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

Topic Area 7 – Advanced Nuclear Materials

Up to 3 years and up to $1,000,000

NM-1: LWR Core or Structural Materials | *Sue Lesica, Federal POC*

NM-2: Advanced Reactor Core or Structural Materials | *Sue Lesica, Federal POC*

NM-3: Advanced Manufacturing Technologies | *Dirk Cairns Gallimore, Federal POC*

NM-4: Material for Fuel Recycling Applications | Kimberly Gray, *Federal POC*

NM-5: Other Advanced Nuclear Materials Topics

Topic Area 7

Advanced Nuclear Materials

- Identification, investigation, and research and development of revolutionary technologies in crosscutting materials science areas have the potential for radical improvement in reactor or fuel cycle performance, safety, and economics.
- This topical area invites applications that cover key materials science topics to better understand:
  - core and structural materials,
  - advanced materials manufacturing techniques,
  - qualifications and/or testing of existing materials,
  - new classes of materials not yet developed for nuclear reactors,
  - materials for advanced fuel recycle,
  - environmental effects,
  - thermal effects,
  - irradiation effects, and
  - other relevant areas including materials to efficiently immobilize fission products and off-gas capture species.

Topic Area 7 NM-1

LWR Core or Structural Materials (NM-1)

Understanding materials degradation in the current fleet of reactors is vital to their continued operation. Proposals are sought to further understand and predict **environmentally-assisted fatigue (EAF)**, a damage mechanism that may limit extended operation of the Light Water Reactor (LWR) fleet.

Test programs in the US, Japan, and Europe have shown that the water environment in LWR significantly reduces the fatigue life of LWR structural materials as compared with their fatigue life in air.

Applications should:

- identify materials and environmental loading conditions pertaining to the existing fleet of reactors.
- study the EAF damage mechanisms in LWR structural materials and the potential effect of loading conditions, material variabilities, and varying water environments via experimental characterization, modeling, or the combination of the two.
- address the uncertainty and conservatism in the current EAF prediction to support the long-term operation (LTO) of US LWR fleets.

Topic
Area 7
NM-1

Ongoing NE Work Relevant to NM-1

The Light Water Reactor Sustainability (LWRS) program Materials Research Pathway (MRP) has on-going research through many avenues of funding including directed research, NEUP, SBIR/STTR, and Industry FOA.

Previous or on-going research includes the following areas for environmentally-assisted fatigue:

Air vs. LWR environment testing
Low alloy steels, stainless steels, and their weldments
Materials cyclic behavior
3D Component level temperature and stress analysis
Temperature and stress analysis during LWR baseline and transient conditions

The above list of R&D examples is not exhaustive, and it is provided to assist applicants in identifying potential research areas as well as avoiding duplicative research.

More information about past/current LWRS MRP R&D can be found on the LWRS website:
https://lwrs.inl.gov/SitePages/Home.aspx

Topic
Area 7
NM-1

Areas Not of Interest

Applications should focus on research that supports the **DOE-NE mission**

Applications with the following focuses would be considered not relevant to this topic:

- Materials solely for nuclear fusion applications
- Materials not in the current fleet of reactors
- Nuclear non-proliferation purposes
- Nuclear weapons R&D
- Nuclear medical isotope production
- Nuclear medicine related technologies

Applications on technologies that crosscut any of these areas could be considered responsive if proposal clearly demonstrates the application to nuclear energy.

Topic Area 7 NM-2

Advanced Reactor Core or Structural Materials (NM-2)

Objective:

- To ensure a pipeline of qualified core or structural materials for advanced reactors to facilitate their economical deployment and efficient operation to contribute to DOE's decarbonization goal.

Technical Issues:

- There are some mechanistic understandings of creep damage and fatigue damage of structural alloys under elevated temperature service.
  - Designers can assess these failure modes separately for existing alloys.
  - Materials engineers can leverage such understanding to develop new alloys against creep damage or fatigue damage.

Challenges:

- The interaction of creep damage and fatigue damage under prototypical advanced reactor operating conditions often significantly reduces the cyclic design lives of structural components.
- Failure due to creep, fatigue and creep-fatigue interaction are dominate structural failure modes for advanced reactor structural applications.
- Current understanding of the creep-fatigue damage mechanism is limited and approaches to down-select existing materials or to develop new materials to establish a pipeline of qualified materials are essentially by the time-consuming and extensive elevated temperature mechanical properties testing.

Scope:

- Proposals are sought to develop a scientific understanding of the underlying mechanisms of creep, fatigue and creep-fatigue interaction for structural alloys under the prototypical advanced reactor operating conditions, and the use of such basis to assess existing material systems or to design new material systems to provide an overall optimum resistance against these structural failure modes, instead of relying solely on extensive mechanical properties testing, to support establishing a pipeline of qualified core or structural materials.
- Materials systems of interest are austenitic stainless steels, ferritic-martensite steels and nickel base alloys.

Topic
Area 7
NM-2

Ongoing NE Work Relevant to NM-2

The Advanced Reactor Core or Structural Materials programs have on-going research through many avenues of funding including directed research, NEUP and SBIR/STTR.

Previous or on-going advanced materials directed research to establish a structural material pipeline includes:

- Elevated temperature mechanical properties test programs to qualify Alloy 617 (nickel alloy), Alloy 709 (austenitic stainless steel), and optimized Grade 92 (ferritic-martensitic steel).

There were no systematic mechanistic studies of creep, fatigue and creep-fatigue damage mechanisms of structural alloys, or any possible strategies to develop an optimum overall resistance to these structural failure modes through such scientific understanding.

The above list of example materials is not exhaustive, and it is provided to assist applicants in identifying research that is not duplicative of previous or on-going research.

Topic Area 7 NM-2

Areas Not of Interest

Applications should focus on research that support the **DOE-NE mission**

Applications with the following focuses would be considered not relevant to this topic:

- Nuclear graphite
- Composite materials
- Refractory metals

Topic
Area 7
NM-3

Advanced Manufacturing Technologies (NM-3)

- This effort seeks to transform materials, processing, and fabrication techniques to significantly change the nuclear manufacturing cost curve.
- This includes but is not limited to the state of practice of processing and fabrication of composites and concrete, metals, joining and repair, as well as emerging capabilities developed within the advanced manufacturing enterprise for components, sub-systems, systems, and structures.

Topic
Area 7
NM-3

Ongoing Work Relevant to NM-3

Advanced Materials and Manufacturing Technologies (AMMT)

Development, Qualification and Demonstration

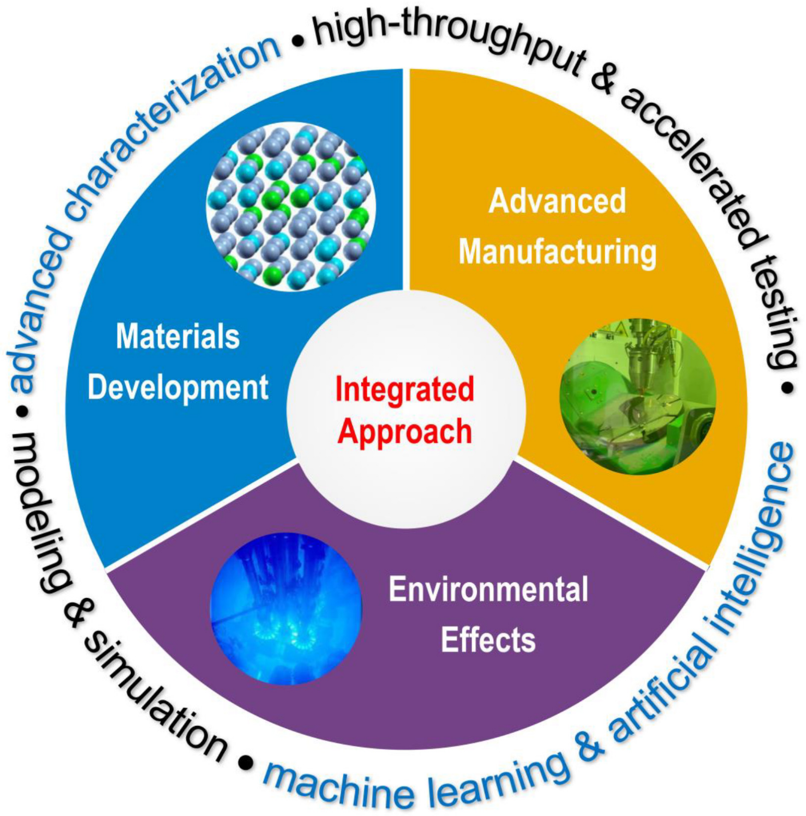
- Develop advanced materials & manufacturing technologies
- Establish a rapid qualification framework
- Evaluate material performance in reactor environments
- Technology demonstration and deployment

Capability Development & Transformative Research

- Develop high-throughput, accelerated testing and characterization techniques
- Develop modeling capabilities for materials design, development and qualification
- Perform transformative research to develop new material concepts and design

Collaborative Research and Development

- Investigate a broad range of advanced materials and manufacturing technologies
- Address reactor-specific issues
- Provide near-term material solutions to nuclear industry



- **AMMT combined three programs**
  - Advanced Methods for Manufacturing (AMM)
  - Transformational Challenge Reactor (TCR)
  - Nuclear Materials Discovery and Qualification Initiative (NMDQi)
- Other ongoing research through many avenues of funding including directed research, NEUP, SBIR/STTR, industry FOA.
- The above list of R&D examples is not exhaustive, and it is provided to assist applicants in identifying research that is not duplicative of previous or on-going research.
- **Helpful links**

AMMT Program Review
https://gain.inl.gov/SitePages/Workshops.aspx
NEUP https://neup.inl.gov
SBIR https://science.osti.gov/sbir/Awards
iFOA https://www.energy.gov/ne/industry-foa-awardees-8

Topic Area 7 NM-3

Areas Not of Interest

Applications should focus on research that support the **DOE-NE mission**

Applications with the following focuses would be considered not relevant to this topic:

- Nuclear non-proliferation purposes
- Nuclear weapons R&D
- Nuclear medical isotope production
- Nuclear medicine related technologies

Applications on technologies that crosscut any of these areas could be considered responsive if proposal clearly demonstrates the application to nuclear energy.

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Material for Fuel Recycling Applications

Kimberly Gray
Federal Program Manager

Advanced Waste Form Materials and Sorbent Materials for Off-Gas Capture

- **The capture and subsequent immobilization of regulated volatile radionuclides from the off-gas streams of an aqueous used nuclear fuel treatment facility has been a topic of substantial research interest for the Department of Energy.**
- **Both Iodine and Krypton capture have been used in various used nuclear fuel treatment facilities worldwide.**
- **Technologies developed and used for capturing gaseous iodine from used fuel treatment facilities off-gas streams are caustic or acidic scrubbing solutions and chemisorption on silver coated or impregnated adsorbents.**
- **Technologies developed and used for capturing noble gases, Krypton, Kr^{85}, can be achieved either by the cryogenic methods or by physical adsorption on solid matrices (e.g. molecular sieves, metal-organic frameworks, or porous organic polymers).**
- **Sorbent material applications should consider the following capture media criteria:**
  - Absorption rates
  - Capture efficiency
  - Loading capacity
  - Consolidation of developed material into a dense and leach resistant waste form for long-term disposal

Relevant Work

- **The Material Recovery and Waste Form Development (MRWFD) Campaign has on-going research through many avenues of funding including NEUP.**
- **Previous and on-going research include the following sorbent materials:**
  - Mordenite species (AgZ, HZ)
  - MOF species
- **References for previous and on-going sorbent material development work in the MRWFD campaign:**

  - Riley, B.J, J.D. Vienna, D.M. Strachan, J. S. McCloy, and J.L. Jerden. 2016 "Materials and processes for the effective capture and immobilization of radioiodine: A review." *Journal of Nuclear Materials* 470:307-26.
  - Soelberg, N.R., T.G. Garn, M.R. Greenhalgh, J.D. Law, R. Jubin, D.M. Strachan, and P.K. Thallapally. 2013. "Radioactive iodine and krypton control for nuclear fuel reprocessing facilities," *Science and Technology of Nuclear Installations*, article ID 702496, Report no. INL/JOU-13-28481, February 19, http://dx.doi.org/10.1155/2013/702496
  - Thallapally, P.K. 2017. Perform Column Breakthrough Measurements on Best Performing Sorbent to Characterize the Co-adsorbed Gases. Report no. PNNL-26506, DOE MRWFD, Pacific Northwest National Laboratory, Richland, WA.

Non-Relevant Work

- Applications should focus on research that support the DOE-NE mission.
- Applications on sorbent material crosscut technologies could be considered responsive if proposals clearly demonstrate the application to nuclear energy.

Questions

- Please email all questions to Kimberly Gray and John Vienna

- Kimberly Gray, Federal Program Manager
- Kimberly.Gray@nuclear.energy.gov

- John Vienna, TPOC
- John.Vienna@PNNL.gov

Topic
Area 7
NM-5

Other Advanced Nuclear Materials Topics (NM-5)

Proposals that are relevant to advanced nuclear materials as described in the Topic Area 7 overview but are not covered by the previous topic categories can be submitted to NM-5 for consideration.

It is important to note that any submission to this category can be crosscutting, but must reinforce the Office of Nuclear Energy's mission and the following supporting goals:

"Advance nuclear energy science and technology to meet U.S. energy, environmental, and economic needs."

1. Enable continued operation of existing U.S. nuclear reactors.
2. Enable deployment of advanced nuclear reactors.
3. Develop advanced nuclear fuel cycles.
4. Maintain U.S. leadership in nuclear energy technology.

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Questions?