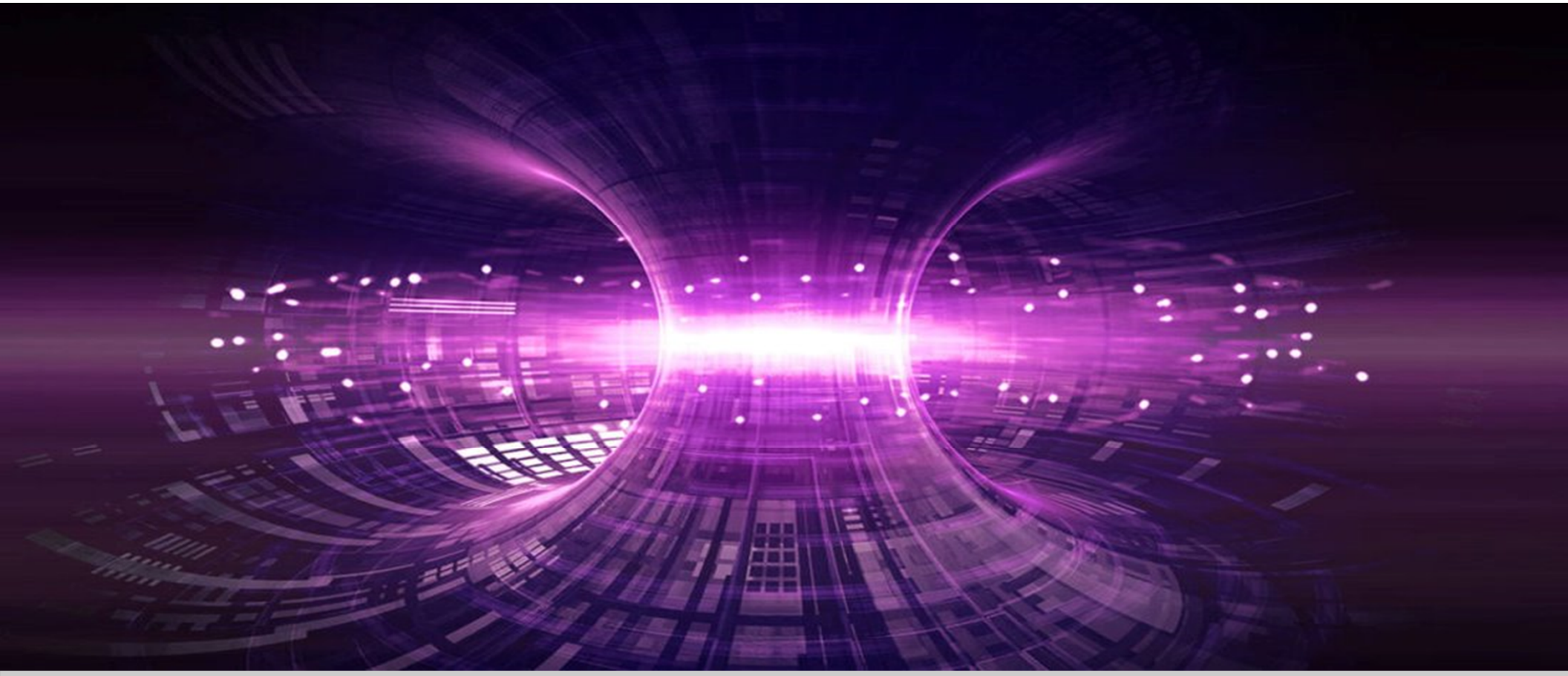

Rulemaking: Regulatory Framework for Fusion Systems

NRC Public Meeting

October 11, 2023

U.S.NRC

United States Nuclear Regulatory Commission

Protecting People and the Environment

AGENDA

Time	Topic	Speaker
1:00 pm	Welcome & Meeting Logistics	Dennis Andrukat
	Opening Remarks	Adelaide Giantelli
	NRC Presentation – Overview of Proposed Regulatory Language	Duncan White
1:50 pm	BREAK	All
1:55 pm	Questions & Answer Session / Public Feedback	All
2:55 pm	Closing Remarks & Adjourn	Dennis Andrukat

Topic times are estimated and, depending on the participation level, the meeting could adjourn earlier than scheduled. If there are concerns with a potential early meeting adjournment, please inform the point of contact for this meeting.

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OPENING REMARKS

Adelaide Giantelli, Branch Chief

State Agreement and Liaison Programs Branch

Division of Materials Safety, Security, State, and Tribal Programs

Office of Nuclear Material Safety and Safeguards

US NRC

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TODAY'S PRESENTATION (ML23258A147)
HANDOUT: Preliminary Proposed Rule Language (ML23258A145)

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OVERVIEW OF PROPOSED REGULATORY LANGUAGE

Duncan White

Division of Materials Safety, Security, State, and Tribal Programs

Office of Nuclear Material Safety and Safeguards

US NRC

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Commission Direction

for Fusion Energy Systems

On April 13, 2023, the Commission issued SRM-SECY-23-0001 “Options for Licensing and Regulating Fusion Energy Systems” (ML23103A449) directing the staff to implement a byproduct material approach to fusion energy system regulation

10 CFR Part 30 - Rules of General Applicability To Domestic Licensing of Byproduct Material

NUREG-1556, “Consolidated Guidance About Materials Licenses”

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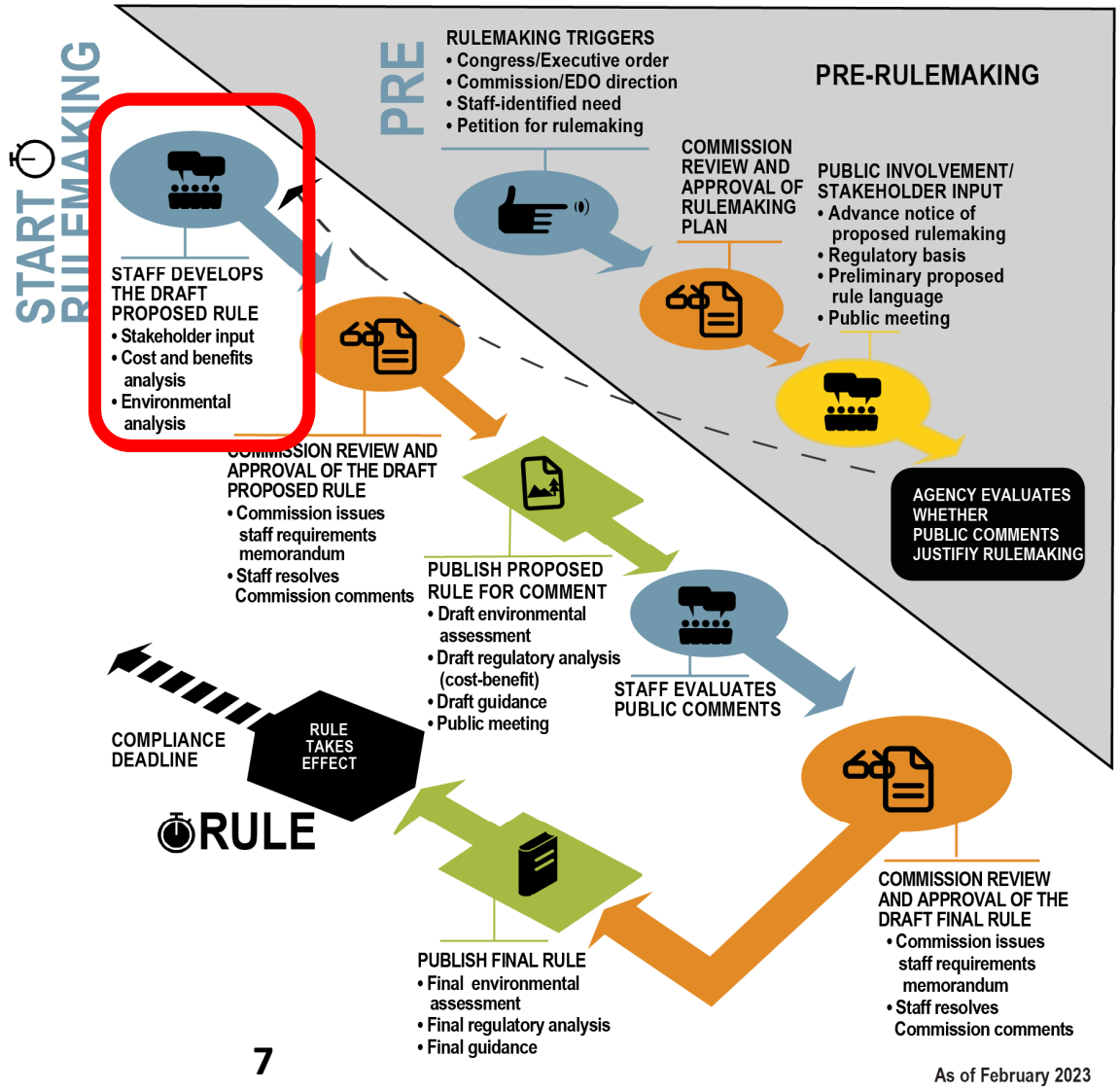
NRC Rulemaking Process



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SCOPE OF FUSION RULEMAKING ACTIVITIES

Rulemaking:

- Based on 11e.(3) definition in AEA of byproduct material
  - Radioactive material for research, commercial or medical purposes
  - Accelerator-produced
- Limited-scope rulemaking in 10 CFR Part 30 to cover only near-term, known fusion energy system designs:
  - Definitions
  - Content-of-application requirements specific to fusion - Use standard Part 30 processes where applicable
  - Other fusion-specific requirements, as needed, to address specialized topics
  - Compatibility determinations part of rulemaking process

PRELIMINARY PROPOSED RULE LANGUAGE

Preliminary Proposed Rule Language Definitions in Parts 20 and 30

Approach for New and Amended Definitions

- Focus on byproduct material and associated radiation
  - Emphasis on containing, processing, or controlling radiation and radioactive materials.
- Limited to specific components – not facility-wide
- No impact on current licensees
- Enhance regulatory clarity and predictability

Preliminary Proposed Rule Language Definitions in Parts 20 and 30

§20.1003 and § 30.4 Definitions

Fusion system means a system that, through use of byproduct material or to produce byproduct material, induces nuclear fusion and includes any associated radiation, radioactive material, and supporting structures, systems, and components that are used to contain, process, or control radiation and radioactive materials.

* * *

Particle accelerator means any machine capable of accelerating electrons, protons, deuterons, or other charged particles in a vacuum and of discharging the resultant particulate or other radiation into a medium ~~at energies usually in excess of 1 megaelectron volt~~. For purposes of this definition, accelerator is an equivalent term.

Preliminary Proposed Rule Language Content of Application in Part 30

Approach for Content of Application

No new regulatory language in Part 30 added, but still applies to fusion systems

- Fees
- Environmental
- Financial assurance and decommissioning funding plan
- Emergency preparedness
- Security
- Transportation
- Export controls

- Additional changes to the draft rule language may be identified during the rulemaking process

Preliminary Proposed Rule Language Content of Application in Part 30

Approach for Content of Application

- Supplement existing Part 30 regulations to address fusion system specific application (§30.32(k))
  - General description of fusion system
  - Operating and emergency procedures
  - Organization structure related to radiation safety
  - Training
  - Inspection and Maintenance
  - Material Inventory

Preliminary Proposed Rule Language Content of Application in Part 30

Approach for Content of Application - continued

- Alternative Approach
  - Radiation safety description of fusion system
  - Encourage pre-application communications
- Regulations are intended to apply to fusion systems during research and development or commercial deployment
- Issuance of license (§30.33(a)(6))

Preliminary Proposed Rule Language Additional Changes to Part 30

Add "production" of byproduct material to § 30.51 and § 30.52

- Many fusion systems will produce neutrons that will activate materials or produce tritium in lithium breeding beds

Preliminary Proposed Rule Language Additional Changes to Part 20

Approach for disposal of fusion systems byproduct material

- New construction materials potentially resulting in activation products consisting of different radionuclides and in different quantities than previously considered
  - Waste streams not considered in the development of the Part 61 tables may require disposal
  - Staff considering whether applications should include an assessment of the disposal pathway as part of the decommissioning funding plan
- Allow waste from fusion systems to be disposed at existing LLW disposal sites
- Use risk-informed approach based on site-specific intrusion assessment at LLW disposal facility to allow disposal of novel waste streams
  - Does not require changes to Part 61
  - Does not require changes to other sections and appendices in Part 20
  - Consistent with LLW rulemaking currently underway

Preliminary Proposed Rule Language Additional Changes to Part 20

New § 20.2008(c)

Waste resulting from fusion systems must be disposed of in a disposal facility that has completed a site-specific intrusion assessment that demonstrates the projected dose to an individual who inadvertently intrudes into the waste at the facility will be less than 5 millisievert (mSv) per year.

Notes:

- *Staff is considering how to exclude fusion system waste streams that are within the Part 61 envelope*
- *Staff is considering how to focus site-specific intrusion assessment on the novel radionuclides of concern*

Preliminary Proposed Rule Language Additional Changes to Part 51

Environmental Report Requirement

- All Part 30 licensing actions are subject to the National Environmental Policy Act (NEPA) implemented by Part 51
  - Specific Part 30 licensing actions are categorically excluded in § 51.22
  - Radioactive material used for research and development is one of these categorical exclusions
- If not categorically excluded, an environmental assessment is necessary with the associated requirement of an environmental report
- This requires a change to § 51.60 to add the regulatory requirement for an environmental report that shall contain the information specified in § 51.45

Preliminary Proposed Rule Language
Additional Changes to Part 51

§ 51.60 Environmental report--materials licenses.

(b) As required by paragraph (a) of this section, each applicant shall prepare an environmental report for the following types of actions:

(1) Issuance or renewal of a license or other form of permission for:

* * *

(viii) Construction and operation of a fusion system for other than research and development purposes.

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Question & Answer Session

Please Note: the NRC is not accepting official comments during this meeting and will not provide any official responses to any feedback provided during this meeting.

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Upcoming Events/Milestones

Upcoming Public Meetings:

- November 1, 2023 – Preliminary Draft Guidance and Some Specific Topics (NUREG-1556, Volume 22)
- November 9, 2023 – More Specific Topics

Proposed Rule Schedule:

- Commission receives proposed rule and draft guidance by Fall 2024

Thank You!

Contacts

- Dennis Andrukat

Rulemaking Project Manager

Dennis.Andrukat@nrc.gov

- Duncan White

Technical Lead

Duncan.White@nrc.gov

Public Information

- NRC Public Website: https://www.nrc.gov/materials/fusion-energy-systems.html
- Docket ID: NRC-2023-0071 (*www.regulations.gov*)

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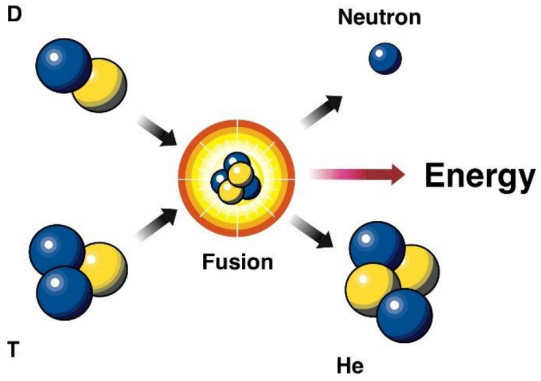
BACKUP SLIDES

Fission vs. Fusion

Fission

Fusion



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Radioactive Material Considerations

The neutronicity of the fuel is the fraction of the fusion reaction energy that is contained in the neutrons. It has important implications for fusion reactor designs. Less neutrons mean less radiation damage and activation products. Fuels with a small neutronicity are referred to as aneutronic fusion. The downside of less neutrons is that you need to develop a direct power conversion system instead of just running a thermal cycle from a neutron heated blanket.

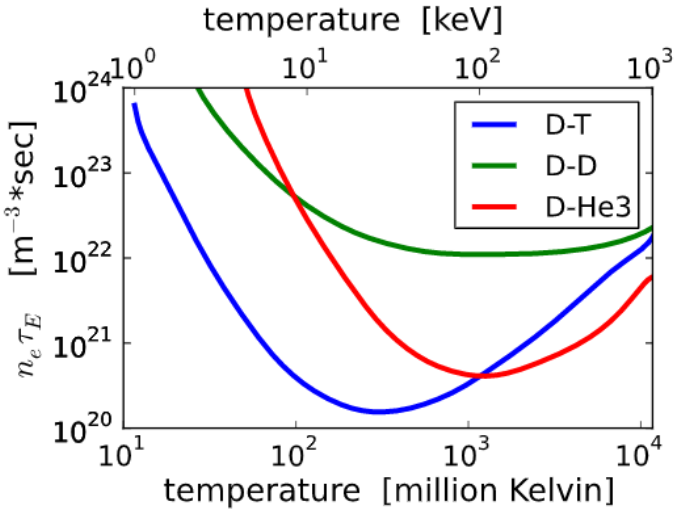
fuel	Z	E_{fus} [MeV]	E_{ch} [MeV]	neutronicity
${}^{2}_{1}D$-${}^{3}_{1}T$*	1	17.6	3.5	0.80
${}^{2}_{1}D$-${}^{2}_{1}D$*	1	12.5	4.2	0.66
${}^{2}_{1}D$-${}^{3}_{2}He$	2	18.3	18.3	≈0.05
p^{+}-${}^{11}_{5}B$	5	8.7	8.7	≈0.001

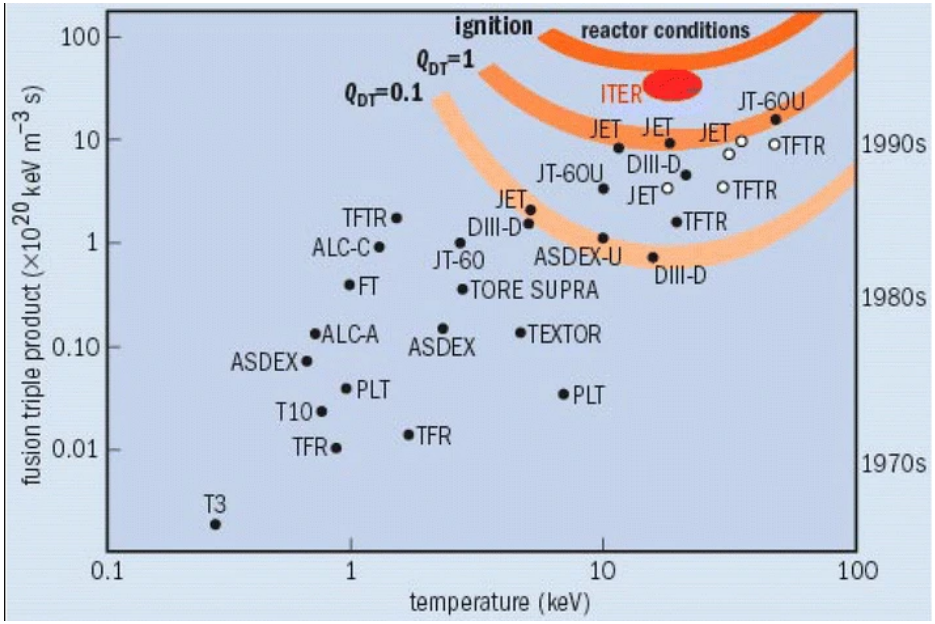
*reaction results in radioactive material

Source: https://en.wikipedia.org/wiki/Nuclear_fusion

Path to Fusion

To initiate a fusion reaction, you must confine the energy long enough in a fuel that is dense enough at a temperature that is high enough. The relationship that quantifies this is called the Lawson criterion.





Sources:
Horvath, A., Rachlew, E. Nuclear power in the 21st century: Challenges and possibilities. Ambio 45, 38–49 (2016). https://doi.org/10.1007/s13280-015-0732-y Figure 4
https://en.wikipedia.org/wiki/Lawson_criterion

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Fusion Approaches

Magnetic Confinement Fusion (steady state)

- Creates “magnetic bottles” to confine the plasma using the Lorentz force.
- Low density and long energy confinement times.
- External heating, fueling, and current drive to sustain the plasma.

Magneto-Inertial Confinement (pulsed)

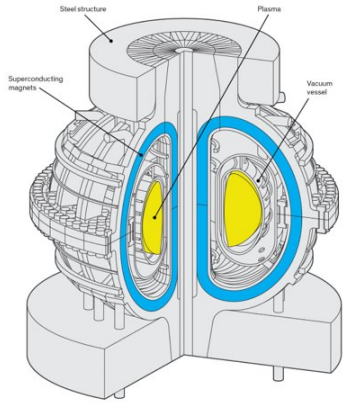
- Forms a magnetically confined plasma and then heats it using magnetic or conducting shell compression.
- Medium density and medium energy confinement times

Inertial Confinement Fusion (ICF) (pulsed)

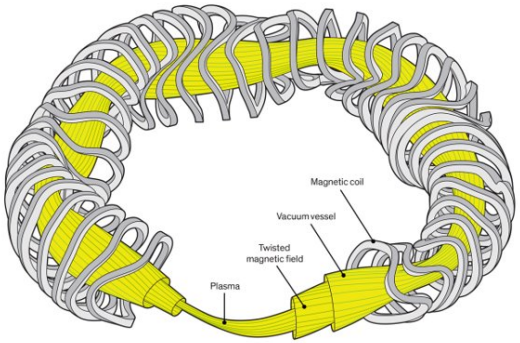
- Uses directed energy in the form of lasers, particle beams or projectiles to heat and compress a plasma to high densities and temperatures.
- Very high density and short energy confinement times.

Magnetic Confinement Concepts

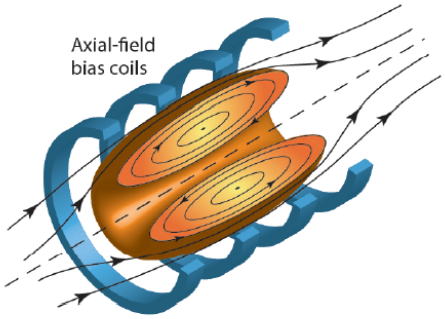
Tokamak



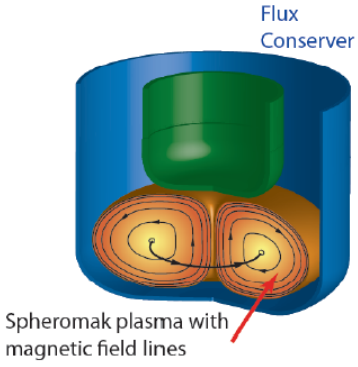
Stellarator



Field Reversed Configuration (FRC)



Spheromak



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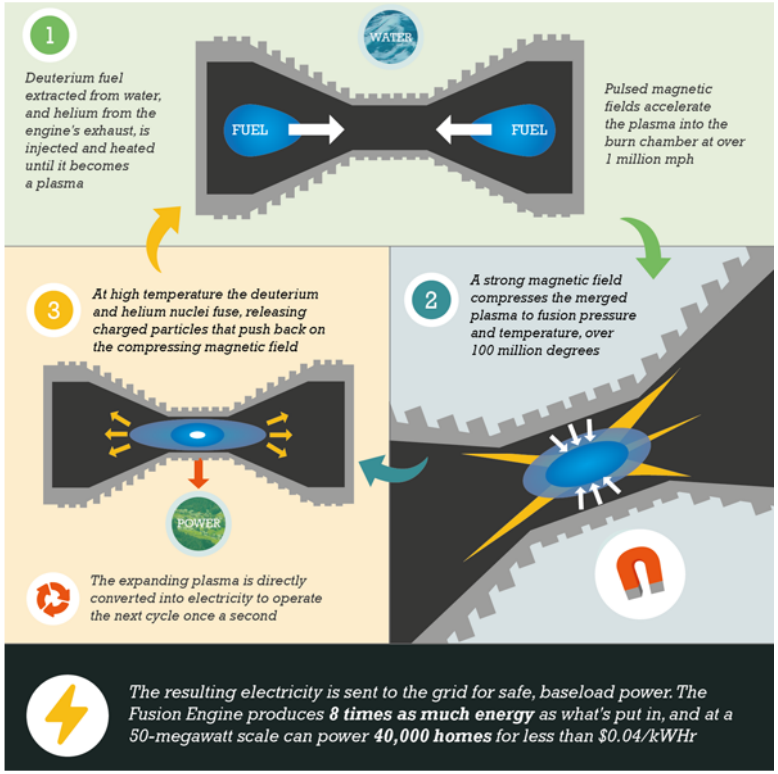
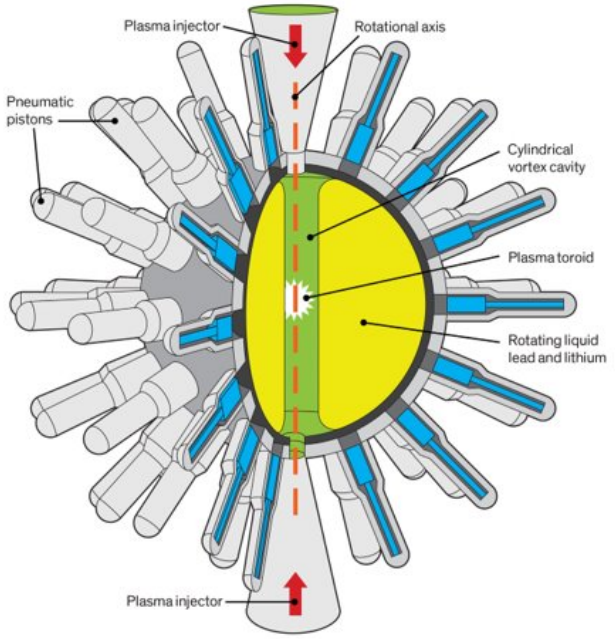
Magneto-Inertial Confinement

Magnetic Compression



Liquid Wall Compression



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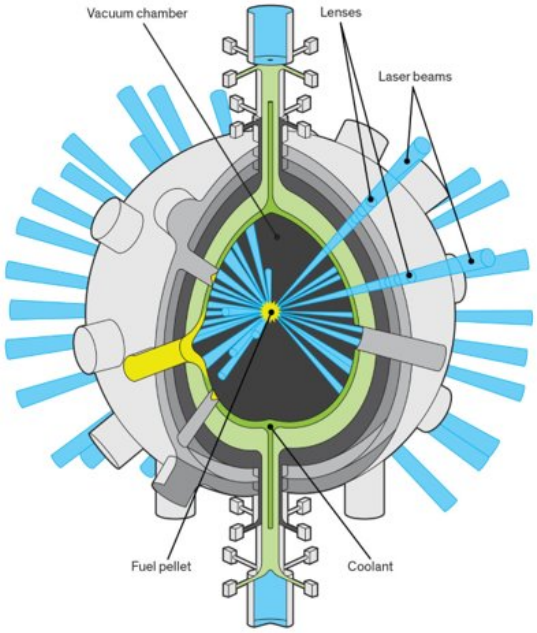
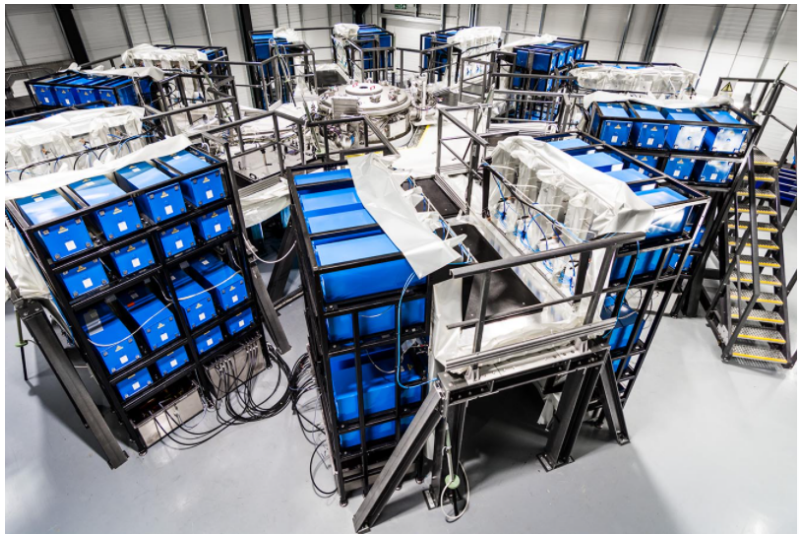
Inertial Confinement

Laser Driver



Projectile Driver



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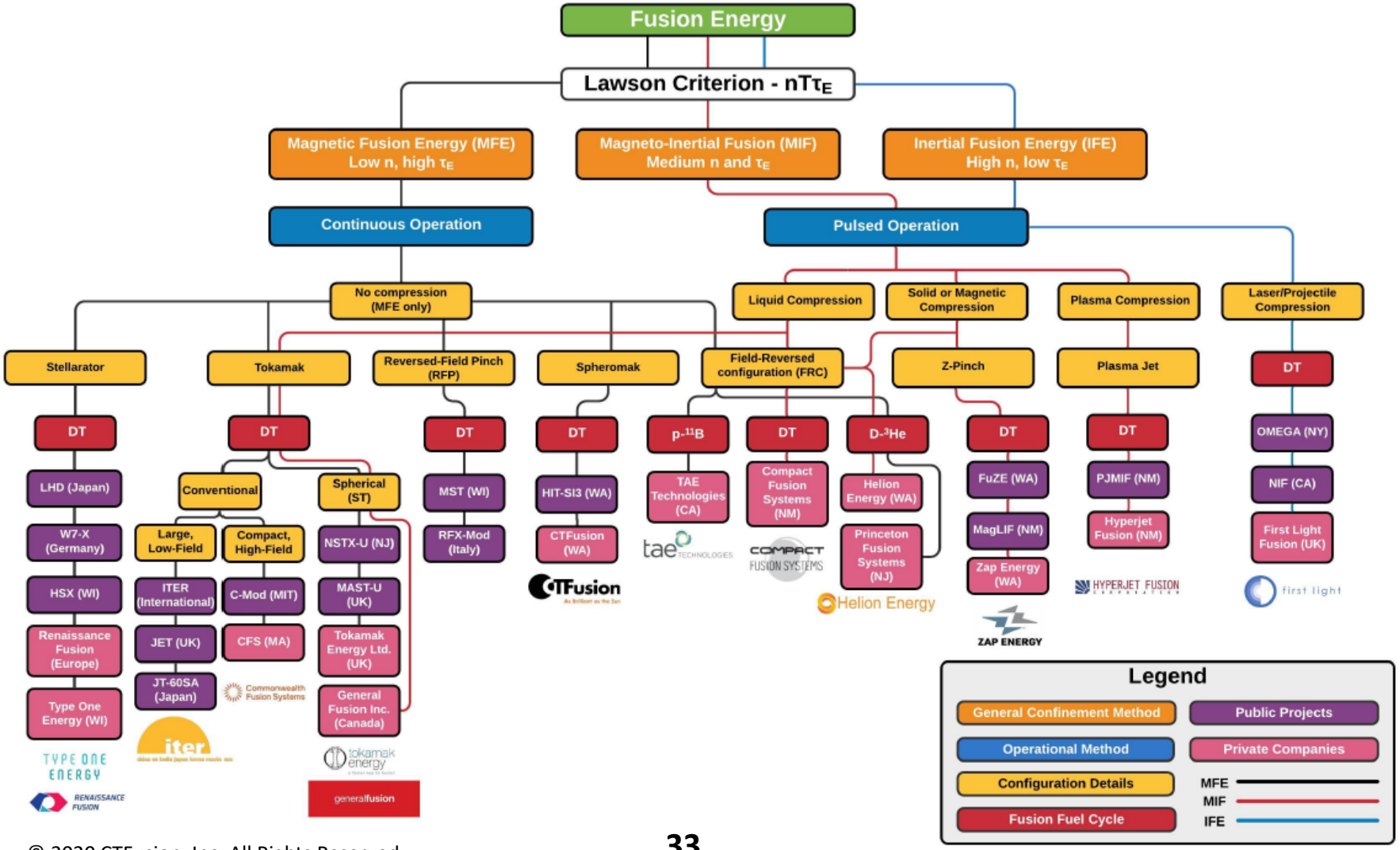
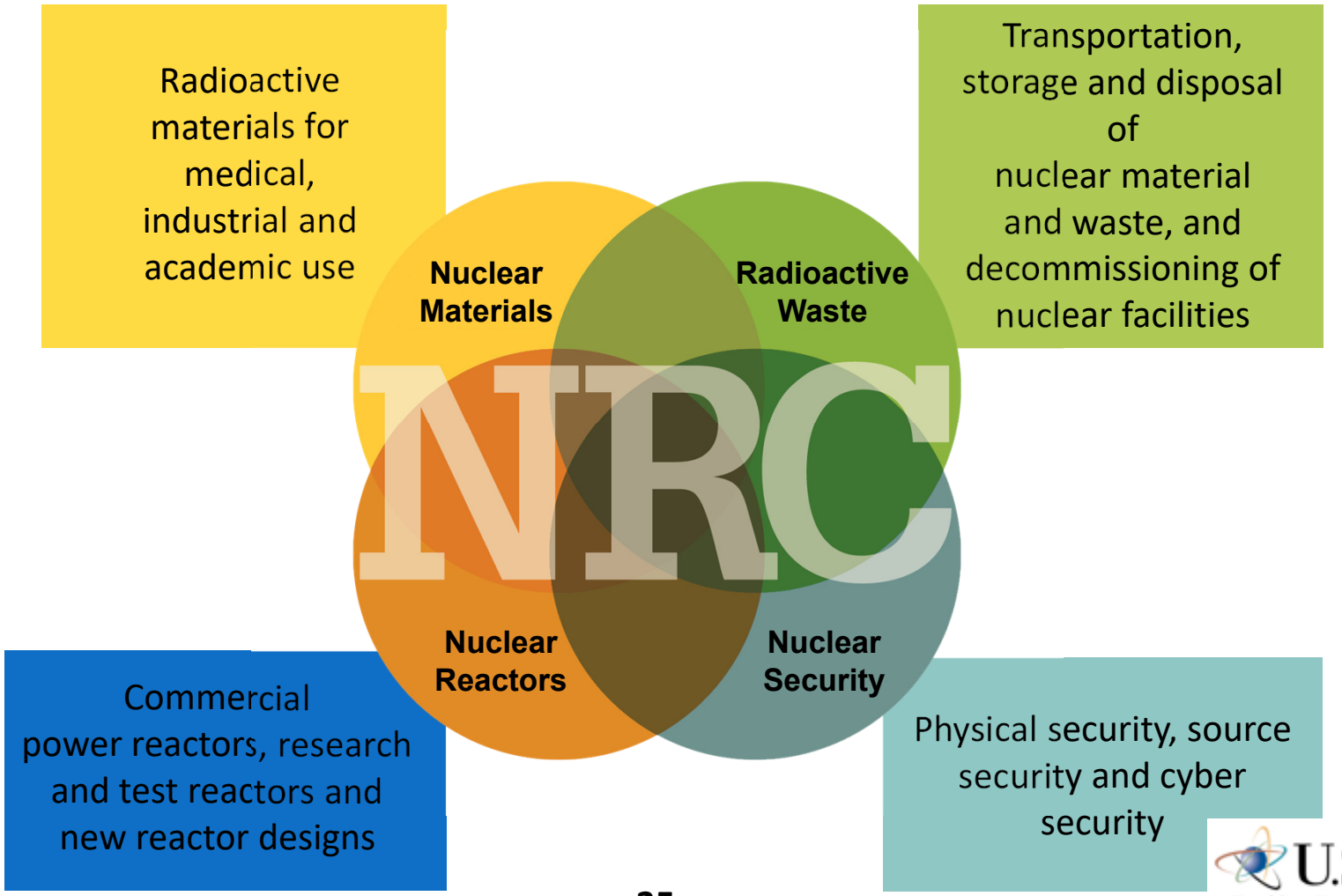


Background

- The Nuclear Energy Innovation and Modernization Act (NEIMA; Public Law 115-439) requires NRC to establish a **technology inclusive regulatory framework** for fusion energy systems by December 31, 2027
  - Definition of advanced reactor includes “fusion reactor”
- On January 3, 2023, staff submitted SECY-23-0001, “Options for Licensing and Regulating Fusion Energy Systems,” with rulemaking plan enclosed (ML22273A178)
  - Three options
  - Proposed rulemaking would be limited in scope to include definitions, content-of-application requirements, and other targeted augmentations



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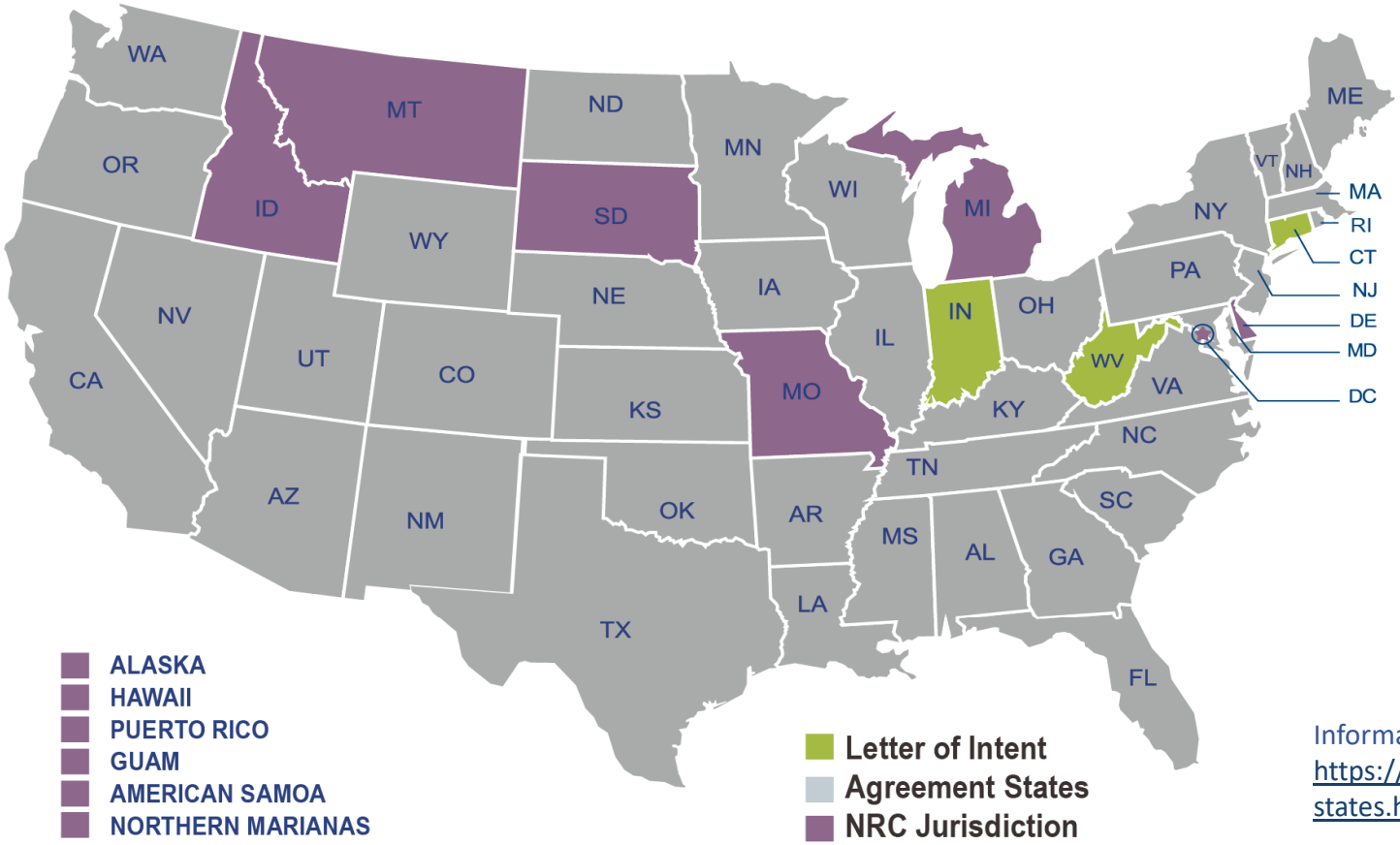
U.S. Agreement States



Information on Agreement State Program: https://www.nrc.gov/agreement-states.html

Note: Data are current as of February 2023. For the most recent information, go to the Agreement State page at https://www.nrc.gov/agreement-states.html. In February 2023, the State of West Virginia submitted a letter of intent to the NRC to become an agreement state.

Source: U.S. Nuclear Regulatory Commission - As of February 2023

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Specific Considerations from the SRM

- Scope limited to currently known fusion energy system designs
- The staff should consider existing fusion energy systems already licensed or under review by Agreement States
- The staff should evaluate whether controls-by-design approaches, export controls, or other controls are necessary for near-term fusion energy systems
- If a design presents hazards sufficiently beyond near-term technologies, staff should notify the Commission and make recommendations for appropriate action

SCOPE OF FUSION RULEMAKING ACTIVITIES

Licensing Guidance:

- New NUREG-1556 licensing volume
  - Well established structure
- Focus on topics that distinguish fusion from other uses of radioactive materials
- Address range of fusion technologies – technology inclusive
- Use standard content from guidance documents to the extent possible
  - NRC, State, and DOE
  - No other licensing guidance development anticipated

Other Related Activities (Non-Rulemaking):

- Technology-specific implementation advice
- Inspection guidance
- Training for NRC and Agreement State staff

NRC Outreach

Leverage Existing Communication Avenues

- State-Tribal Communication letters
- Government-to-Government meetings
- Public Meetings
- User Group(s)

Build Capabilities and Knowledge

- Workshops
- Seminars
- Training
- Staff rotations/details

Engagement Timeframe

- Start of official rulemaking
- Middle of draft development *(before concurrence)*
- After publication of proposed rule

(during public comment period)

Additional meetings as needed

Leverage Existing Regulatory Experience

- Agreement States
- DOE
- ARPA-E
- SDOs (ASME, ANS)
- International

Diverse Stakeholder Engagement

- Agreement States
- Tribal Nations
- Federal Agencies
- Fusion Industry
- Professional Associations
- Utilities
- Universities
- International community
- Non-Government Organizations

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