II safety test takeaways

- These are sensational results. Two of the most severe accidents that can threaten nuclear power systems have been shown to be of no consequence to safety or even operation of EBR-II. The reactor was inherently protected without requiring emergency power, safety systems, or operator intervention.”

Notes on Laboratory Efforts and Interest to Other Reactor Types

• Presentation from Argonne at one of these meetings in June
• Efforts at Argonne
• Other technology types may want to follow or learn about
NEI 18-04 LMP Guidance Document Updates
LMP Guidance Document Introduction

• The NEI 18-04 LMP Guidance Document represents a framework for the efficient licensing of advanced non-light water reactors (non-LWRs).

• It is the result of the LMP led by American nuclear utilities and cost-shared by the US Department of Energy (DOE).

• The LMP Team prepared this document for establishing licensing technical requirements to facilitate risk-informed and performance-based (RIPB) design and licensing of advanced non-LWRs.

• Such a framework acknowledges enhancements in safety achievable with advanced designs and reflects current states of knowledge regarding safety and design innovation, creating an opportunity for reduced regulatory complexity with increased levels of safety.
LMP Guidance Document Recent Activities

• June 19 – The LMP Guidance Document (Working Draft M) was reviewed and discussed by the Advisory Committee on Reactor Safeguards (ACRS) Future Plants Subcommittee. [transcript available at ML18184A148]


• September 13 – NRC stakeholder public meeting. [announcement available at ML18249A337]
LMP Guidance Document Upcoming Meetings and Milestones

• NLT September 28 – Near final draft of NEI 18-04 LMP Guidance Document submitted to the ACRS Future Plant Designs (FPD) Subcommittee chair in preparation for the October 30 ACRS FPD Subcommittee meeting.

• October 30 – ACRS FPD Subcommittee meeting to review and discuss the draft LMP Guidance Document, draft NRC SECY, and draft NRC Regulatory Guide DG-1353 addressing the LMP Guidance Document.

• December 6 or 7 – Full ACRS meeting to review and discuss the draft of the LMP Guidance Document, draft NRC SECY, and draft NRC Regulatory Guide DG-1353 addressing the LMP Guidance Document.
LMP Guidance Document Upcoming Opportunities for Industry and Public Participation

• By 2Q19 we expect between four and six advanced reactor designers to have exercised the LMP RIPB processes on their designs to obtain potential insights. The LMP team is interested in demonstrating the LMP RIPB processes with additional vendors.
  • X-energy has generously publicly shared their report on the LMP demonstration on a TRISO pebble-bed, high-temperature, gas-cooled reactor via NRC ADAMS at Accession Number ML18228A779.

• Anytime – The LMP team always welcomes questions, comments, and feedback. Please contact me at jpredd@southernco.com or 205-992-6435.
LMP Feedback on DG-1353 Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Approach to Inform the Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors with associated draft SECY
DG-1353 and draft SECY Acknowledgement and Thanks

• LMP recognizes the extensive work by Bill Reckley and Amy Cubbage, along with the contributions and oversight from the NRC Staff and management, to prepare DG-1353 Guidance for a Technology-Inclusive, Risk-Informed, and Performance-Based Approach to Inform the Content of Applications for Licenses, Certifications, and Approvals for Non-Light-Water Reactors with its draft SECY.
Key Messages from the LMP Team on DG-1353 and draft SECY

• No significant deltas have been identified between the RIPB process proposed by the draft NEI 18-04 LMP Guidance Document and DG-1353 with draft SECY.

• The LMP Team is pleased to offer verbal feedback to the NRC Staff on DG-1353 and the draft SECY paper.
Questions?