Advanced Reactor Stakeholder Public Meeting

December 12, 2024

Time	Agenda	Speaker
10:00 - 10:15 am	Opening Remarks	NRC
10:15 - 10:45 am	ADVANCE Act Section 207 - Combined License Review Procedures	NRC
10:45 - 11:30 am	CNSC-NRC Memorandum of Cooperation: Joint Report on Classification of Structures, Systems, and Components	NRC
11:30 am - 12:00 pm	NEI White Paper Discussion on Selection of a Seismic Scenario for an EPZ Boundary Determination	NEI/NRC
12:00 - 1:00 pm	LUNCH	
1:00 - 3:00 pm	ADVANCE Act Section 203 - Nonelectric Uses of Nuclear Technology	NRC/DOE
3:00 - 4:00 pm	Risk-Informed, Performance-Based Regulatory Approaches	NRC

Time	Agenda	Speaker
4:00 - 4:15 pm	Public Comment Period	Public
4:15 pm	Closing Remarks/Adjourn	NRC

Opening Remarks

Advanced Reactor Program Highlights

- ***Recent Accomplishments:***
  - Issued construction permits for the Hermes 2 test reactor facility to Kairos Power LLC on November 21, 2024
- ***Updates:***
  - Comment period for Part 53 proposed rule closes on 2/28/25. Publication of the final rule is expected by 4/30/2027, ahead of December Nuclear Energy Innovation and Modernization Act (NEIMA) deadline.
  - Policy paper on nth-of-a-kind licensing expected to be released in early 2025
  - White paper of draft regulatory guide endorsing NEI 22-05, “Technology Inclusive Risk Informed Change Evaluation (TIRICE)” to be issued this month. Public meeting to follow in early 2025
  - White paper of policy paper on alternatives to Part 53 Framework B to be issued this month. Public meeting to follow in January.
- ***Upcoming Public Meetings:***
  - Discussion with NEI on Operator Cold License Training
    - December 19 from 10 a.m. – 12 p.m.
  - Part 53 Public Meeting
    - January 8 – 9

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Regulatory Frameworks and Technical Approaches to Ensure Appropriate Qualification and Through-Life Performance of Non-Light Water Reactor Materials

The NEA Working Group on New Technologies (WGNT) is developing a report on qualification and through-life performance of NLWR materials. The report will include workshop conference proceedings and summarize best practice attributes for addressing regulatory needs.

Workshop time and location: June 3-5, 2025, in Rockville, MD (hybrid option available)

The call for abstracts has been released

Topics

- General qualification
- Qualification of advanced manufacturing technologies, graphite, and composites
- General through-life performance
- Through-life performance of advanced manufacturing technologies, graphite, and composites

Tentative Timeline

- Feb. 17, 2025 – Abstract submission
- May 12, 2025 – Paper submission
- May 28, 2025 – Presentation submission
- June 3-5, 2025 – Workshop
- July 21, 2025 – Final paper submission
- 2026/2027 – Report completed

To receive the call for abstract, be included on future distributions, or for more information, please contact ryann.bass@nrc.gov and wendy.reed@nrc.gov

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Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy Act of 2024
(ADVANCE Act of 2024)
Section 207 - Combined License Review Procedure

Samuel Lee, Deputy Director, Division of New and Renewed Licenses

Michelle Hayes, Chief, Licensing and Regulatory Infrastructure Branch

Carolyn Lauron, Project Manager, Licensing and Regulatory Infrastructure Branch

December 12, 2024

Advanced Reactor Stakeholder Meeting

Opening Remarks

NRC Core Team
For the Implementation of the ADVANCE Act of 2024

Mike King, Special Assistant for ADVANCE Act
Shilp Vasavada, Executive Technical Assistant
Luis Betancourt, Executive Technical Assistant
Aaron McCraw, Sr. Communications Specialist

Purpose

To share information on the ADVANCE Act Section 207 – Combined License Review Procedure through:

- An Overview of ADVANCE Act Section 207
- A Discussion of NRC Staff Considerations
- Identification of Opportunities for Stakeholder Feedback
- Questions and Answers

- This Advanced Reactor Stakeholder Meeting was first noticed on November 2, 2024.

ADVANCE Act of 2024

The ADVANCE Act of 2024 was passed with bipartisan support and signed by President Biden in July 2024. It requires the NRC to take a number of actions, particularly in the areas of licensing of new reactors and fuels, while maintaining the NRC's core mission to protect public health and safety. The Act affects a wide range of NRC activities, including by supporting the recruitment and retention of the NRC workforce, adding flexibility in the NRC's budgeting process, enhancing the regulatory framework for advanced reactors and fusion technology, and requiring initiatives to support the NRC's efficient, timely, and predictable reviews of license applications.

ADVANCE Act of 2024, Section 207
Combined License Review Procedure

(a) IN GENERAL.—In accordance with this section, the Commission shall establish and carry out an expedited procedure for issuing a combined license pursuant to section 185 b. of the Atomic Energy Act of 1954 (42 U.S.C. 2235(b)).

ADVANCE Act of 2024, Section 207
Combined License Review Procedure

(b) QUALIFICATIONS.—To qualify for the expedited procedure under subsection (a), an applicant—

- (1) shall submit a combined license application for a new nuclear reactor that—
  - (A) references a design for which the Commission has issued a design certification (as defined in section 52.1 of title 10, Code of Federal Regulations (or any successor regulation)); or
  - (B) has a design that is substantially similar to a design of a nuclear reactor for which the Commission has issued a combined license, an operating license, or a manufacturing license under the Atomic Energy Act of 1954 (42 U.S.C. 2011 et seq.);

ADVANCE Act of 2024, Section 207
Combined License Review Procedure

(2) shall propose to construct the new nuclear reactor on a site—

(A) on which a licensed commercial nuclear reactor operates or previously operated; or

(B) that is directly adjacent to a site on which a licensed commercial nuclear reactor operates or previously operated and has site characteristics that are substantially similar to that site; and

(3) may not be subject to an order of the Commission to suspend or revoke a license under section 2.202 of title 10, Code of Federal Regulations (or any successor regulation).

ADVANCE Act of 2024, Section 207
Combined License Review Procedure

(c) EXPEDITED PROCEDURE.—With respect to a combined license for which the applicant has satisfied the requirements described in subsection (b), the Commission shall, to the maximum extent practicable—

(1) not later than 18 months after the date on which the application is accepted for docketing—

(A) complete the technical review process and issue a safety evaluation report; and

(B) issue a final environmental impact statement or environmental assessment, unless the Commission finds that the proposed agency action is excluded pursuant to a categorical exclusion in accordance with the National Environmental Policy Act of 1969 (42 U.S.C. 4321 et seq.);

ADVANCE Act of 2024, Section 207 Combined License Review Procedure

(2) not later than 2 years after the date on which the application is accepted for docketing, complete any necessary public licensing hearings and related processes; and

(3) not later than 25 months after the date on which the application is accepted for docketing, make a final decision on whether to issue the combined license.

ADVANCE Act of 2024, Section 207
Combined License Review Procedure

(d) PERFORMANCE AND REPORTING.—

(1) DELAYS IN ISSUANCE.—Not later than 30 days after the applicable deadline, the Executive Director for Operations of the Commission shall inform the Commission of any failure to meet a deadline under subsection (c).

ADVANCE Act of 2024, Section 207
Combined License Review Procedure

(2) DELAYS IN ISSUANCE EXCEEDING 90 DAYS.— If any deadline under subsection (c) is not met by the date that is 90 days after the applicable date required under that subsection, the Commission shall submit to the appropriate committees of Congress a report describing the delay, including—

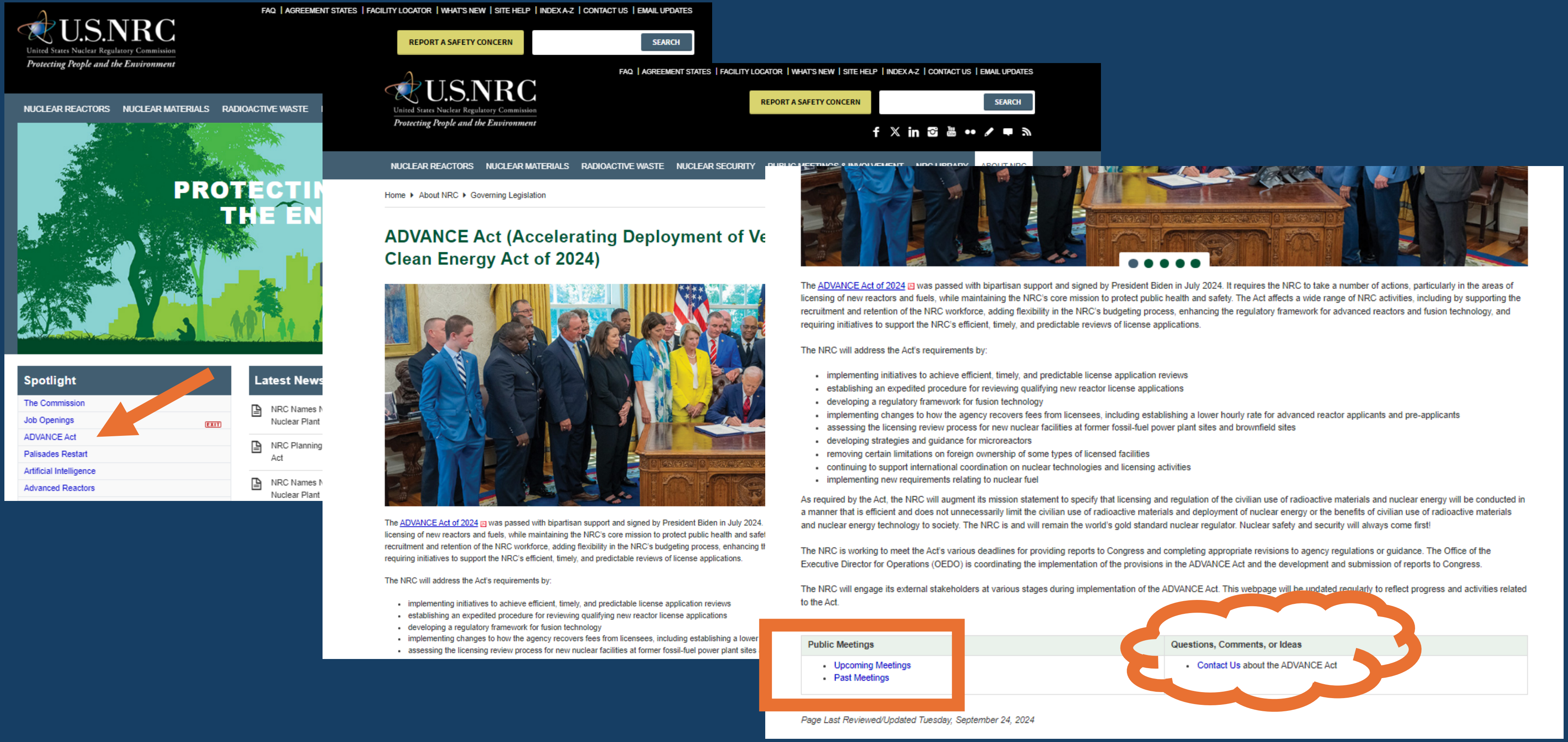
a detailed explanation accounting for the delay; and

a plan for completion of the applicable action.

NRC Staff Plans to Address ADVANCE Act Section 207

- The NRC staff has initiated seeking stakeholder input on an expedited review procedure for COL applications.
  - The NRC staff plans to conduct a comment-gathering meeting in early 2025.
- The NRC staff is considering issuing a Regulatory Issue Summary to address the requirements in Section 207.

NRC Public Website for ADVANCE Act of 2024



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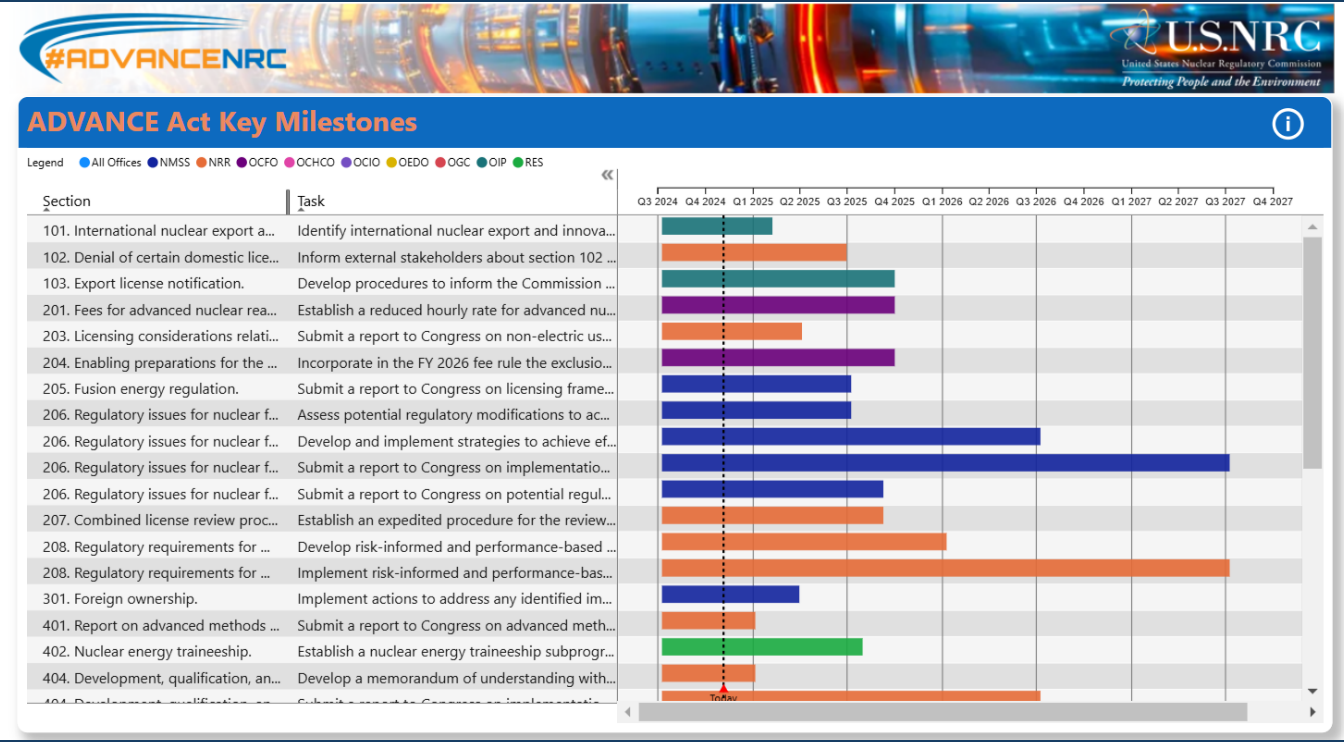

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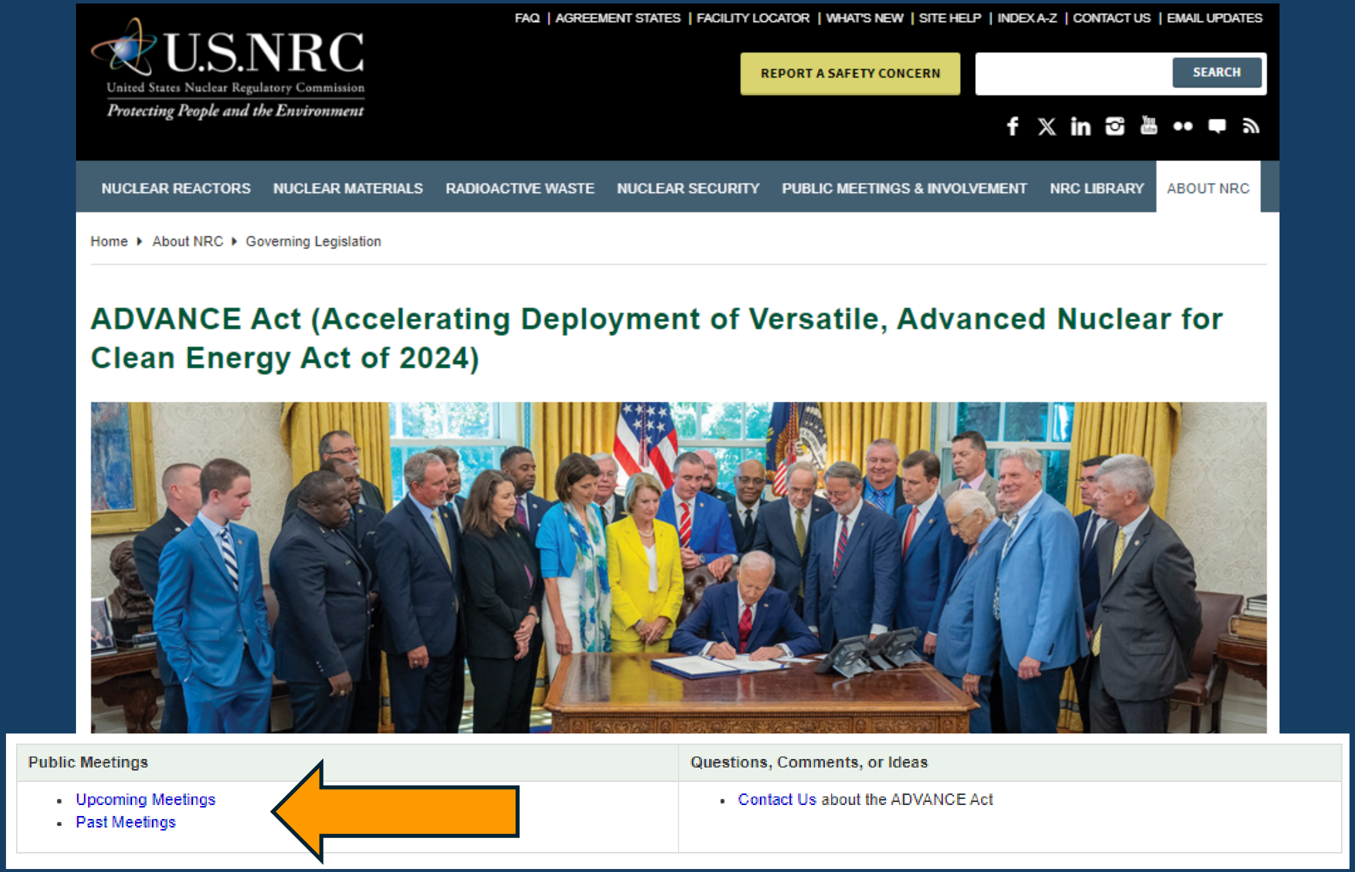

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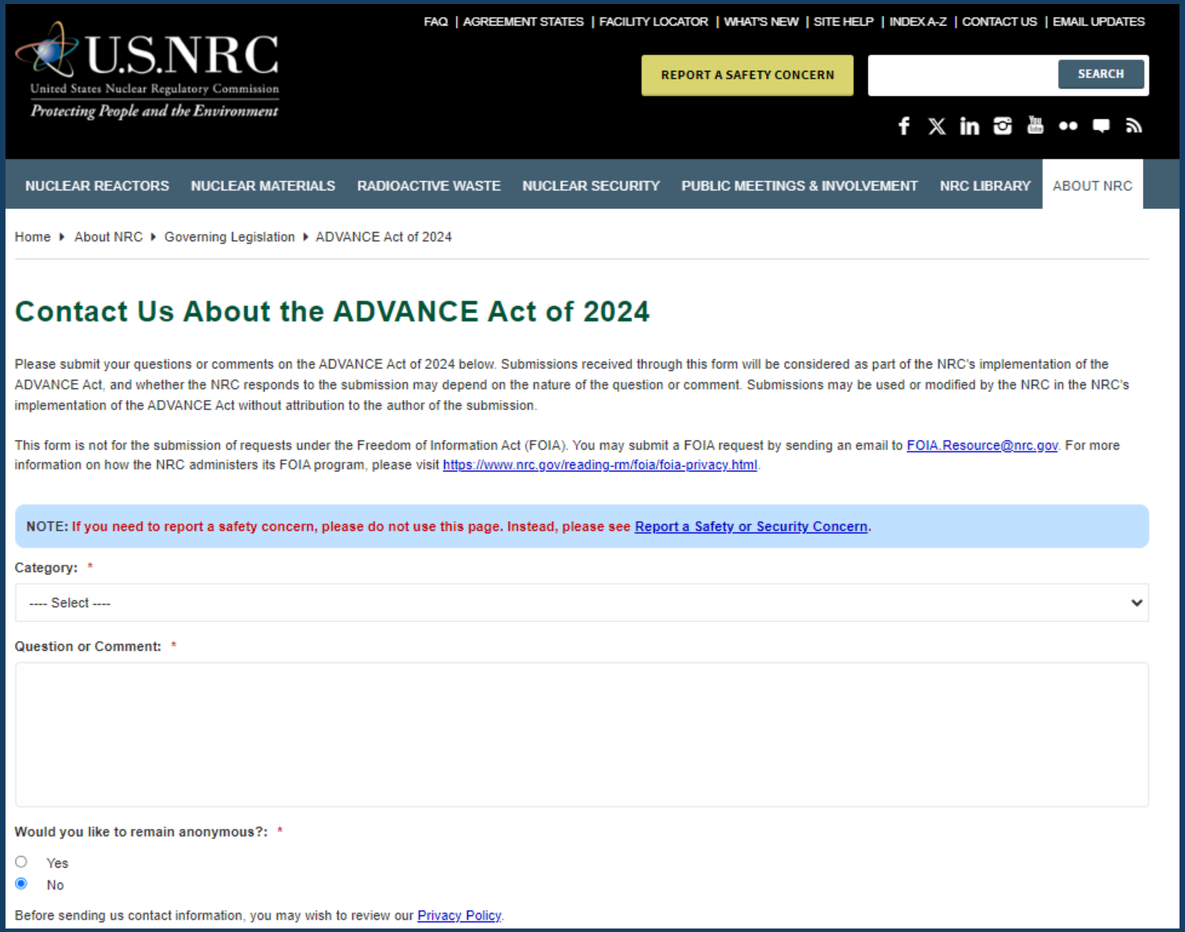
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CNSC-NRC Memorandum of Cooperation: Joint Report on Classification of Structures, Systems, and Components

Steve Jones
Division of Advanced Reactors and Non-Power Production and Utilization Facilities
Office of Nuclear Reactor Regulation

AGENDA

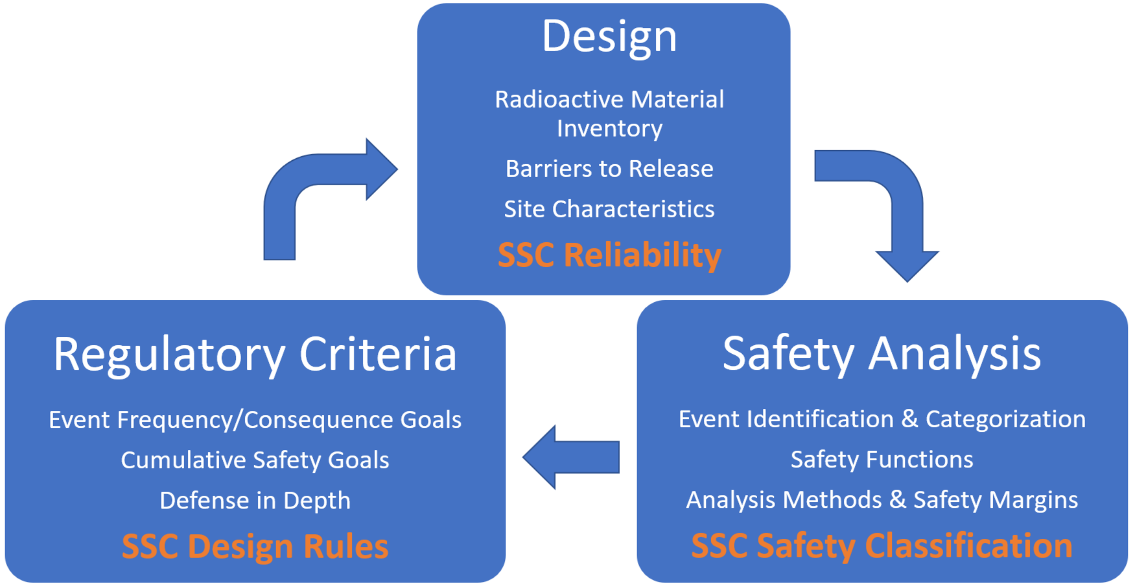
- Work Plan
- Scope of Safety Classification Project
- Findings
  - Safety Significance Determination
  - Classification of Structures, Systems, and Components
  - Engineering Design Rules and Specifications
- Use in Application Development

WORK PLAN OBJECTIVES

- Identify key similarities and differences in the safety significance determination process, the scope of SSCs subject to the process, and the process outcomes
- Identify key similarities and differences in the engineering design rules and specifications applied to each safety class and how this impacts the outcomes
- Review how each organization applies existing codes and standards and interacts with Standards Development Organizations (SDOs) to verify appropriate codes and standards are being developed, applied, and endorsed.

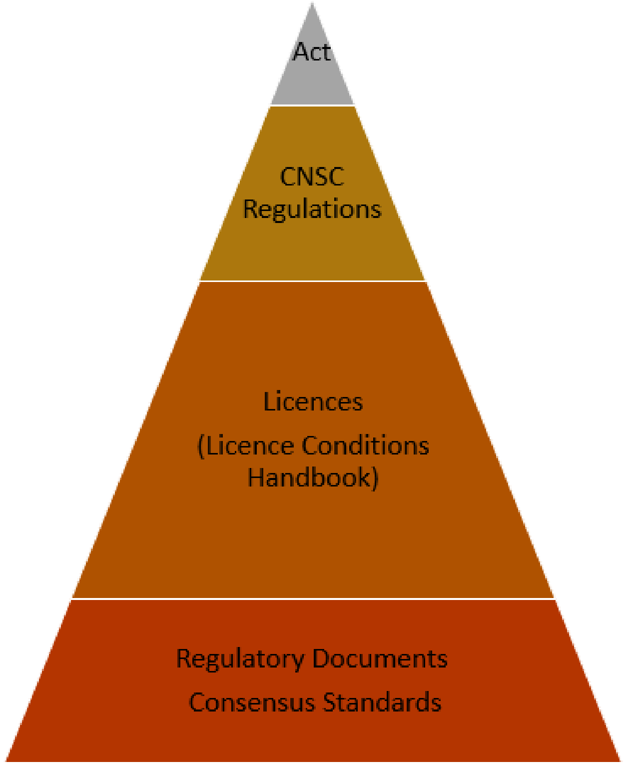
SCOPE

- New Water-Cooled Small Modular and Advanced Non-Water-Cooled Reactors
- Safety Significance Determination and SSC Classification

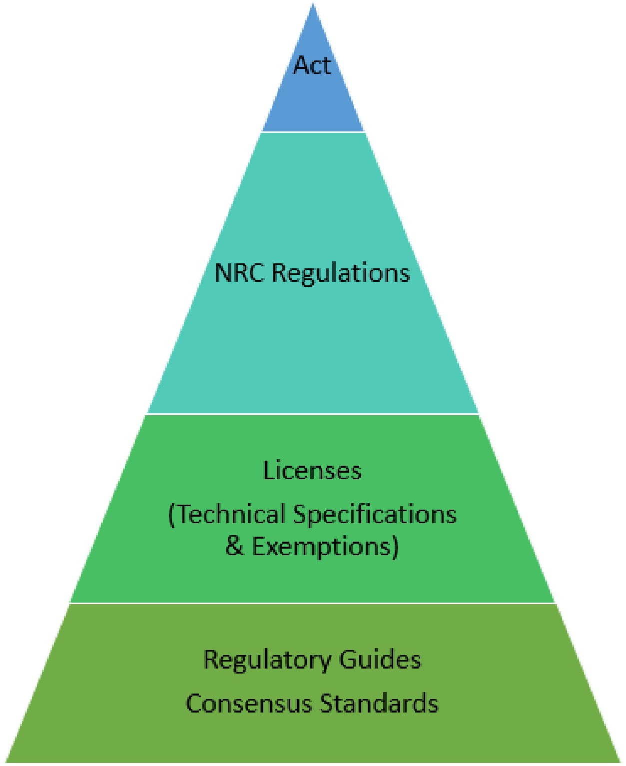


- Design rules and specifications
  - Reliability Programs
  - SSC Design
  - Hazard Protection

REGULATORY BACKGROUND



CNSC Regulatory Hierarchy



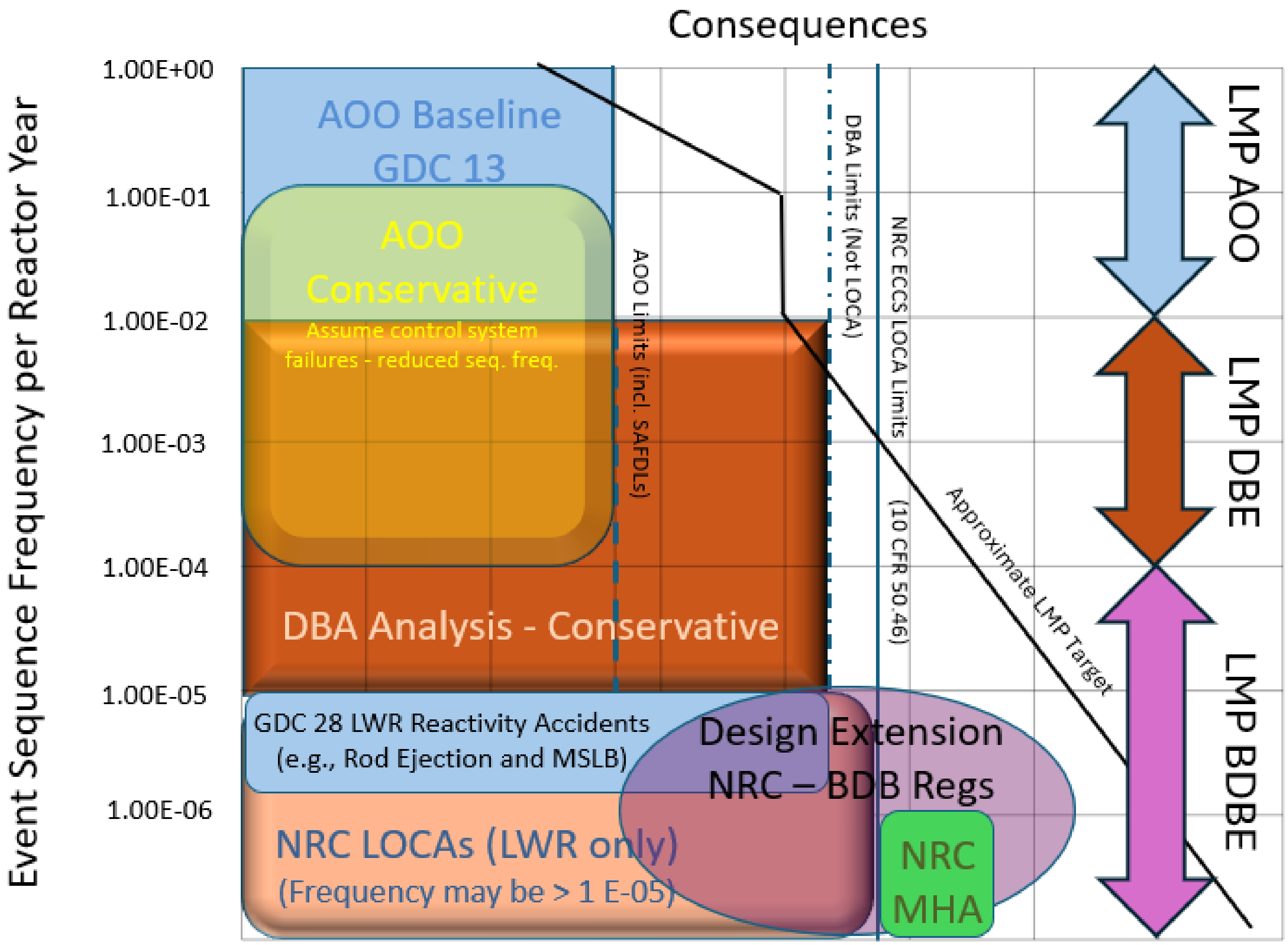
NRC Regulatory Hierarchy

- CNSC places detailed requirements in license
- NRC has more detailed regulations
  - Many regulations specific to LWRs
  - Exemption process provides flexibility

SAFETY ANALYSIS APPROACHES

Element	CNSC	NRC Traditional	NRC LMP
Use of PRA	Level 2 – Complementary to deterministic analysis	Level 1 - Confirmatory and identification of risk insights	Level 3 - Foundational; supported by deterministic analyses
Defense in Depth	Structured defense-level review	Established by design criteria and special regulations	Structured review of capabilities and programs
Safety classification	Applicant designated classifications of important to safety SSCs; safety systems selected for accident mitigation	Safety-related SSCs selected to mitigate accidents; important to safety for defense in depth functions	Safety-related SSCs selected to mitigate accidents; nonsafety-related with special treatment for defense in depth functions
Accident Classification	Sequence frequency	Guidance (Qualitative assessment)	Sequence frequency

SAFETY SIGNIFICANCE DETERMINATION



Similarities and Differences
AOO Baseline/ GDC 13/ LMP essentially the same
AOO conservative analysis captured among LMP DBEs
DBA analysis methods reasonably consistent
LMP dose/consequence target at DBE/BDBE boundary inconsistent with CNSC DBA dose criterion
NRC Traditional Approach limiting LWR analyses (LOCA, GDC 28 reactivity accidents, maximum hypothetical accident [MHA], and regulated events) help with DID in absence of quantitative risk criteria
Containment bounding analysis (maximum hypothetical accident – MHA) for traditional NRC vs. mechanistic DBA (CNSC and LMP)
CNSC Design Extension substantially overlaps with NRC BDB regulations and LMP BDBE analysis

SAFETY CLASSIFICATION

- CNSC Safety System performs DBA prevention/mitigation function like NRC Safety-Related
- Risk-informed NRC classification schemes better aligned with CNSC graded classification
- Safety classification has more prescriptive relationship with engineering design rules under NRC regulations than under CNSC.

Safety Significance	High			Low
CNSC	Important to Safety (ITS)			Not Important to Safety (NITS)
	Safety Systems			
	ITS - High	ITS - Medium	ITS - Low	NITS
NRC LMP	LMP Risk Significant (and Safety Significant)	LMP Safety Significant		Not Safety Significant
	Safety-Related			Non-Safety-Related No Special Treatment
	Non-Safety-Related with Special Treatment			
NRC Traditional	Important to Safety			NITS
	Safety-Related (RISC-1)		Safety-Related (RISC-3)	NITS
	ITS (Not Safety-Related) (RISC-2)		ITS (RISC-4)	

SPECIAL TREATMENT SCOPE

Special Treatment	Similarity	Important Considerations
Quality Assurance	Substantial	Improved by NRC risk-informed programs
Operational Reliability	High	Identical for TSs; risk-based availability monitoring scope for CNSC; flexible testing and condition monitoring scope supports alignment
Pressure-Retaining	High	Similar quality group definitions
Electrical / I&C	High	Same types of electrical and I&C components
Civil Structures	High	Structures perform identical functions
Seismic Qualification	Moderate	CNSC qualifies more defense-in-depth SSCs
Fire protection	High	Similar goals to control and confine fires
Environmental Qualification	High	Similar definitions of required scope

SPECIAL TREATMENT EXTENT

Special Treatment	Similarity	Important Considerations
Quality Assurance	Substantial	Appendix B more prescriptive; NRC &CNSC support graded application of QA measures
Operational Reliability	High	Similar programs for availability, performance, and condition monitoring; ASME Code ISI/IST
Pressure-Retaining	High	Equivalent reliance on ASME Code
Electrical / I&C	High	Many overlapping IEEE and IEC standards
Civil Structures	Substantial	Overlapping standards; but many country-specific standards as well.
Seismic Qualification	High	Similar qualification process and standards
Fire protection	High	Overlapping standards and program goals
Environmental Qualification	High	Overlapping standards

USE IN APPLICATIONS

- Compliance with regulatory requirements:
  - Good agreement on design criteria (Appendix A of report)
  - CNSC approach flexibility supports alignment of SSCs with highest safety significance to those classified as safety-related (risk-informed classification)
  - CNSC design-extension aligned with NRC special regulations and LMP BDBEs
- Defense-in-depth:
  - Evaluation necessary to ensure NRC traditional approach supports structured defense-level evaluation
  - LMP aligns with CNSC; provides structured evaluation
- Assignment of design rules:
  - Significant commonality in scope and extent of design rules supported by many shared standards
  - Conservative use of Appendix B to Part 50 for quality assurance of SSCs with highest safety significance (Appendix B of Report)
  - Justification of seismic qualification scope and civil structure standards may be necessary

AVAILABILITY OF JOINT REPORT

- Expected to be available on NRC and website December 2024
- Availability will be under the following link:

  - https://www.nrc.gov/reactors/new-reactors/advanced/who-were-working-with/international-cooperation/nrc-cnsc-moc/joint-reports.html

Selection of Seismic Scenario for EPZ Sizing Determination

December 12, 2024

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Response to NRC Comments & Questions on Subject NEI White Paper

Comment/Question #1

- Please discuss how the approach can be implemented at the construction permit stage
  - The design of the SSCs will already be at the stage where a margin assessment can be performed. This being the case, the fragility parameters will be available that are needed to perform the calculation of $C_{10\%}$. This will be shown in a Tabletop.
  - Level-3 PRA is not required. All that is needed is a source term and dose calculation model that can be set up to evaluate the specified seismic scenario (plant damage state). This will be shown in the Tabletop.

Comment/Question #2

- Please discuss (i) appropriateness of $C_{10\%}$ criterion (2 × GMRS), and (ii) assumption that any SSC that has $C_{10\%}$ capacity greater than 2 × GMRS is considered fully successful
  - (i) is shown to be appropriate through the detailed analysis provided in Section 5 of the NEI White Paper. As explained, a holistic consideration of the insights from past SPRAs with knowledge of the safety improvements in new plant designs indicates that a scenario based on 2 x GMRS adequately represents the conditions where emergency response should be required.
  - (ii) is based on the approach approved by NRC for use in the assessment of seismic MSA per R.G. 1.226, which endorses NEI 12-06. The use of the $C_{10\%}$ as a "pass-fail" criterion for success is a fundamental part of Appendix H of NEI 12-06.

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Comment/Question #2 (continued)

- Discuss how cliff-edge effects will be determined under these circumstances.
    - The check for cliff edge effects is discussed in Section 10 of the NEI White Paper. The scenario (plant damage state) will add the additional failures of any SSCs whose $C_{10\%}$ is within 10% of 2 x GMRS. This captures the concept of what would be the impact on the results of a step increase in the earthquake severity.
    - This will be illustrated in the Tabletop.

Comment/Question #3

- There is an implicit assumption in the White Paper that the site-specific GMRS is the ASCE 43 SDC-5 GMRS. This assumption needs to be explicitly stated.
  - It will be stated that the GMRS to be used is that specified in R.G. 1.208, i.e., “a site-specific, performance-based GMRS, satisfying the requirements of paragraphs (c), (d)(1), and (d)(2) of 10 CFR 100.23, and leading to the establishment of an SSE to satisfy the design requirements of Appendix S to 10 CFR Part 50.”
  - This is what was used as the basis for the evaluations in the NEI White Paper.

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Comment/Question #4

- It is not clear why the cut-off of 1.0g PGA is needed and is appropriate for sites with higher seismicity. In addition, PGA, as a ground motion measure, is by itself, not a good determinant for damage.
    - As discussed in Section 6 of the NEI White Paper, there is a need to establish some upper severity above which Emergency Planning is not practical, accounting for the post-earthquake status of the necessary infrastructure to support implementation.
    - While PGA is used as a common reference point for ease of understanding (which has always been the practice), all of the analysis done for the NEI White Paper used the entire spectral shape.

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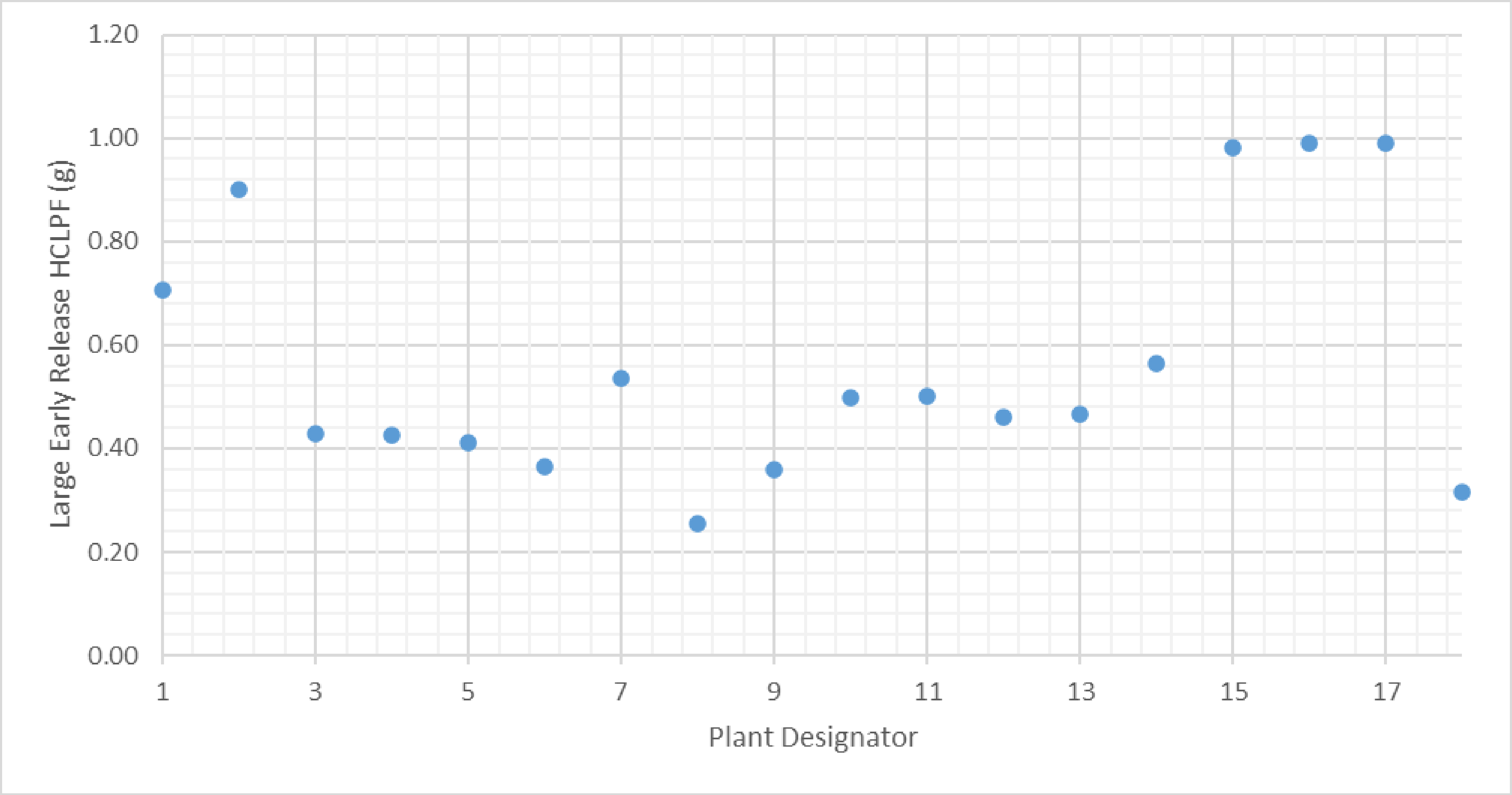
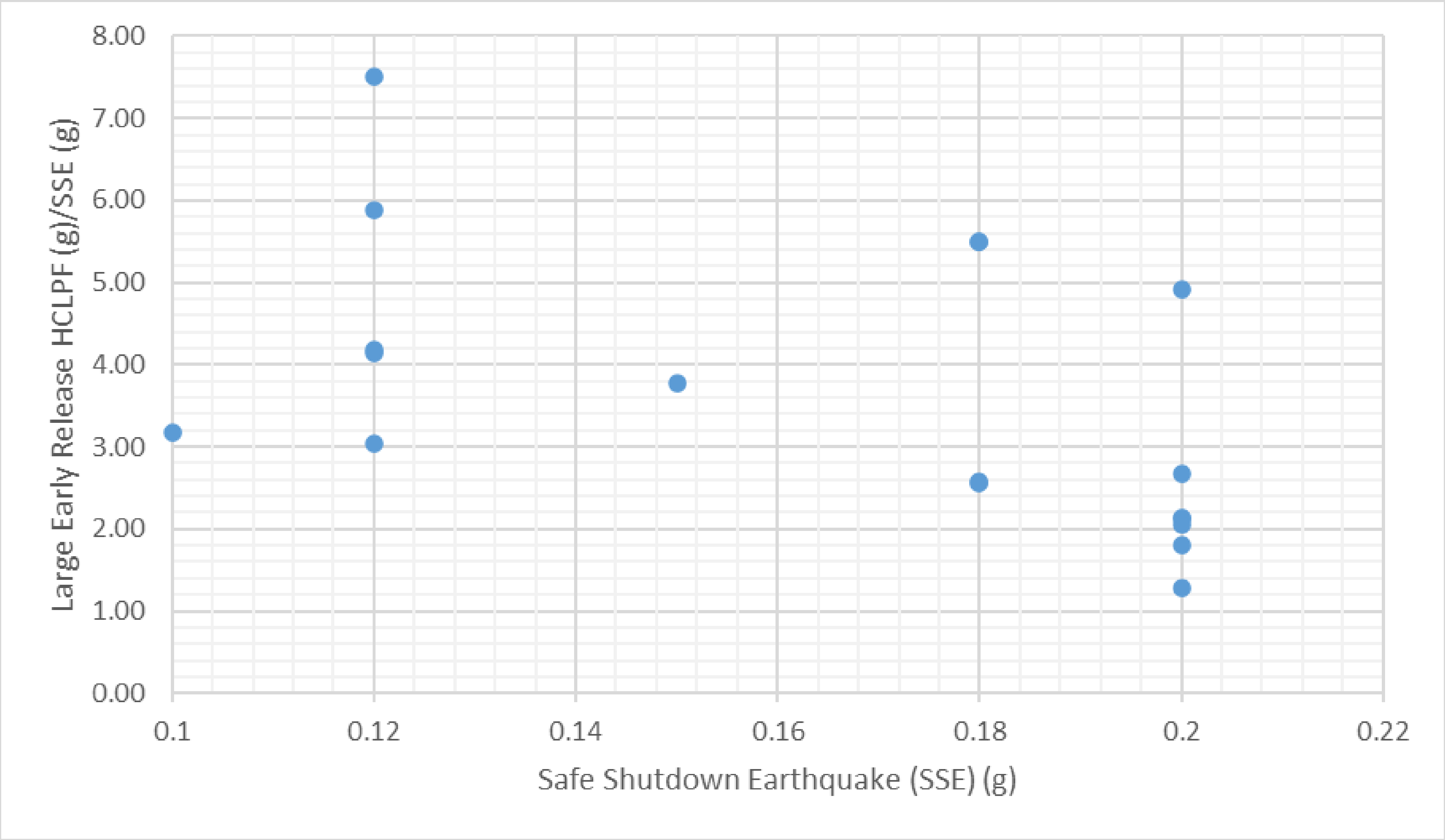
Comment/Question #5 (1/3)

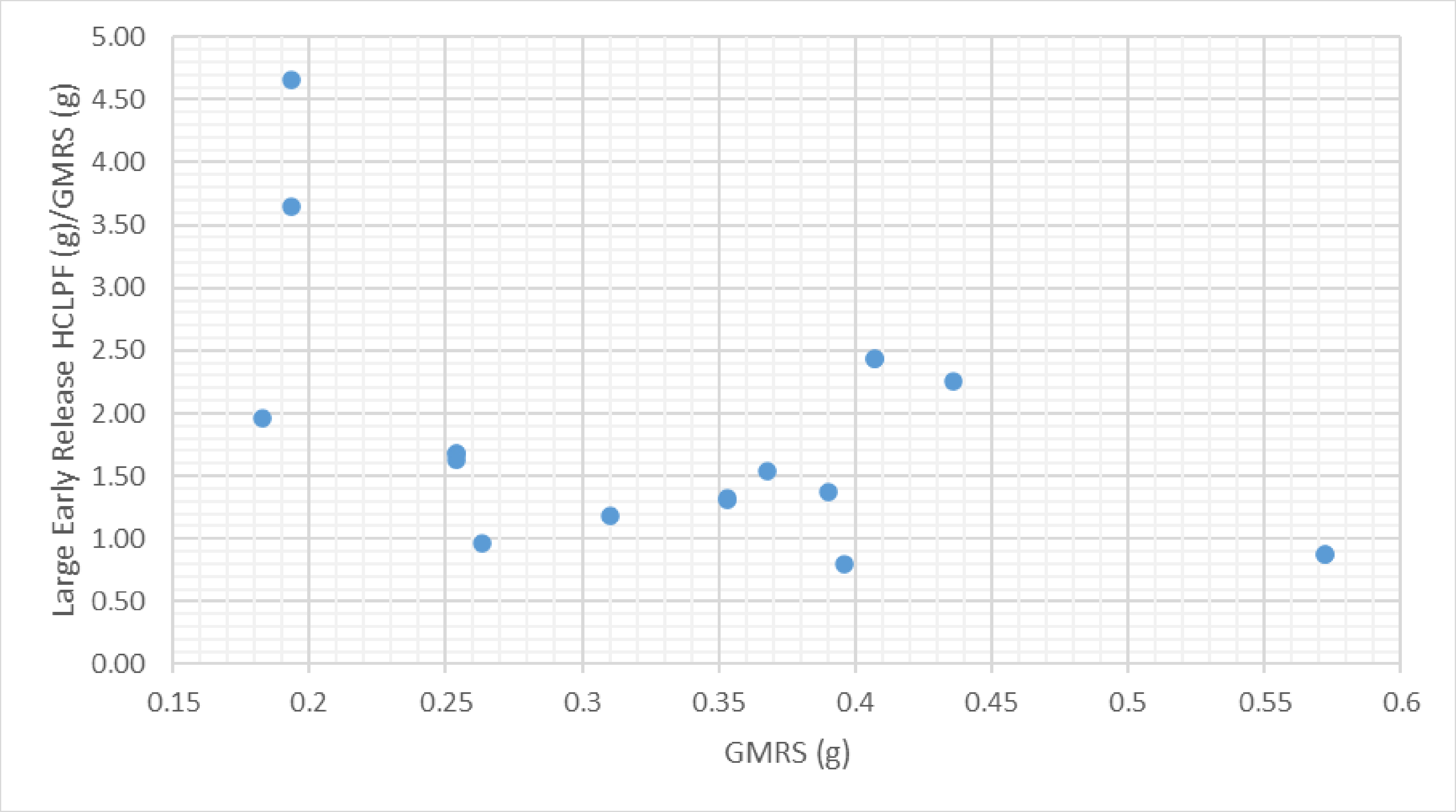
- Please provide the HCLPF data for LERF for the plants studied.



Comment/Question #5 (2/3)



Comment/Question #5 (3/3)



Comment/Question #6

- Please provide examples that show how the $C_{10\%}$ criterion is applied at a cutset level, how a plant damage state is determined, and how the doses were calculated. The examples should also include evaluation of cliff-edge effects.
  - This will be illustrated in the Tabletop.
- The examples should include sensitivity studies considering various design options under the non-LLWR RIPB based seismic design.
  - We believe that the single design example in the Tabletop will be adequate to demonstrate the approach.

Comment/Question #7

- Please clarify whether the application of the approach in the White Paper results in a single scenario failure or if there are multiple failure scenarios.
  - A single scenario.
  - This will be demonstrated in the Tabletop.

Comment/Question #8

- Please discuss whether your suggested scenario approach will always bound the results from the ANL approach.
  - ANL_NSE-21-56 does not actually propose an approach, but rather investigates using a PRA-based margin assessment for the purpose of determining the challenges, opportunities, and next steps.
  - ANL and NEI have been exchanging information, and the NEI White Paper was one input to ANL_NSE-24-42, the “next steps” from ANL_NSE-21-56 are currently in draft.
  - ANL_NSE-24-42 proposes to use the same 2 x GMRS and $C_{10\%}$ as its check on cliff-edge effect. This is the base case for the NEI White Paper, which has then a further, stricter cliff-edge check.
  - Difference is that ANL_NSE-24-42 is intended to develop plant-level safety insights per Part 53; the NEI White Paper is intended to identify the single scenario required for EPZ determination.

Comment/Question #9

- Please discuss how this approach differs from that was used in the recently approved NuScale design certification.
    - NuScale considers their approach to be proprietary and has chosen not to make it available to NEI or other industry organizations.
    - As a note, we expect that the NuScale approach (while it could probably be adapted to other designs in some way) was designed specifically for use with that design. The NEI White Paper is intended to be technology neutral with regard to any light-water or non-light-water SMR.

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Comment/Question "#10"

- It is unclear how the result will be used to compare against criteria in 10 CFR 50.160 and how the methodology interfaces with the remainder of the rule.
  - The NEI White Paper is not a stand-alone document for compliance with 10 CFR 50.160. The result is simply one input into the overall risk-informed, performance-based approach to emergency planning described in NEI 24-05.
  - The white paper is limited to describing the approach to defining the seismic scenario and plant damage state to be used in the overall assessment (i.e., it feeds into Chapter 4, Section 4.3.4, of NEI 24-05 as an Alternative Hazard Event).
  - All other interfaces with the rule are handled identically to the other EPZ scenarios as described in NEI 24-05.

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Comment/Question "#11"

- NEI should address how changes in the facility during the life of the plant would be addressed to assess any changes needed to the emergency plan.
  - The approach in the NEI White Paper is only for the purpose of determining the boundary of the EPZ.
  - The need for changes would be addressed in accordance with Section 5.1 of NEI 24-05, Maintenance of Performance – 50.160(b)(1)(i).

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Discussion

LUNCH BREAK

Meeting will resume at 1:00 pm EST

December 12, 2024

Microsoft Teams Meeting

Bridge line: 301-576-2978

Conference ID: 765 241 117#

ADVANCE Act Section 203 Nonelectric Uses

William Reckley
Ryan Mott

December 12, 2024

Scope of Meeting

- Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act of 2024
  - #ADVANCENRC

Today's Discussions

- Section 203 – Licensing Considerations Relating to the Use of Nuclear Energy for Nonelectric applications
- Seeking insights into unique licensing issues or requirements
- Added to stakeholder meeting agenda on November 28, 2024

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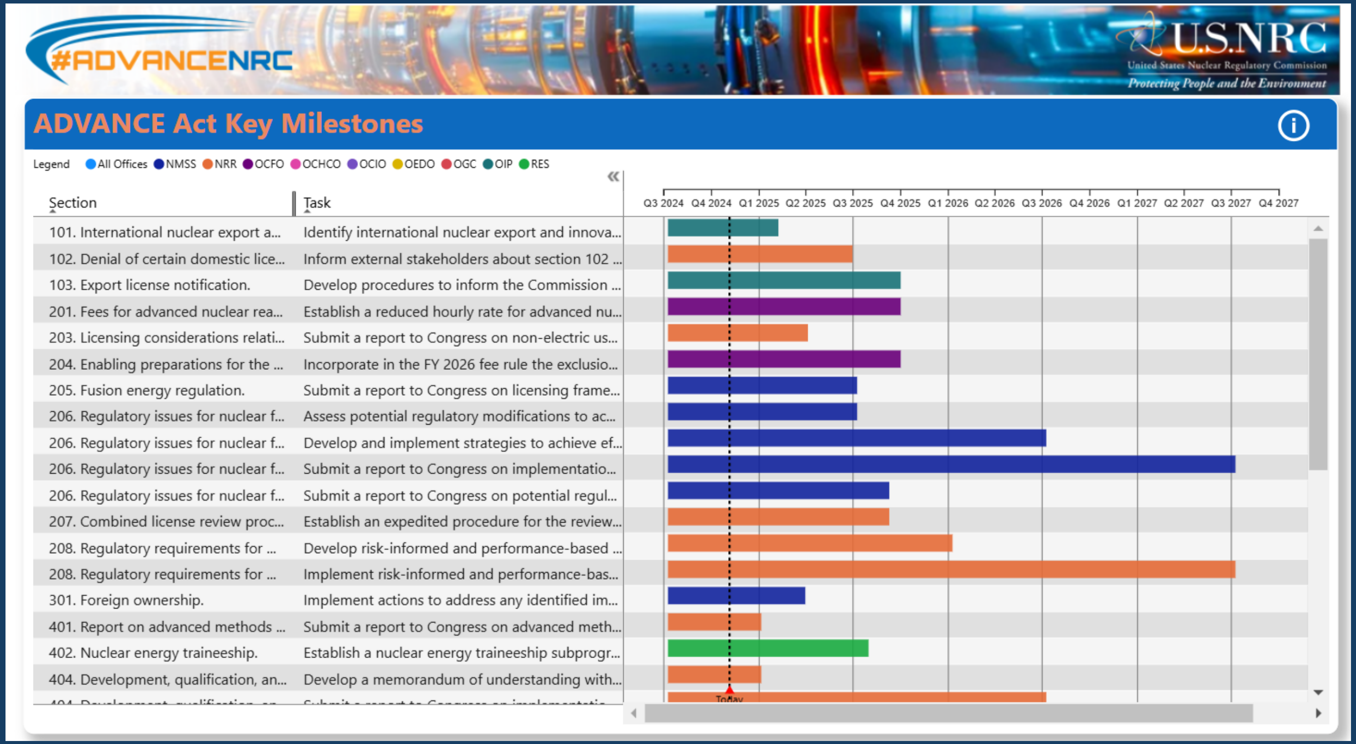

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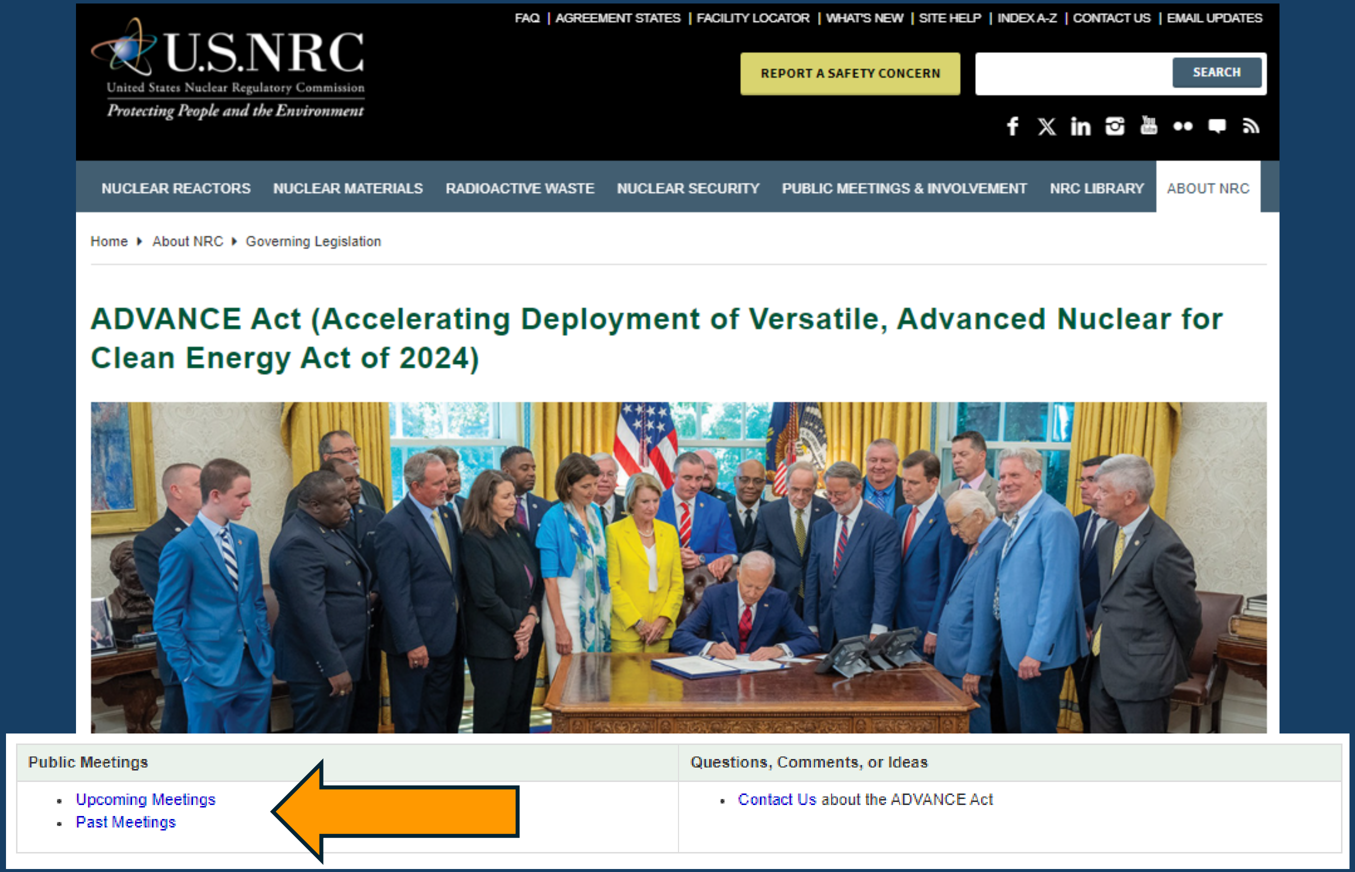

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Would you like to remain anonymous?: *

- Yes
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Section 203 – Nonelectric Applications

ADVANCE Act § 203. LICENSING CONSIDERATIONS RELATING TO USE OF NUCLEAR ENERGY FOR NONELECTRIC APPLICATIONS.

- **General Issues**
- Specific Applications
- Framework

(a) IN GENERAL.— Not later than 270 days after the date of enactment of this Act, the Commission shall submit . . . a report addressing any unique licensing issues or requirements relating to—

(1) the flexible operation of advanced nuclear reactors, such as ramping power output and switching between electricity generation and nonelectric applications;

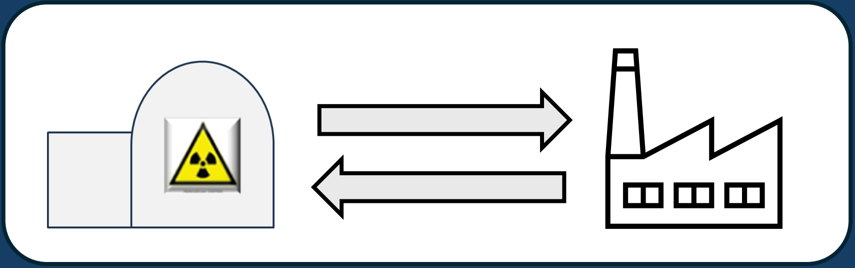
(2) the use of advanced nuclear reactors exclusively for nonelectric applications; and

(3) the colocation of nuclear reactors with industrial plants or other facilities.

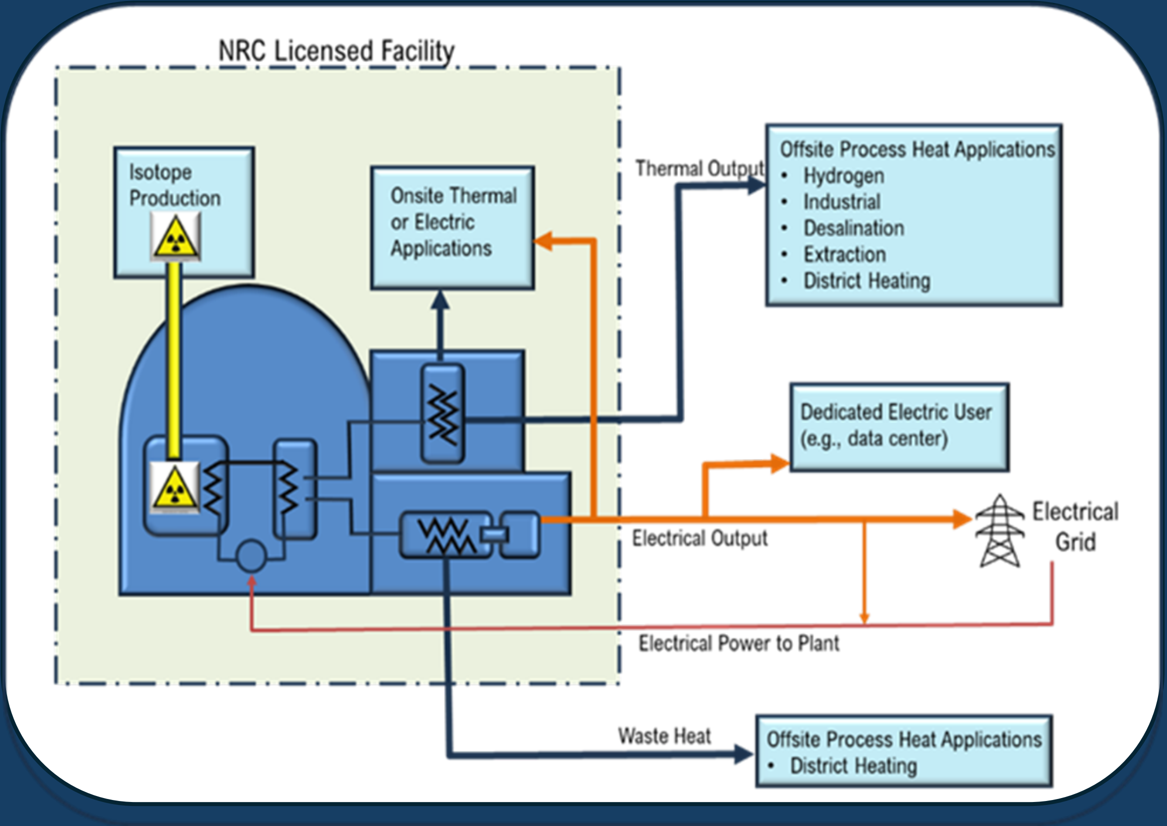
Section 203 – Nonelectric Applications

Key Topics

- Siting
  - **Onsite.** Within boundaries of NRC licensed facility.
  - **Offsite.** In proximity to but outside boundaries of NRC licensed facility.



- Routine operations (effluents)
- Postulated accidents



Section 203 – Nonelectric Applications

BACKGROUND – Licensing and Siting Nuclear Plants

- Reactor Design Reviews
  - Light-Water Reactor (LWR) Standard Review Plan (NUREG-0800)
  - Non-Light-Water Reactor (non-LWR) Advanced Reactor Content of Applications Project (ARCAP) Roadmap (ISG-DANU-2022-01)
  - Plant Systems Designed Considering External Hazards
    - Natural Hazards (e.g., seismic, flooding, winds, precipitation)
    - Constructed Hazards (e.g., industrial, military, transportation)
- Siting Considerations
  - Site Characteristics - External Hazards
  - Population Considerations
  - Environmental Reviews

Section 203 – Nonelectric Applications

ADVANCE Act § 203. LICENSING CONSIDERATIONS RELATING TO USE OF NUCLEAR ENERGY FOR NONELECTRIC APPLICATIONS.

- General Issues
- **Specific Applications**
- Framework

(c) CONTENTS.—

(1) IN GENERAL.—The report under subsection (a) shall describe—

(A) any unique licensing issues or requirements relating to the matters described in paragraphs (1) through (3) of subsection (a), including, with respect to the nonelectric applications referred to in paragraphs (1) and (2) of that subsection, any licensing issues or requirements relating to the use of nuclear energy—

- for specific applications

Section 203 – Nonelectric Applications

ADVANCE Act § 203. LICENSING CONSIDERATIONS RELATING TO USE OF NUCLEAR ENERGY FOR NONELECTRIC APPLICATIONS.

- General Issues
- **Specific Applications**
- Framework

(c) CONTENTS.—

Specific applications under (c)(1)(A):

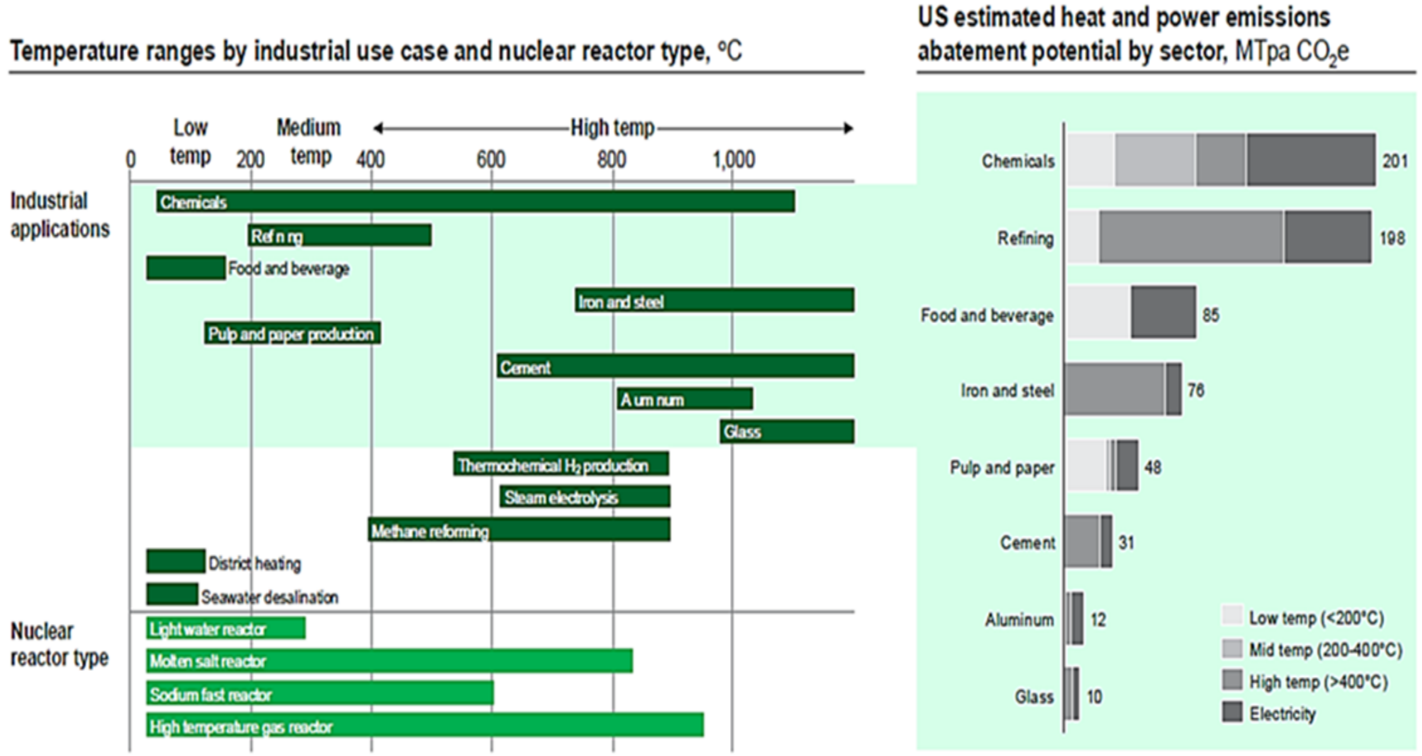
i. for hydrogen or other liquid and gaseous fuel or chemical production;
ii. for water desalination and waste water treatment;
iii. for heat used for industrial processes;
iv. for district heating;
v. in relation to energy storage;
vi. for industrial or medical isotope production; and
vii. for other applications, as identified by the Commission

Section 203 – Nonelectric Applications

ADVANCE Act § 203. LICENSING CONSIDERATIONS RELATING TO USE OF NUCLEAR ENERGY FOR NONELECTRIC APPLICATIONS.

- General Issues
- **Specific Applications**
- Framework

Figure 16: Nuclear provides high temperature heat that can decarbonize industrial applications[65,66,67]



From DOE report "Pathways to Commercial Liftoff: Advanced Nuclear"

Section 203 – Nonelectric Applications

ADVANCE Act § 203. LICENSING CONSIDERATIONS RELATING TO USE OF NUCLEAR ENERGY FOR NONELECTRIC APPLICATIONS.

- General Issues
- Specific Applications
- **Framework**

(c) CONTENTS.—

(1) IN GENERAL.—The report under subsection (a) shall describe—

* * *

(B) options for addressing those issues or requirements

i. within the existing regulatory framework;

ii. as part of the technology-inclusive regulatory framework required under subsection (a)(4) of section 103 of [NEIMA]; or

iii. through a new rulemaking;

Section 203 – Nonelectric Applications

ADVANCE Act § 203. LICENSING CONSIDERATIONS RELATING TO USE OF NUCLEAR ENERGY FOR NONELECTRIC APPLICATIONS.

- General Issues
- Specific Applications
- **Framework**

(c) CONTENTS.—

(1) IN GENERAL.—The report under subsection (a) shall describe—

* * *

(C) the extent to which Commission action is needed to implement any matter described in the report.

(2) COST ESTIMATES, BUDGETS, AND TIMEFRAMES.—The report shall include cost estimates, proposed budgets, and proposed timeframes for implementing risk-informed and performance-based regulatory guidance in the licensing of nuclear reactors for nonelectric applications.

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U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

Nuclear – Integrated Energy Systems

Jason Marcinkoski, DOE-Nuclear Energy Federal Program Manager

Richard Boardman, National Technical Director

December 2024

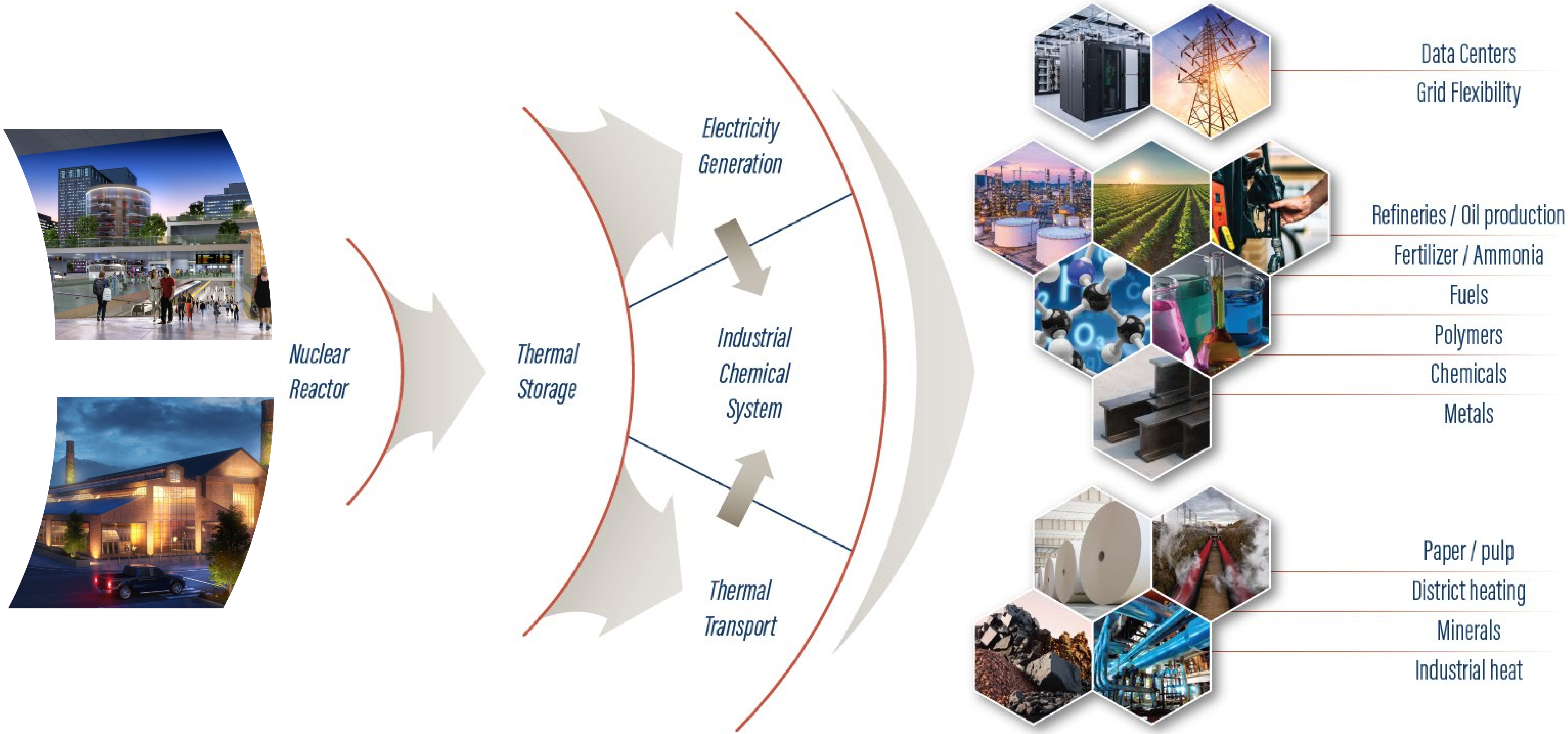
Prepared for:
Bill Reckley, Senior Policy Analyst at US Nuclear Regulatory Commission

Nuclear Reimagined

(images from thirdway)

- Liquid coolants enable low pressure cooling systems. (e.g. molten salt, liquid metal)
- Higher temperature reactors enable more efficient and broader industrial use, as well as dry cooling. (e.g. molten salt, liquid metal, high temperature gas)
- Fast reactors can be technically capable of making their own fuel inside the reactor core, and burning high-level waste.
- Passive cooling and reactivity control enable walk-away safety.
- Smaller Emergency Planning Zone allows close proximity to industrial applications
- High power density results in low land-use and low embodied emissions.
- High availability and reliability– high capacity factor / good economics.
- 200 GW new nuclear expected by 2050 (DOE Nuclear Liftoff Report).

The Future Landscape for Nuclear Energy Systems



Integrated Energy Systems Program

Vision Statement: Affordable, clean, reliable energy generation and delivery systems

Mission Statement

- **Maximize the use of nuclear energy by developing technologies to support chemical, thermal and electrical energy pathways that deliver nuclear energy to the industrial, transportation and commercial sectors.**

How to achieve the vision

- **NUCLEAR INTEGRATED ENERGY SYSTEMS**
  - Systems that integrate nuclear reactors with industrial processes that produce fuels, chemicals, materials, and electricity
  - Identify/develop novel energy use technologies resulting from greater availability of clean, reliable, low-cost nuclear heat and electricity.
- **FOUR PILLARS**
  - **National Potential**
  - **Nuclear Applications R&D**
  - **Thermal Systems R&D**
  - **Chemical Conversion R&D**

Objective & Goals

- **INDUSTRIAL**
  - Enable the deployment of nuclear reactors with distribution and control systems capable of delivering heat directly to major industrial and commercial applications.
  - Convert nuclear energy into fuels for industry (e.g. substitute natural gas, synthetic liquid fuels)
- **ELECTRIC POWER**
  - Provide flexible electrical generation capacity with thermal energy storage
- **TRANSPORTATION**
  - Convert nuclear energy into transportation fuels

Nuclear Integrated Energy Systems

National Impact of Nuclear Integrated Energy Systems

- Estimates the U.S. market potential and environmental impact of systems that integrate nuclear reactors and their thermal energy into industrial processes that produce fuels, chemicals, materials, and electricity.

Nuclear Applications R&D

- Develops industrial requirements, reference processes, and plant designs to support techno-economic assessments, site integration, and the safety basis for implementing nuclear energy applications.

Thermal Systems R&D

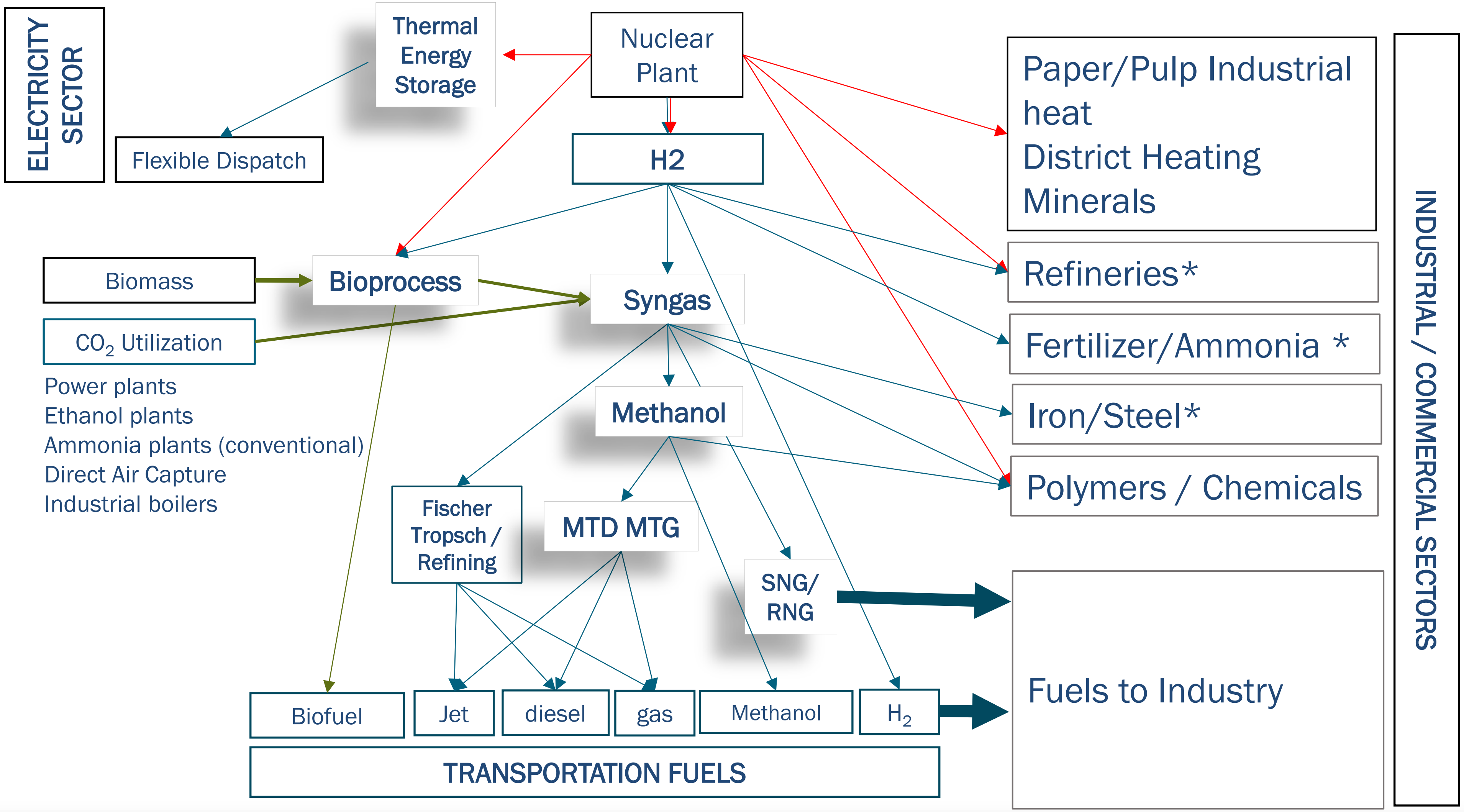
- Evaluates and develops thermal energy transport systems for a variety of temperatures, distances, and industrial uses. This includes heat extraction, thermal storage, temperature boosting, and control systems.

Chemical Conversion R&D

- Develops chemical conversion pathways and tests processes for synthesis of fuels, chemicals, and materials from nuclear energy.

Advanced Nuclear Energy Pathways by Sector

Future Nuclear Energy Currencies are Chemical Feedstocks (Syngas, FT liquids, Methanol, H2)



* significant additional electricity use not shown to simplify diagram

U.S. DEPARTMENT OF ENERGY | Office of NUCLEAR ENERGY

First-Order Embedding of Nuclear Reactors with Process Industries

- Heat and Power
  - Go-generation or combined
  - Heat delivery systems
- Clean hydrogen production
- CO_2 capture and management

Crude Oil Refinery

Methanol Plant

Integrated Steel Manufacturing Plant

Wood Pulp Plant

MW-Scale Thermal Component Test System (INL)

- **Plan:** Develop a modular, reconfigurable technology test facility at MW-scale to reduce risk of commercial deployment of nuclear power for production of hydrogen, biofuels, and chemicals
  - Functions include testing of components, integrated thermal and electrical systems (including grid connections), controls and concepts of operations
  - Initial focus: HXers and thermal energy storage
  - System will be built at INL and will be accessible to connect to industrial demonstration equipment
- **In FY25:** Develop (1) functional & operational requirements, (2) conceptual design, and (3) five-year facility plan
- **In FY26:** (1) Develop front-end engineering design (FEED), and (2) purchase long lead-time items.

Site of the MW Thermal Component Test System

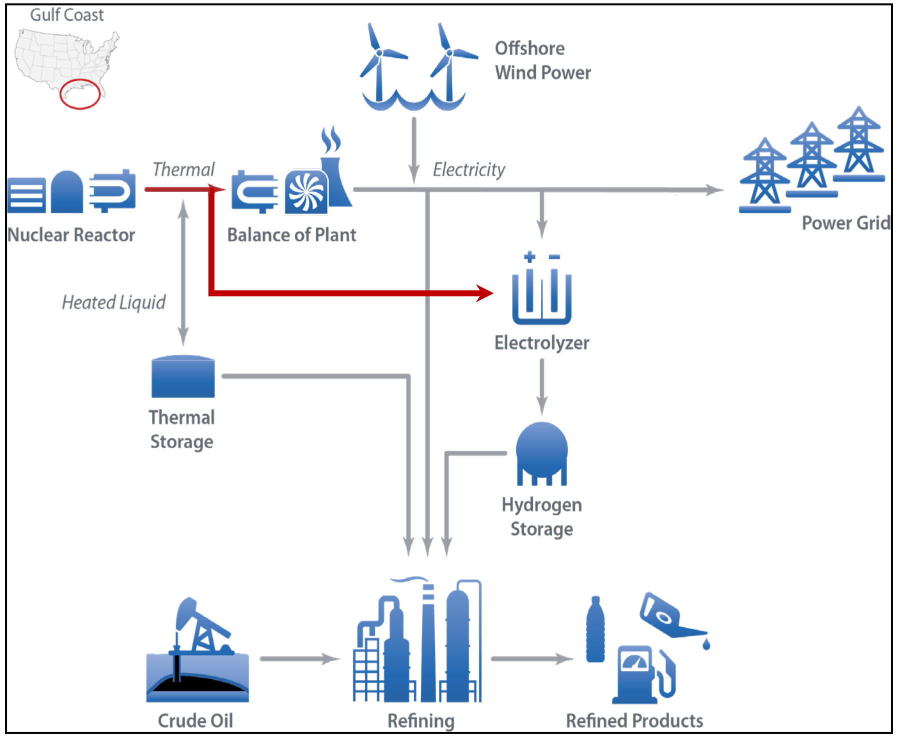
Impact:

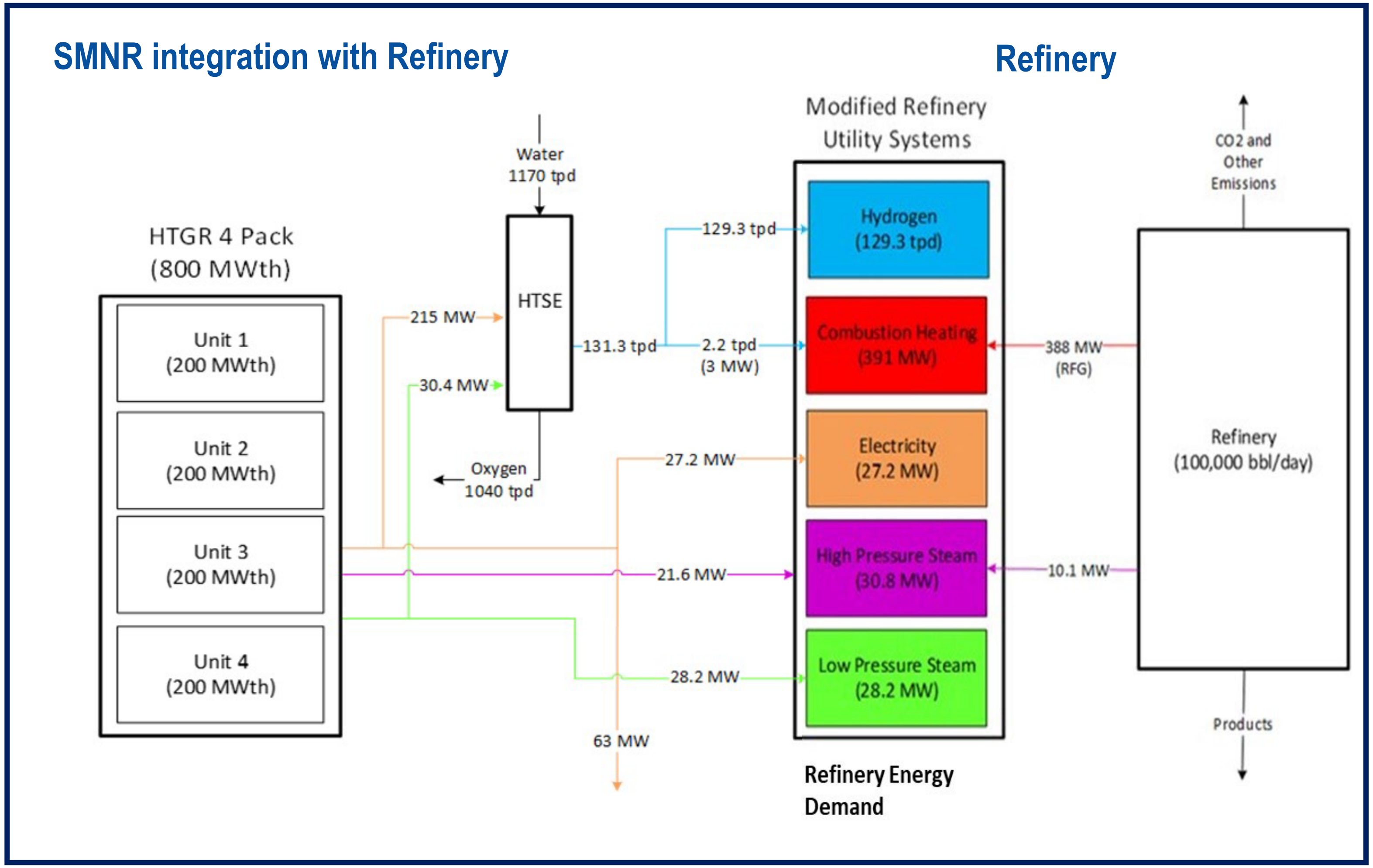
- Provides test capabilities to assess the integrated performance of industrial processes with adv. nuclear power to validate modeled performance and reduce the risk commercial deployment
- Specifically addresses critical materials and heat transfer design and testing activities for HTGR systems to improve system efficiencies and increase economic value

Take aways and inferences

1. Thermal systems component and heat delivery systems is needed to reduce technical, economic, safety, and regulatory risks.
2. Systems testing supports development of operating concepts for industrial applications, including potential remote operation

Nuclear Integration with Petroleum Refineries





Take aways and inferences

1. Nuclear energy can reduce ~50% of refinery without any modification to the refinery unit operations
2. Nuclear energy can be incrementally added with small modular reactors
3. Deeper emissions reduction requires new approaches to manage refinery by-product fuel gas

tpd: Tons per day
bbl: Oil barrel

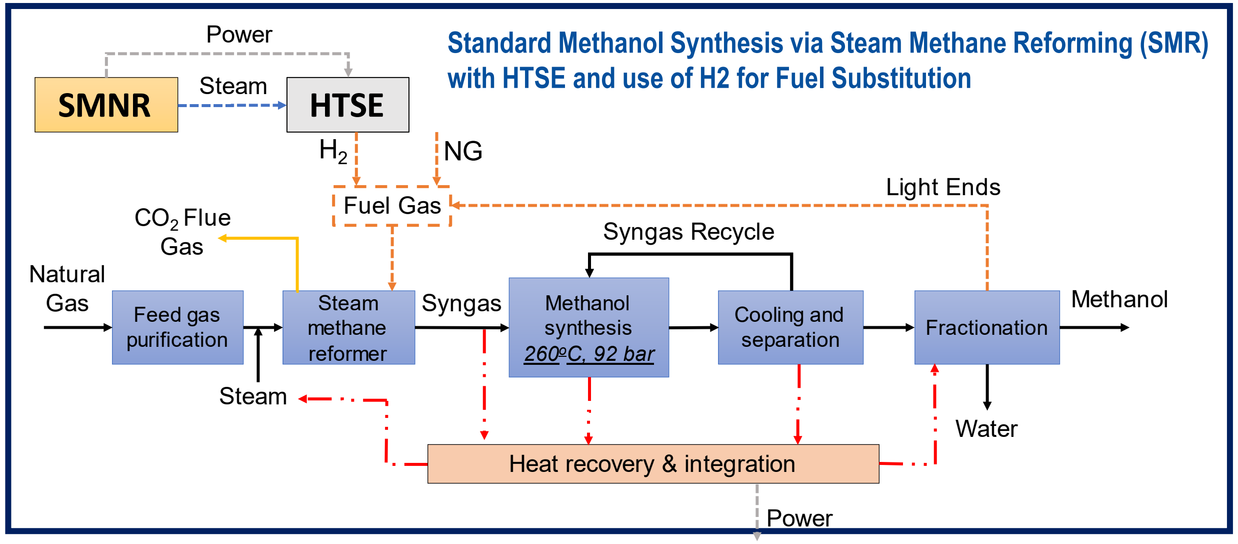
HTSE: High temperature steam electrolysis
SMNR: Small modular nuclear reactor
PRELIM: Petroleum Refinery Life Cycle Inventory Model

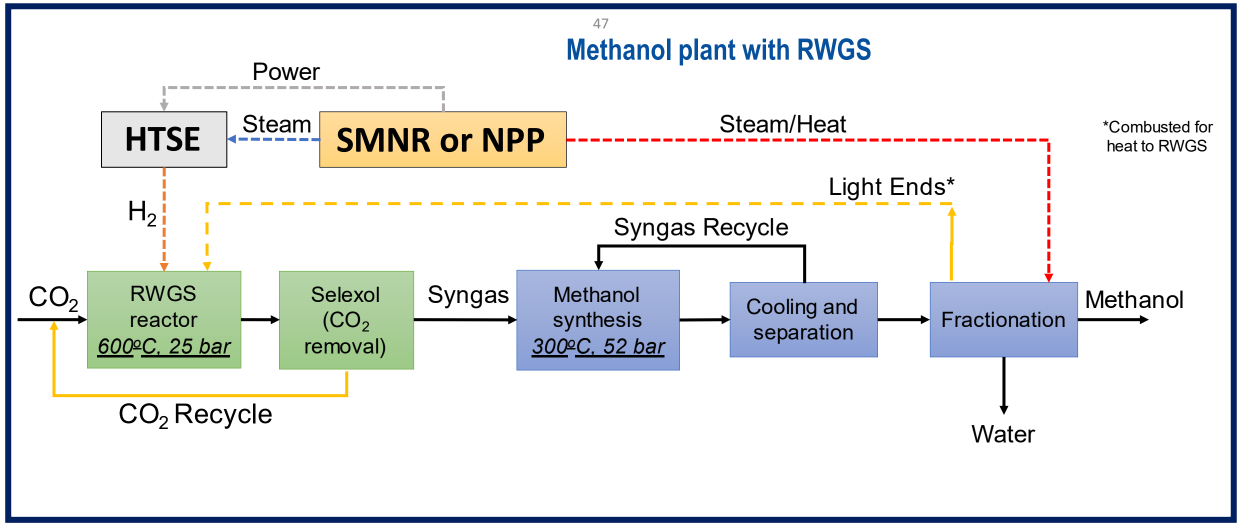
Nuclear Integration with Methanol Production

- Three methanol production processes using nuclear energy were modeled
  1. Natural gas-based methanol (conventional, top figure)
     - Autothermal reforming
       - Nuclear-supplied heat below 850°C cannot be used
       - Hydrogen can be used to replace the heat from natural gas
       - CO_2 reduction could be achieved from stack gas scrubbing, hydrogen to fuel, or alternative syngas or methanol production processes.
  2. CO_2-based methanol with reverse water gas shift (bottom figure)
     - ($CO_2 + H_2 \rightarrow CO + H_2O$; $CO + 2H_2 \rightarrow CH_3OH$)
     - 90% reduction overall from RWGS reduces emissions by 90%
     - 64% reduction in plant emissions by eliminating the NG import for SMR furnace, replaced by nuclear H_2 blending (top diagram)
  3. CO_2-based methanol with one-step
     - ($CO_2 + H_2 \rightarrow CH_3OH + H_2O$)
     - >90% CO_2 emissions reduction is achievable
     - Reduces capital cost

Take aways and inference

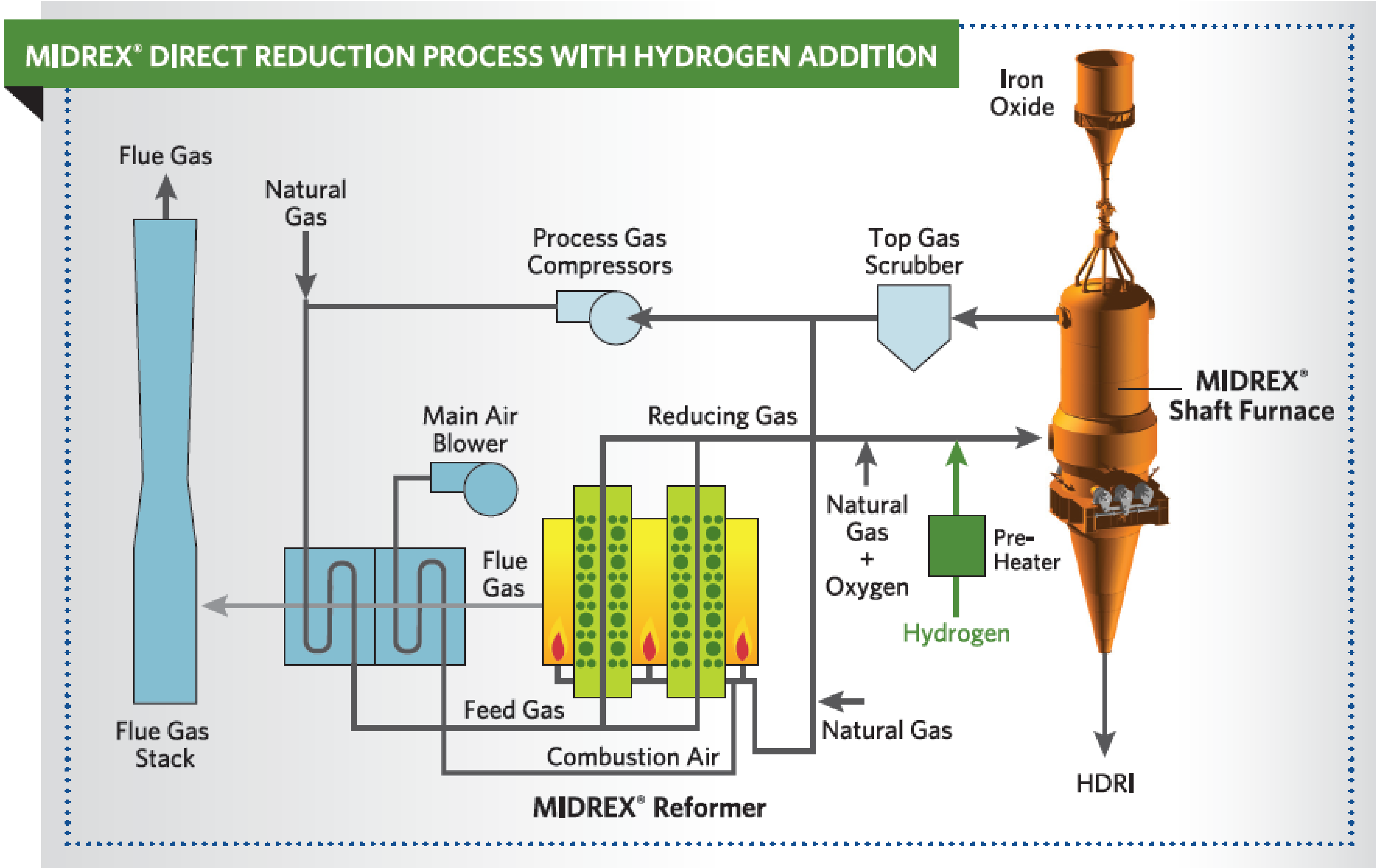
1. Nuclear reactors can significantly reduce the emissions of methanol and other basic chemicals manufacturing
2. When methanol is used to produce synthetic fuels, a significant reduction in total U.S. CO_2 emissions can be realized





NG: Natural Gas
NPP: Nuclear Power Plant

Nuclear Integration with Iron and Steel Manufacturing



Midrex® Hot Direct Reduced Iron Shaft Furnace is ready to add hydrogen to Midrex Reformer gas without process modifications

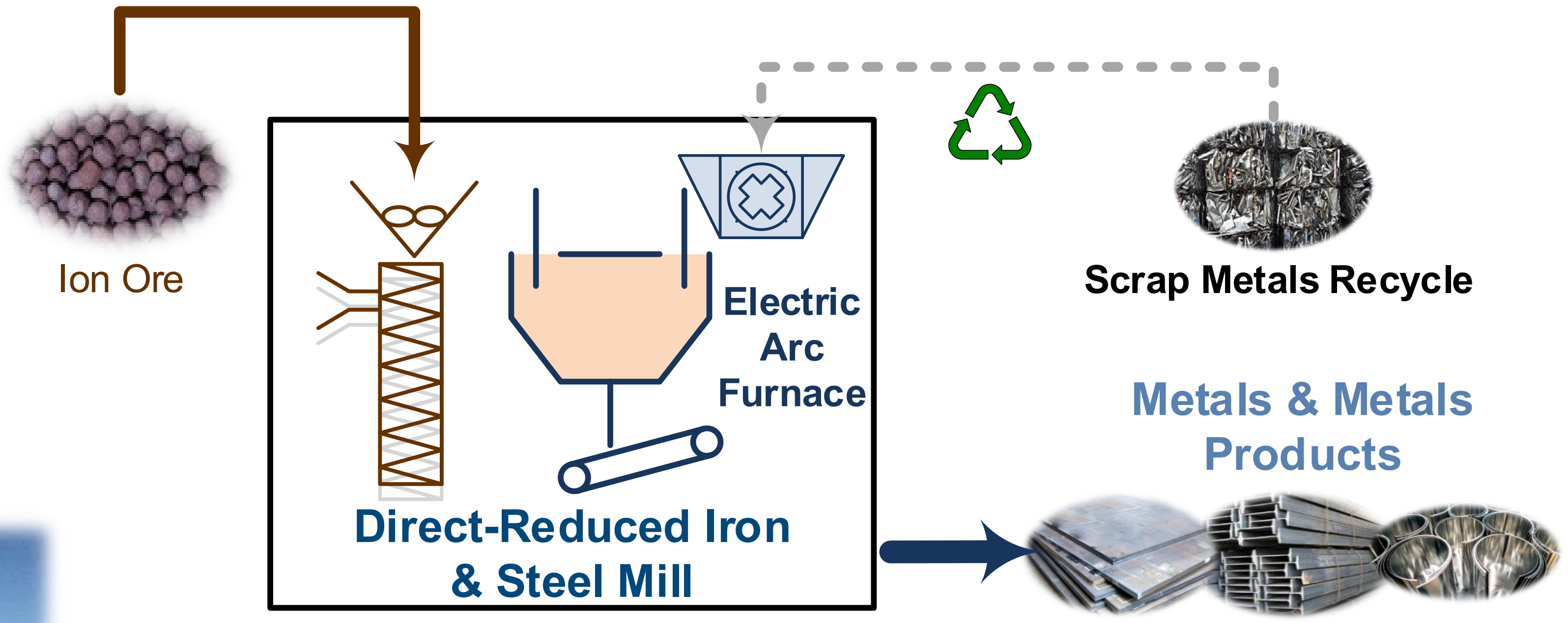
IES
Integrated Energy Systems

https://www.midrex.com/assets/user/media/Midrex_2017_DFM3QTR_FinalPrint.pdf

Nuclear Integration with Iron and Steel Manufacturing

$$Fe_2O_3 + \{H_2 + CO\} = Fe + H_2O + CO_2$$

Step 1.
Produce Syngas
Step 2.
Directly Reduce Iron Ore
Step 3.
Refine in Electric Arc Furnace



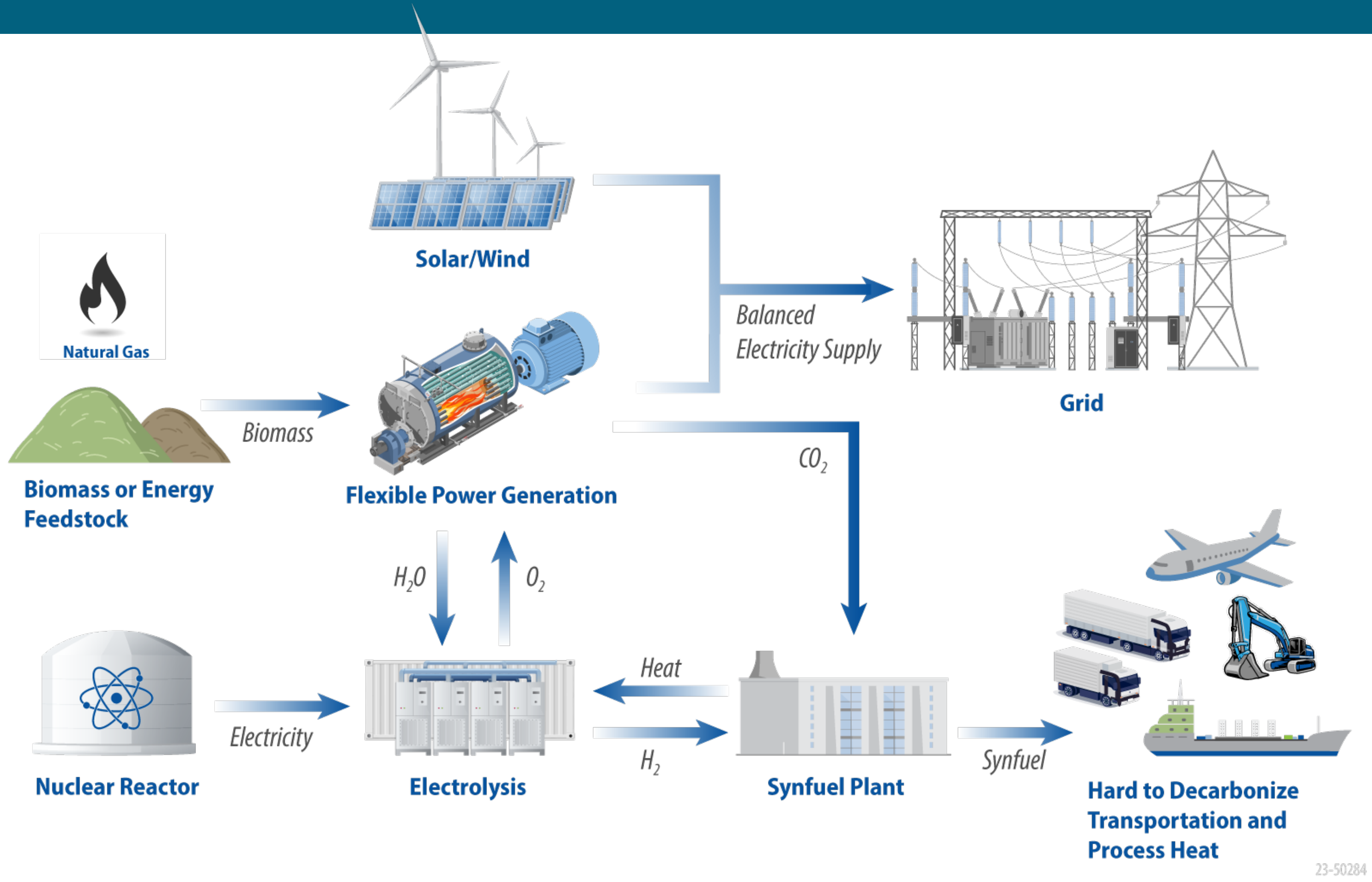
Midrex® Voestalpine HBI plant
Corpus Christi, Texas/USA

POSCO Electric Arc Furnace
Changwon, Korea

Integrated System for Clean e-Fuels

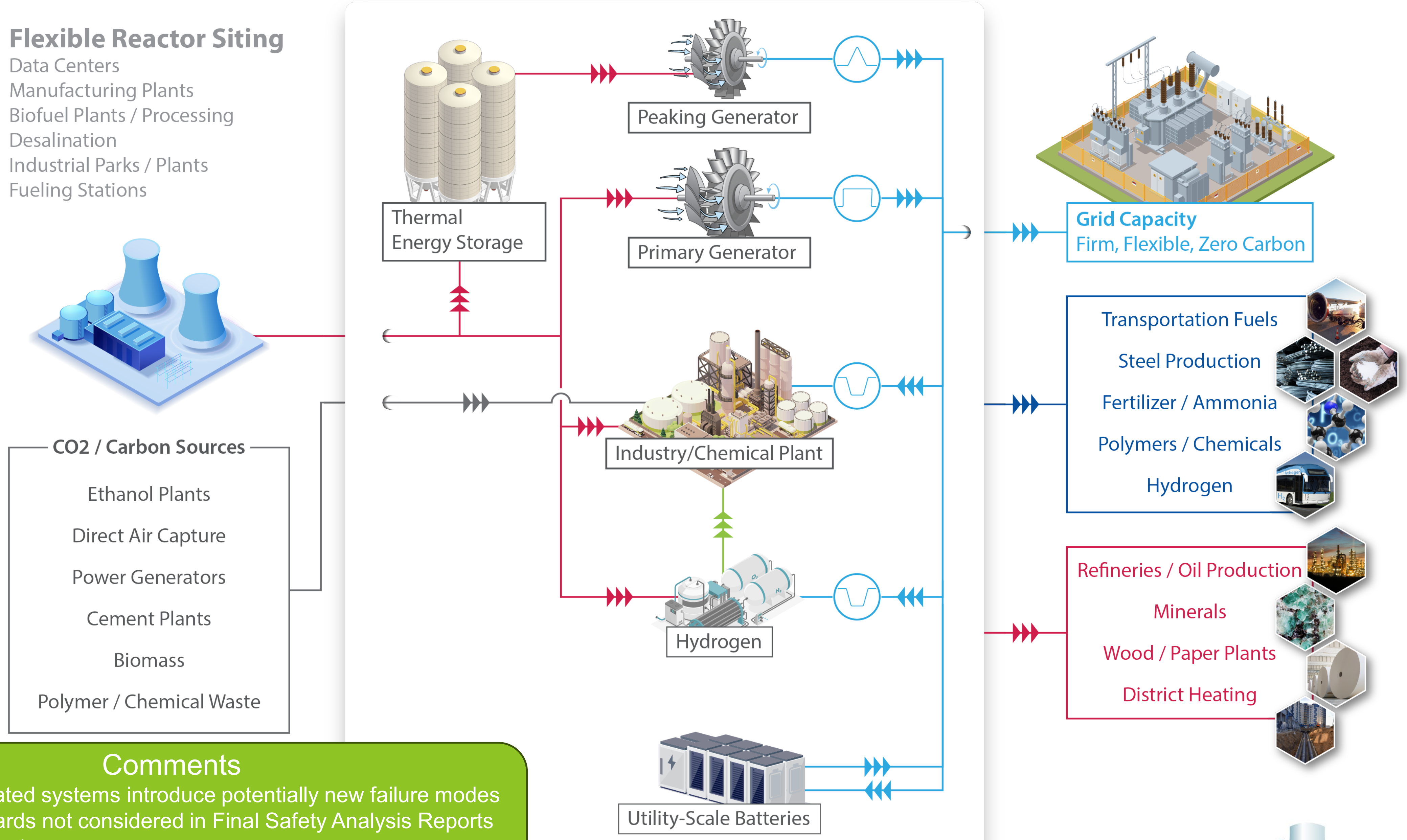
Potential CO_2 sources:

- Natural Gas Electricity Generators
- Biomass Electricity Generators
- Ethanol Plants
- Ammonia Plants
- Refineries
- Paper/pulp plants



Comments

1. Tightly integrated systems require joint nuclear and industry safety risk assessments and fire protection engineering evaluations
2. Systems testing will provide important data for permit applications



Comments

1. Tightly integrated systems introduce potentially new failure modes and fires hazards not considered in Final Safety Analysis Reports for nuclear plants
2. Probabilistic and deterministic risk assessments are needed to address license requirements

DOE-NE/Light-Water Reactor Sustainability Program and DOE-EERE/Hydrogen and Fuel Cell Technologies Office are Supporting R&D to Power Large-scale Electrolysis up to 1,000 MW

First of a kind Nuclear-H_2 production demonstration projects

Nine Mile Point Nuclear Power Plant

Constellation.

1.25 MWe Low Temperature Electrolysis

H2 production began February 2023

Davis-Besse Nuclear Power Plant

VISTRA

1-2 MWe

345kV plant upgrade with new switch gear at the plant transmission station

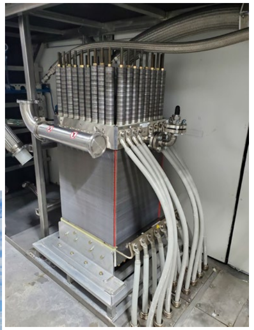
Prairie Island Nuclear Power Plant

Xcel Energy

150 kWe High Temperature Electrolysis

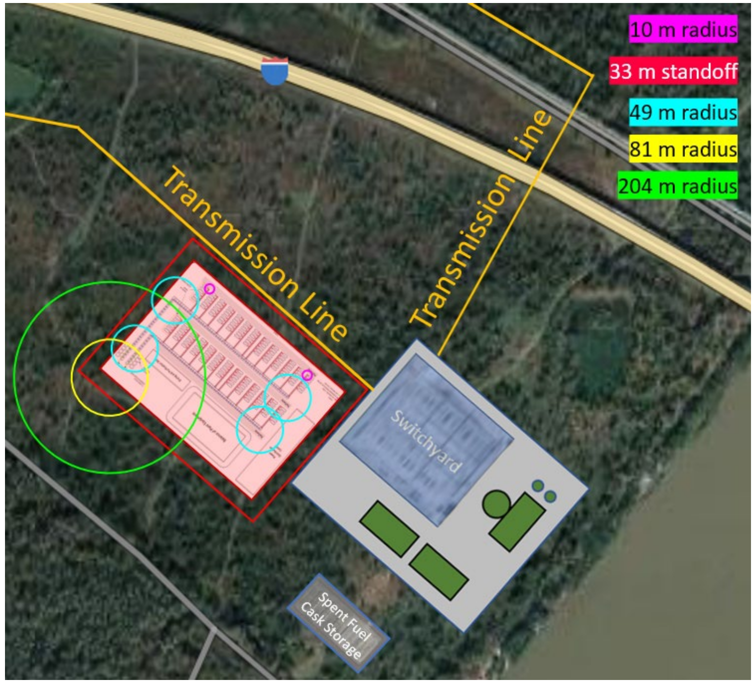
Tie into plant thermal line

H_2 production beginning ~July 2024



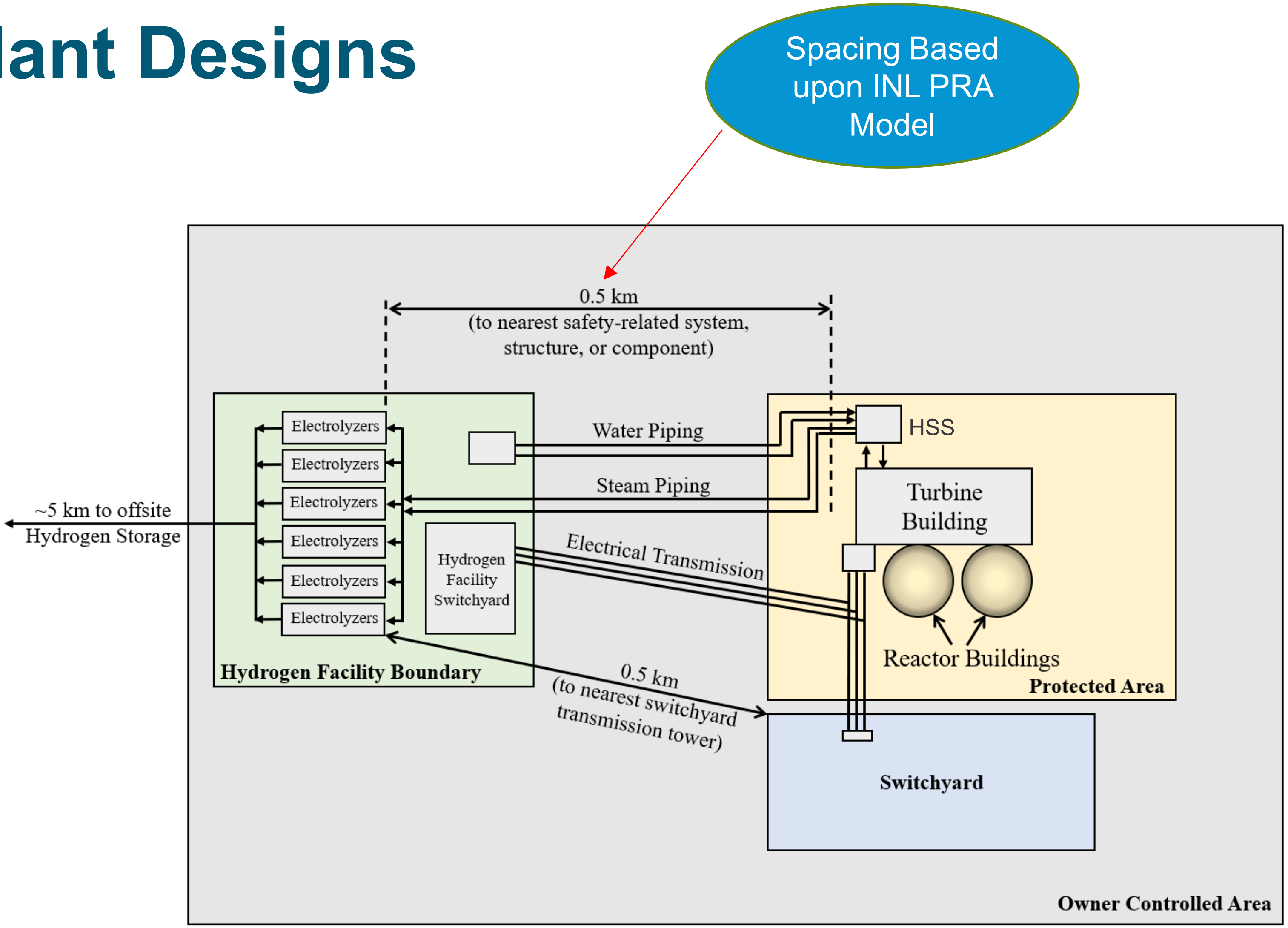
Scale-up

Hazards, PRAs, human factors, full-scope simulation for 100, 500, 1000 MW_e

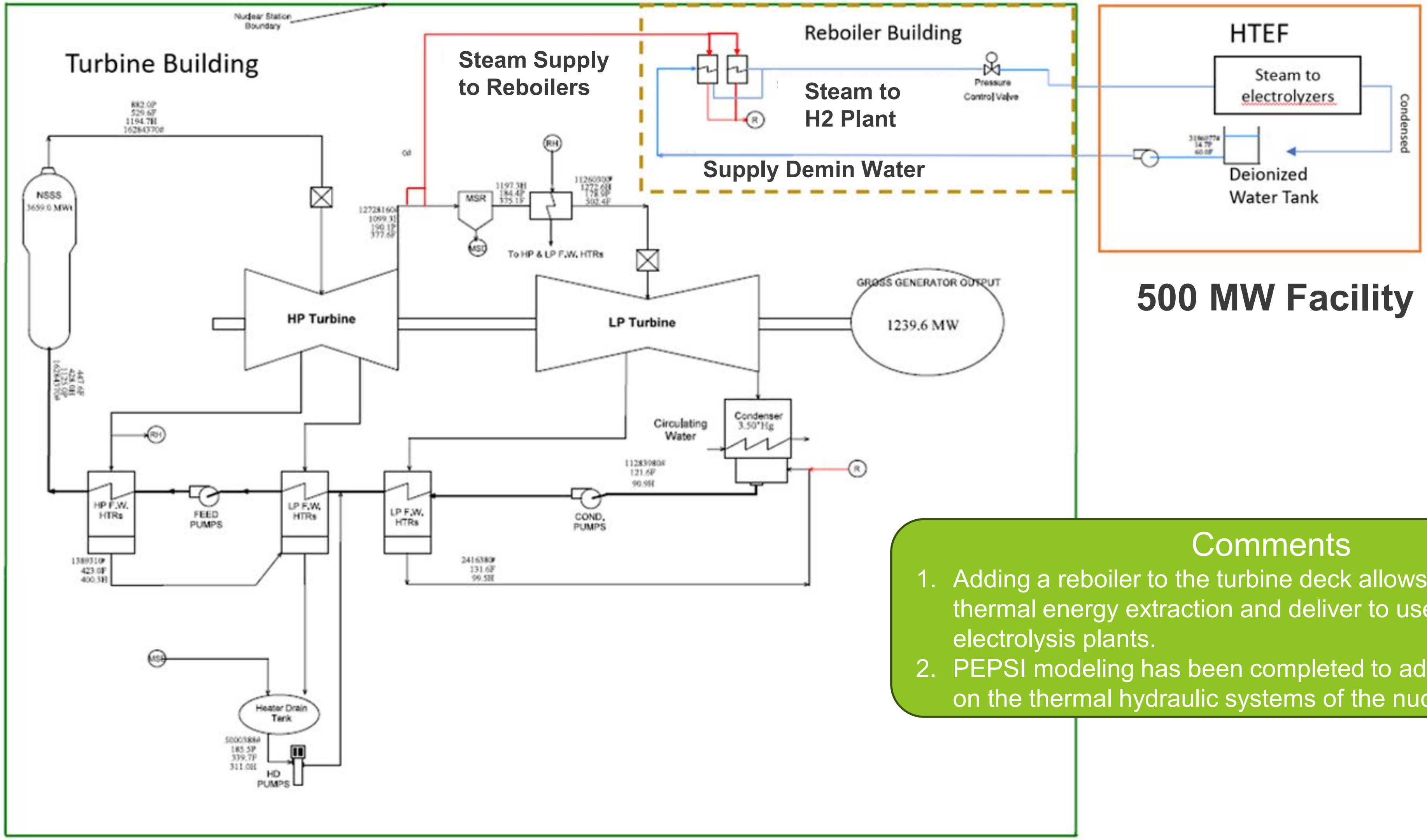


S&L Pre-Conceptual Plant Designs

- **NPP Reference Plant**
  - Based upon typical for 1/3 of operating US NPP Units
    - Westinghouse 4-loop PWR
    - $1200MW_e$ / $3{,}700MW_{th}$ / SWYD: 345kV
    - Hydrogen Steam Supply (HSS) Equipment
- **Hydrogen Facility Plants**
  - $100MW_{DC}$
    - Thermal Load – $20MW_{th}$
    - Hydrogen Production - 60 tons/
  - $500MW_{DC}$
    - Thermal Load – $100MW_{th}$
    - Hydrogen Production - 300 tons/day



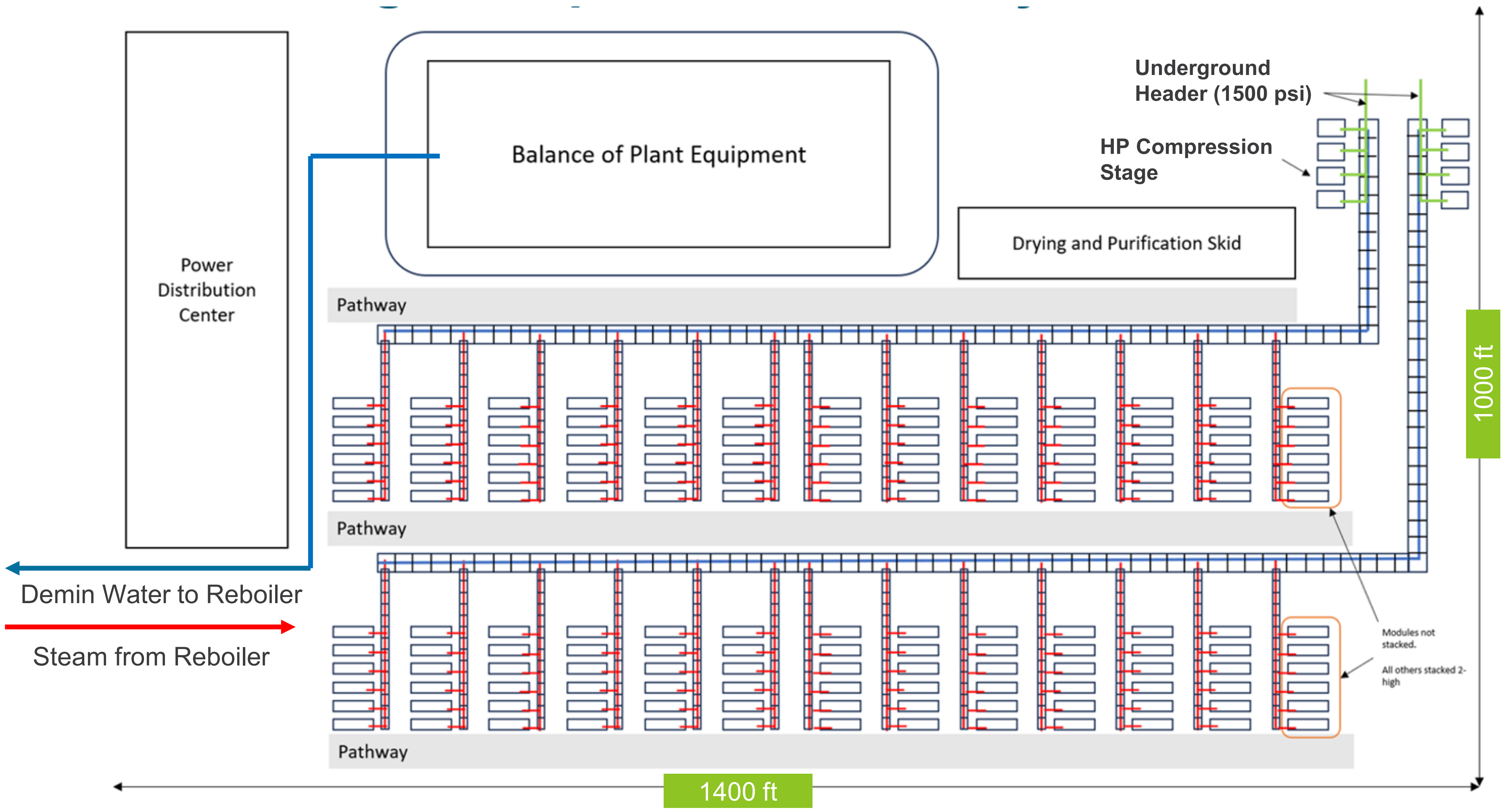
Hazard Assessment: Considering the Modifications to the NPP



Comments

1. Adding a reboiler to the turbine deck allows efficient and safe thermal energy extraction and deliver to users such as an electrolysis plants.
2. PEPSI modeling has been completed to address the impacts on the thermal hydraulic systems of the nuclear plant

Hazard Assessment: Defining the High Temp Electrolysis Facility



Typical 500 MW $_{nom}$ HTEF Layout.

Low Pressure (<5 PSIG) Intermediate Pressure (200-300 PSIG) High Pressure (~1500 PSIG)

Comments

1. A conceptual design of a modular electrolysis plant provides a reference plant for generic safety and hazards evaluation
2. Deterministic evaluation of fire and explosion hazards have been completed to evaluate the consequences of accidental hydrogen releases at critical points in the hydrogen plant

LWRS LIGHT WATER REACTOR SUSTAINABILITY

Modular HTSE Component Design

- Low Pressure, high temperature electrolysis (HTE) prototype modules installed at INL for performance testing
- 100 kW each
  - Other module types under development
- Rated for outdoor service
- Combined into 1.8 MW ganged units ("Stamps")
- Various open-air field layout configurations including single and stacked level
- The enclosures in the layouts above measure 52 × 8 × 8.5 ft.

Comments

1. Commercial unit operating data support probabilistic risk assessments.
2. Commercial-scale hydrogen plants are based on modular unit expansion.

Hydrogen Safety Analysis

Detonation Consequences:

- TNT equivalent method
  - Current standard for the 1.0 psi safe distance in RG 1.91
- Alternate Bauwens method for hydrogen leak jet detonation
  - Hydrogen-specific methodology
  - More precise than TNT equivalence

Scenario 15

Scenario 15 is a 200.0 mm break with a temperature of 50°C and pressure of 7.0 MPa

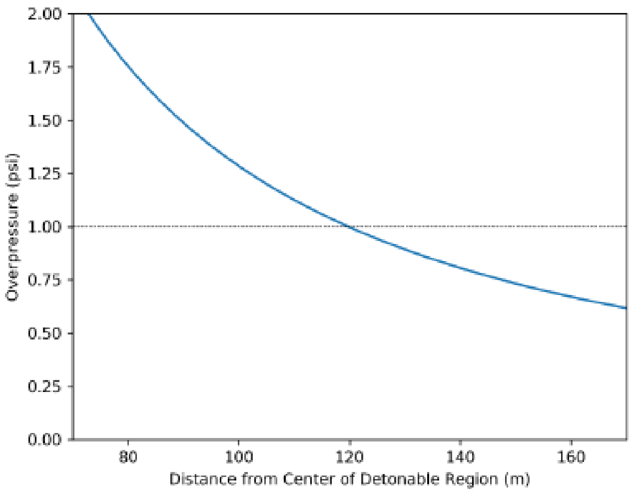


Figure E-15. Scenario 15 Separation Distance Results

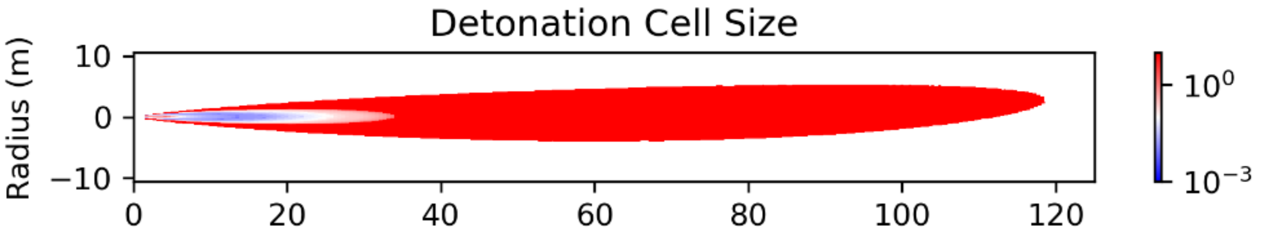
Hydrogen Fuel Production Risks

Very difficult to detonate an uncontrolled leak in open air

- Low ignition event frequency
- Lower detonation event frequency

Contained hydrogen can detonate as a cloud

- NFPA standards primary concern is to avoid structures that can contain the hydrogen

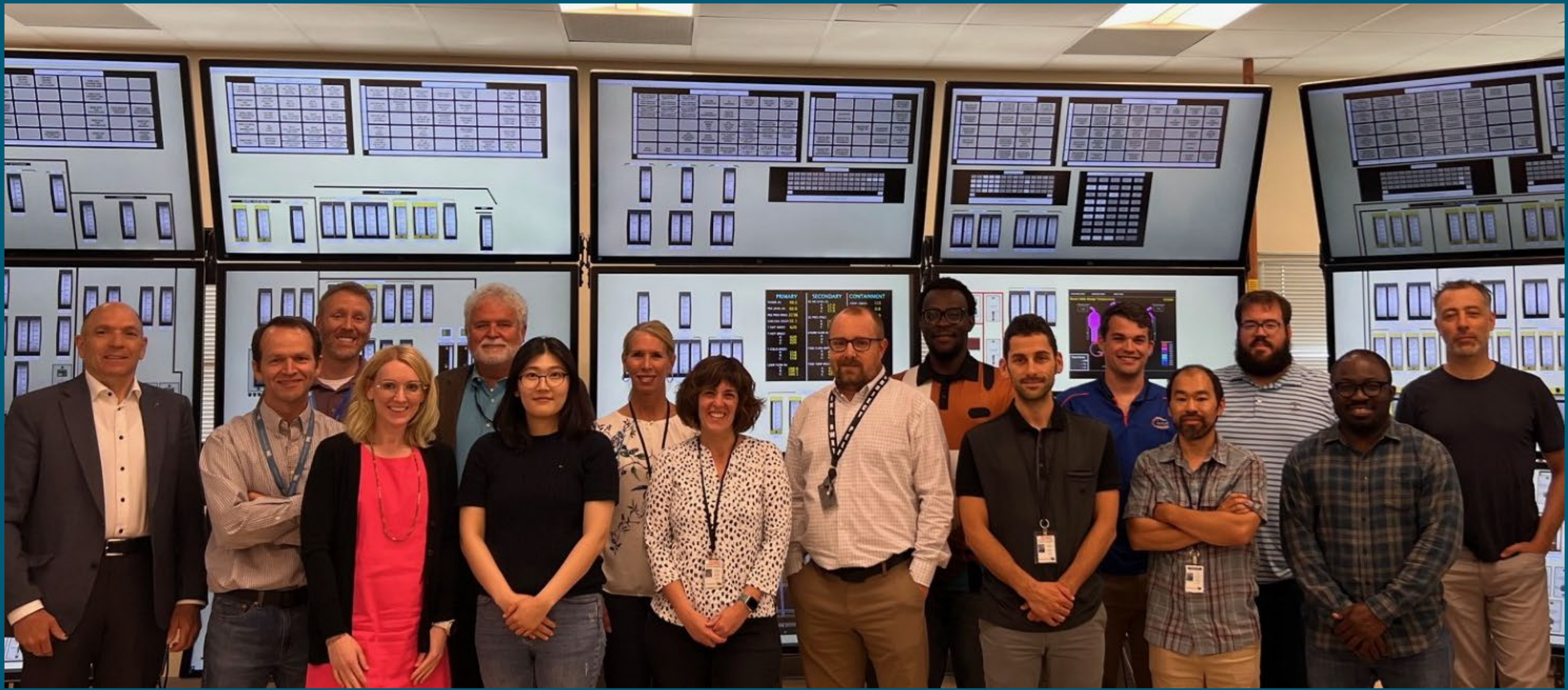


Hydrogen Safe Siting Distance – 500 MW_{nom} RG 1.91 TNT Equivalent

Comments

1. Selective replacement of hydrogen compressors and storage tanks reduces the safe separation distance between the nuclear plant and hydrogen electrolysis plant.
2. The footprint of a commercial scale, ~500 MWe hydrogen electrolysis plant is approximately the same dimensions as the controlled area of the nuclear power plant.

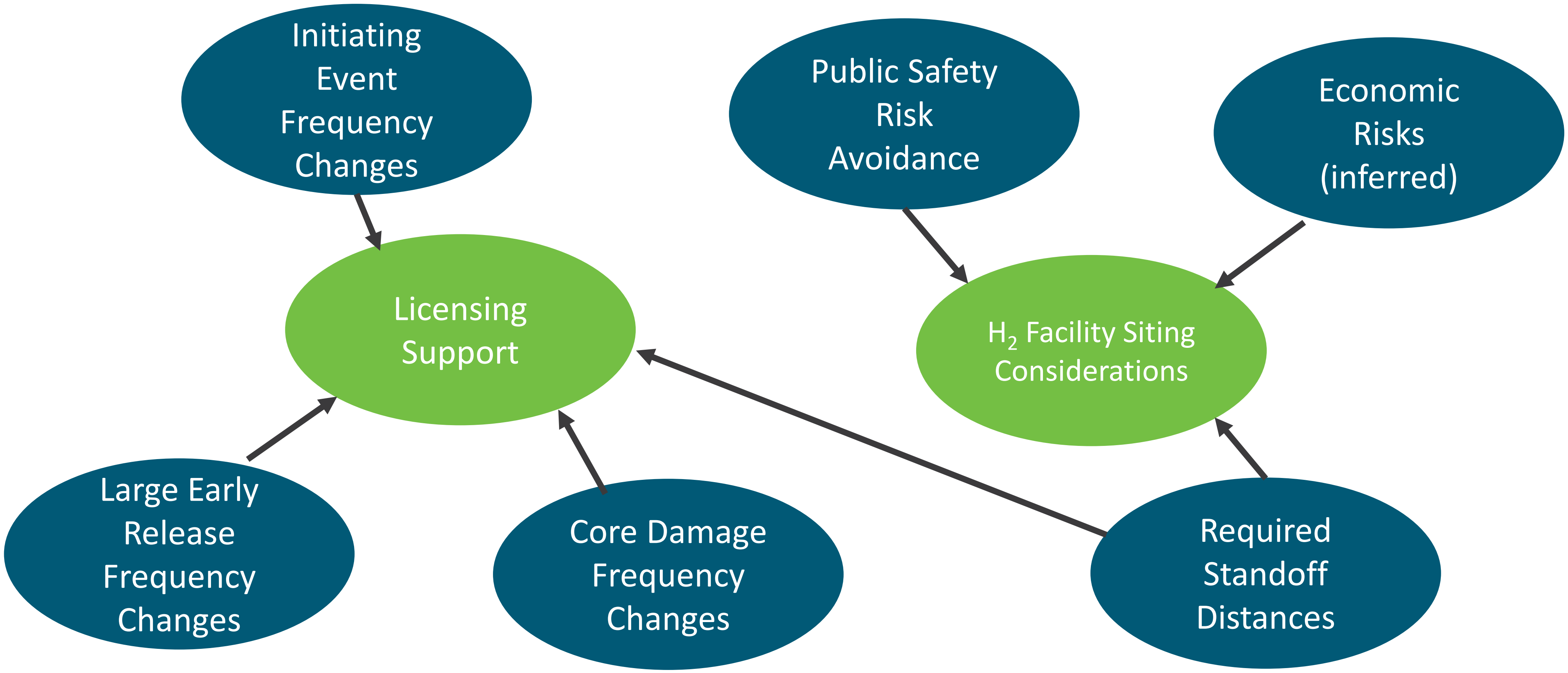
Human Factors Simulation and Operations Team



Comments

1. Nuclear power plant control concepts are being developed and testing with support of relevant industries and university research faculty
2. Experienced nuclear power plant operators are proving it is possible to rapidly dispatch thermal and electrical power to the hydrogen electrolysis plant.
3. Nuclear reactors can be used to supply spinning reserve when switching between hydrogen production and dispatching power entirely back to the grid.

Hazards and Risk Assessment - Putting it all together



Minimal Impact on Public Health and Safety

Risk Informed Performance Based Regulation

December 12, 2024

Ryan Mott
Jackie Harvey
Advanced Reactor Policy Branch
Division of Advanced Reactors and Non-Power Production and Utilization Facilities

ADVANCED REACTOR READY

https://www.nrc.gov/reactors/new-reactors/advanced.html

Content

- Background
- Development of the RIPB Approach
- Current Approach
- Questions

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Protecting People and the Environment

Background

- The purpose of this presentation is to provide an overview of the NRC's risk-informed, performance-based (RIPB) approach to regulation for advanced reactors.
- The NRC uses this approach for regulatory decision-making for advanced reactors.
- The NRC continues to welcome feedback on the topic and aims to engender an open dialogue with stakeholders.

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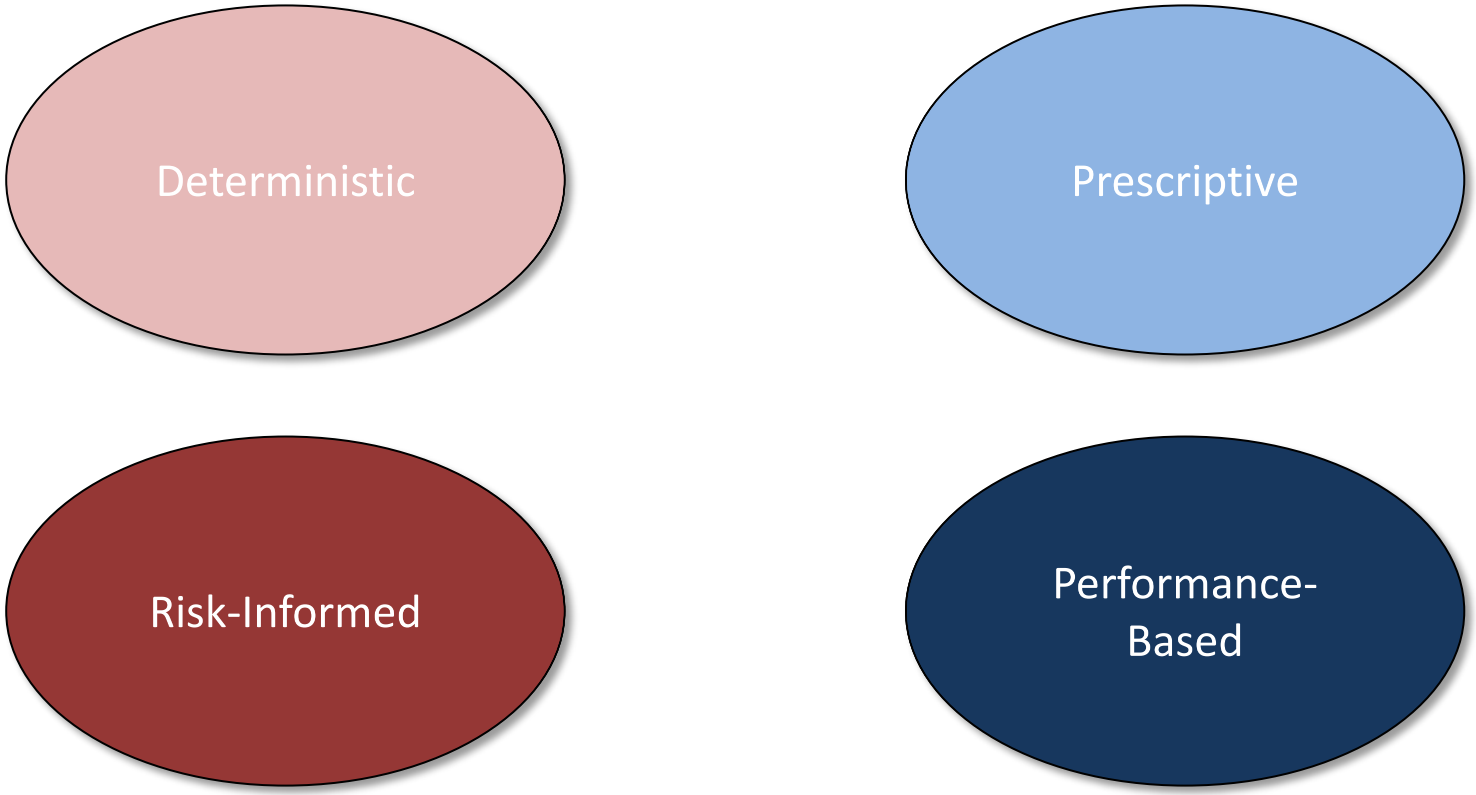
Development of the RIPB Approach

- **1997**
  - <u>SRM, January 22, 1997.</u> Commission decision to include performance-based strategies as part of the risk-informed regulatory decision-making process (SECY-96-218)
- **1999**
  - <u>SRM, March 1, 1999</u>. Commission approves publication of white paper describing RIPB framework (SECY-98-144)
- **2006**
  - <u>SRM, June 1, 2006</u>. Commission instructs Staff to adopt implementation plan to reach “a holistic, risk-informed and performance-based regulatory structure.” (*See:* SECY-06-0217, SECY-07-0074)

Development of the RIPB Approach



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Current Approach with the Advanced Reactor Program

- Risk-informed and performance-based
- Does not entirely replace deterministic and prescriptive approaches
- Flexible, holistic approach
- E.g., ARCOP, Part 53, functional containment and ARCAP/TICAP

A risk-informed, performance-based regulation is an approach in which risk insights, engineering analysis and judgment (including the principle of defense-in-depth and the incorporation of safety margins), and performance history are used, to

(1) focus attention on the most important activities,
(2) establish objective criteria for evaluating performance,
(3) develop measurable or calculable parameters for monitoring system and licensee performance,
(4) provide flexibility to determine how to meet the established performance criteria in a way that will encourage and reward improved outcomes, and
(5) focus on the results as the primary basis for regulatory decision-making.

(1999 White Paper)

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Questions?

RIPB Perspectives

December 12, 2024

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Risk - Informed

- Risk-Informed is a spectrum!
- Traditional deterministic and heavily Risk-Informed (LMP) should be OK

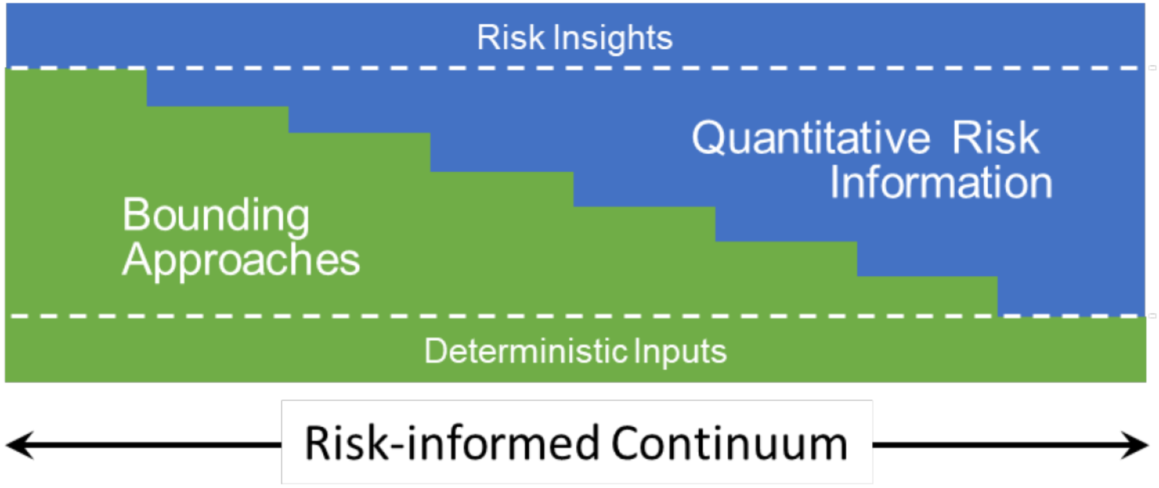

Figure 3: Spectrum of Possible Risk-Informed Approaches

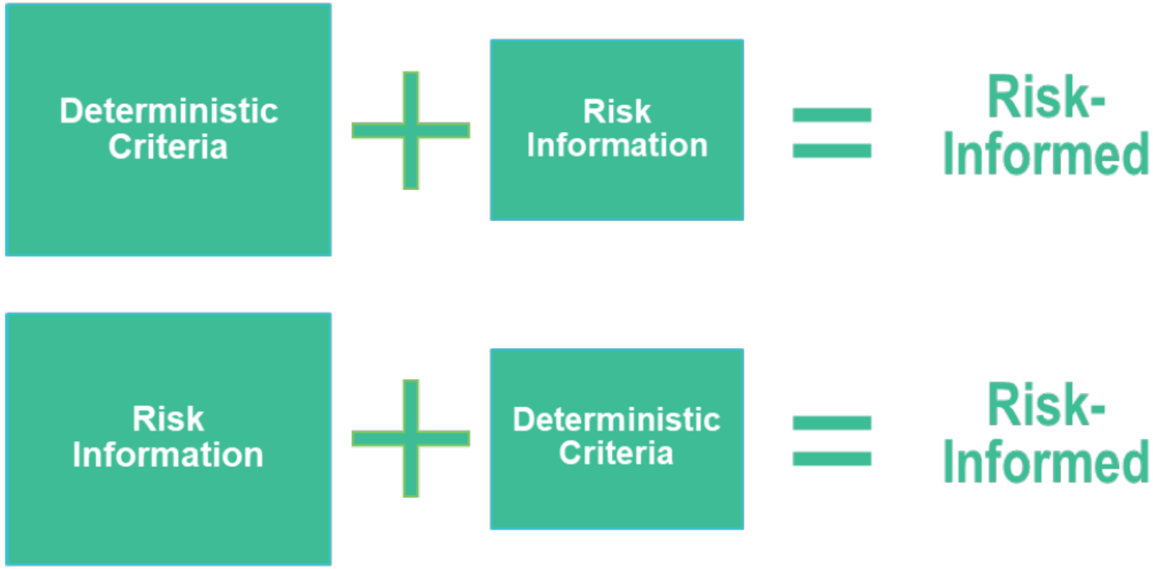

Figure 1: Viable Risk-Informed Approaches

NEI White Paper: Technology-Inclusive, Risk-Informed, Performance-Based Approaches Sept 2021

Performance - Based

- Requirements should be high-level: what to do, not how to do it
- Applicants should have flexibility in demonstrating performance!

Prescriptive (Current Proposed Part 53)	More Performance-Based (NEI Proposals)	Performance-Based (Informed by NUREG-0303)
53.450(a) requires PRA assessing internal and external hazards	Current draft comment suggests a "Risk Evaluation" allowing flexibility to use PRA or other risk-informed and/or performance-based methods.	Subpart B – Technology-Inclusive Safety Requirements defines Performance-Objectives (currently including Part 20, traditional DBA – 25 rem, and comprehensive risk metrics). Analysis methodologies in Subpart D to meet those criteria are not needed and can be handled in guidance
53.530(c) prescribes siting away from population centers regardless of risk profile	Current draft comment suggests deleting prescription including 25,000 in 53.020 population center distance definition	Dose requirements in Subpart B would be informed by siting which can be considered in guidance.

Much more information on these topics in the February 2021 Part 53 Industry Concerns and Alternative (ML21042B889), December 2020 Industry Comments on Part 53 Rulemaking (ML20363A227), and the October 2020 Industry Comments on Part 53 Rulemaking Plan

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Open Discussion

Public Comments

Closing Remarks