Is there Life Beyond Eighty (LBE) ?
Why we should prepare for License Renewal to 100 years

Thomas M. Rosseel
Xiang (Frank) Chen
Materials Science and Technology Division
Oak Ridge National Laboratory

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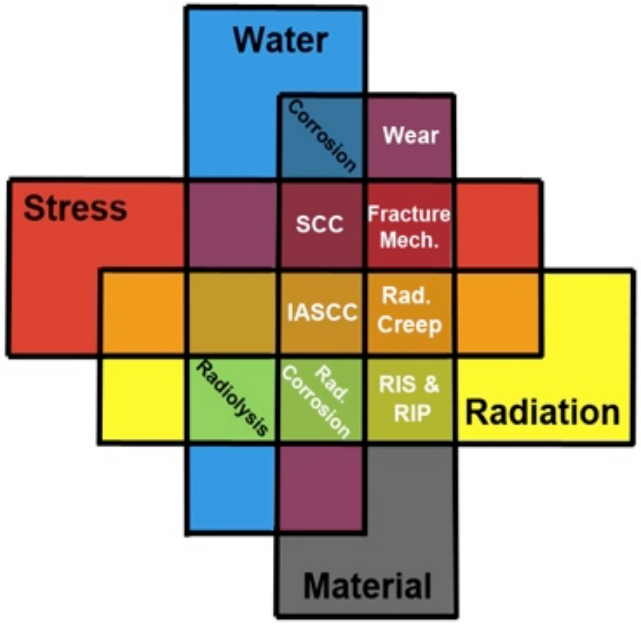
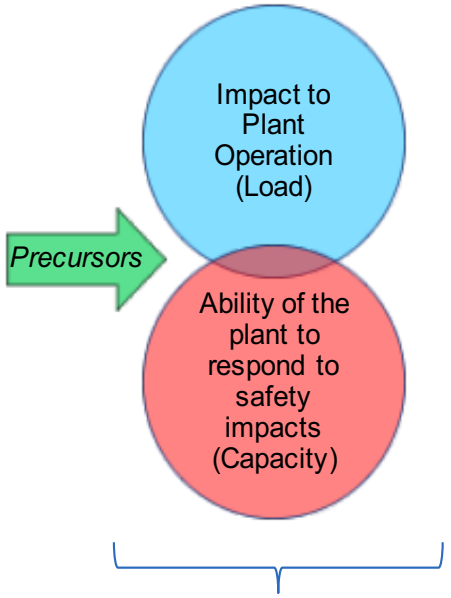
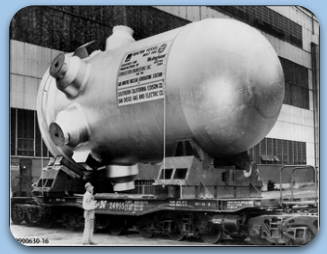
Current US DOE Materials Research: Goals and Objectives

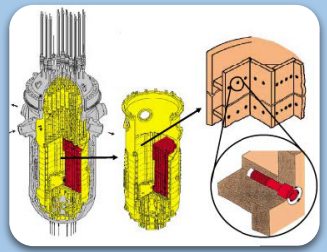


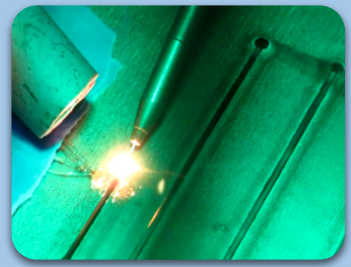


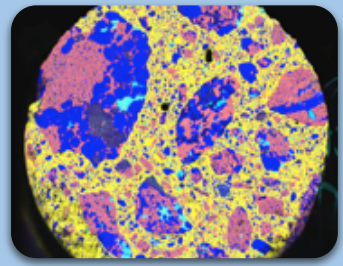
- Develop the **scientific basis for understanding and predicting long-term environmental degradation behavior** of materials in nuclear power plants and
- **Provide data and methods to assess the performance of systems, structures, and components essential for the safe and economically sustainable operation** of the US NPP fleet.

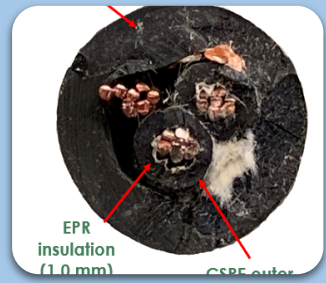
Current US DOE Materials Research:











Reactor Pressure Vessel

Core Internals and Piping

Mitigation Technologies

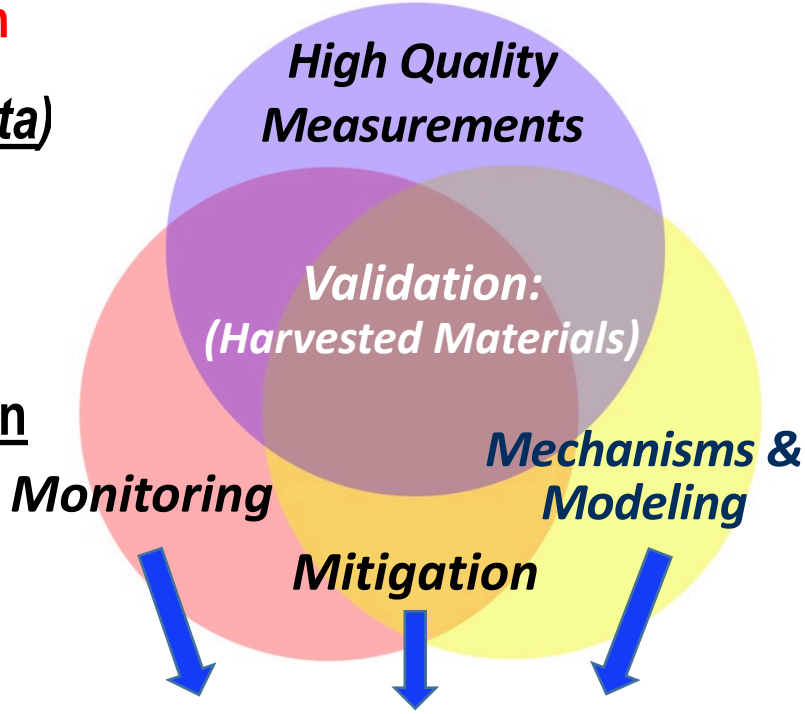
Concrete Degradation

Cable Aging Degradation

Addressing aging management knowledge gaps requires a multifaceted research approach

Guided by sound nuclear materials research approach

- *Measurements of degradation* (*high quality data*)
  - *Structure and properties of materials under stress*
- *Mechanisms of degradation* (scientific understanding)
- *Modeling and simulation* to predict degradation
- *Monitoring degradation* (*non-destructive examination*)
- *Mitigation strategies* *for sustainability*

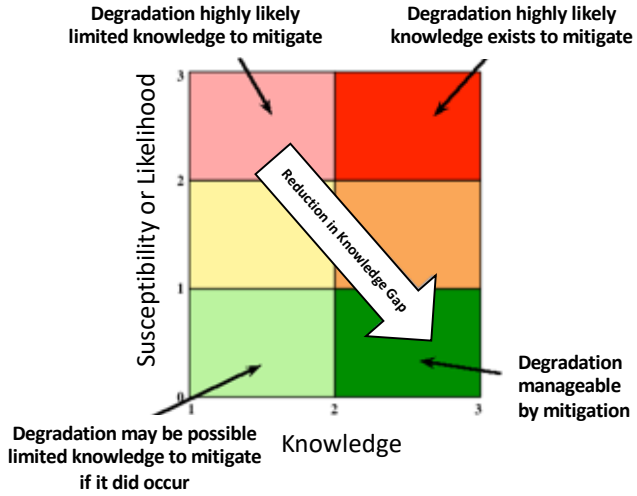


Regulator and Industry Engagement:
Margins Reduction & Improve Sustainability

What approach has been used: Research Needs Assessment for License Renewal

First License Renewal: 40 – 60 years

- **US NRC: Proactive Materials Degradation Assessment (PMDA, NUREG / CR-6923)** of **internals** to identify possible degradation effects for extending operation from 40 to 60 years of operation.
- **Expert panel** from the nuclear community led by the US NRC and including: (**industry, universities, & international experts**)
- **PMDA** findings used as **inputs to develop** Generic Aging Lessons Learned (**GALL**).
- **Addressed gaps but did not rank in terms of priority.**

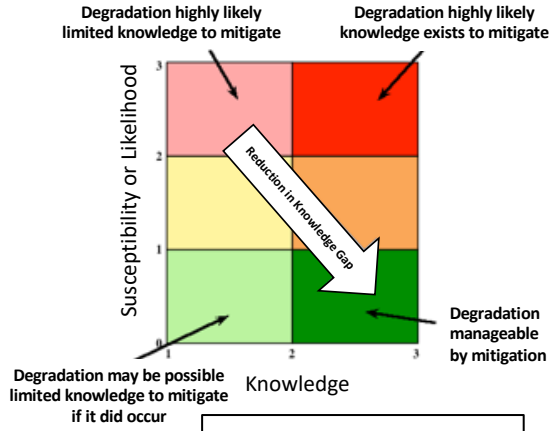


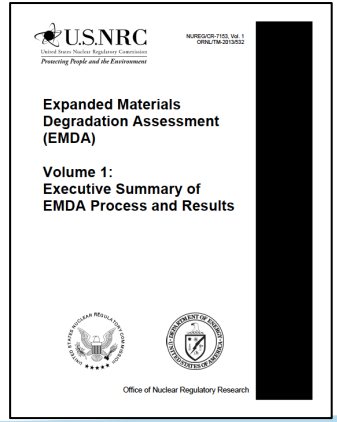
What approach has been used: Research Needs Assessment for Life Beyond 60

Second License Renewal: 60 – 80 years

Expanded Materials Degradation Assessment (EMDA):
NUREG / CR-7153 (joint DOE / NRC effort) 2011 - 2013

- **Expanded scope of the Proactive Materials Degradation Assessment (PMDA, NUREG / CR-6923) from internals to identify degradation effects and scenarios beyond 60 years of operation.**
- **Expert panel from the nuclear community (industry, EPRI, national labs, universities, international, & NRC)**
- **Addressed gaps but does not rank in terms of priority.**
- **EMDA: RPV, Internals, Concrete, and Cables**





Materials Research: What's Next for Extended Operation of NPPs?

DOE, NRC and Industry materials research programs have significantly advanced the understanding, characterization, modeling of materials degradation in nuclear power plants

Current Research Focus:

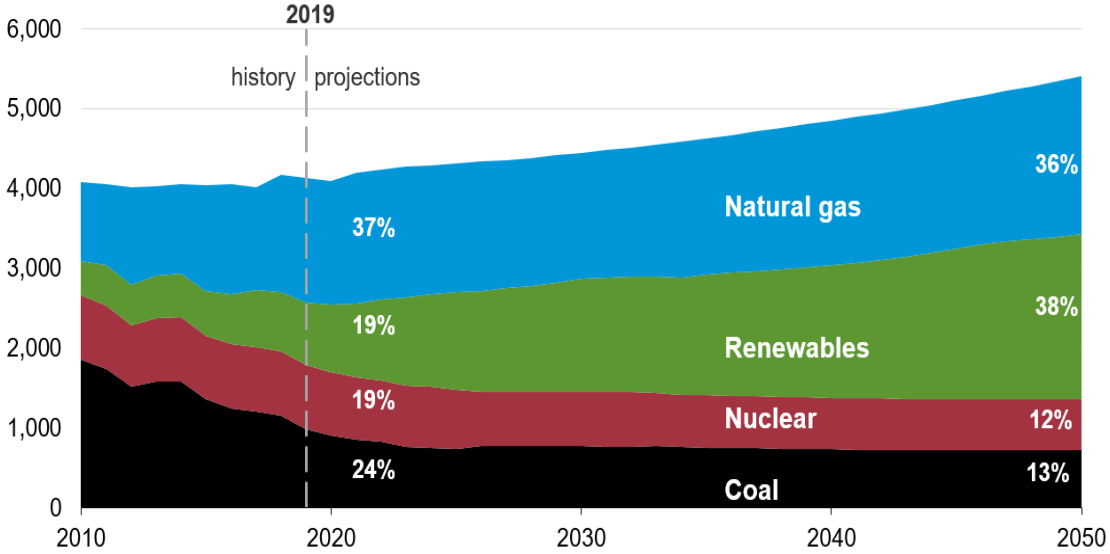
- **Complete development of predictive degradation models**
- **Refine predictive models through Codes and Standards evaluations for use by the nuclear industry**
- **Continue engagement with stakeholders (EPRI, NRC, utilities, and vendors) to solve critical sustainability issues**

Extended Operation (LBE):

- **How should we prepare for a possible need to provide electrical capacity from the existing LWR fleet?**

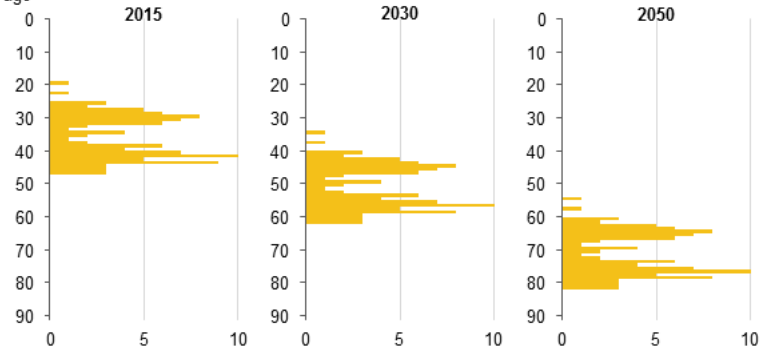
What will US electrical power generation and capacity look like in 2050?

Electricity generation
(U.S. Energy Information Administration Annual Energy Outlook 2020 Reference case)
billion kilowatthours



	Nuclear electricity generation (BkWh)	Nuclear Capacity (GW)
2019	807	98.1
2050	642	78.5

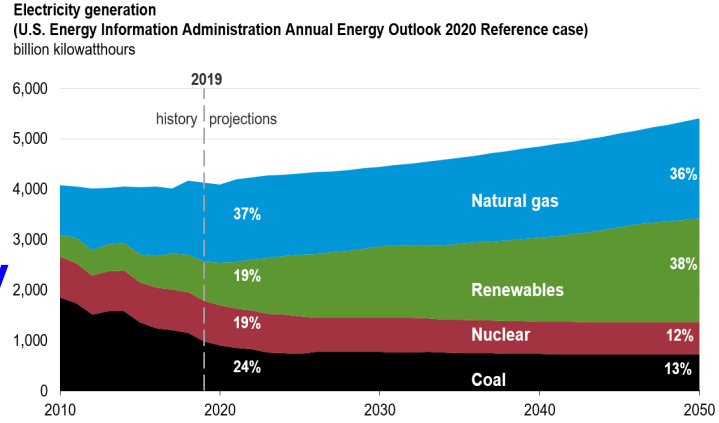
Age distribution of existing U.S. nuclear reactors at selected dates



- Based on the US Energy Information Administration (EIA) predictions, **by 2050 nuclear capacity and electricity generation (including new builds) will decrease to ~ 80% of 2019 levels**
- Based on the age distribution of existing US nuclear reactors, **by 2050, 50% of US nuclear fleet will be within 10 yrs. of 80 years of operation** and, therefore, **without a LBE plan, the US could lose 50% of its nuclear capacity due to closures and limited new builds, resulting in ~30 GW capacity shortage in 2060**

Options: SMRs, Advanced Reactors, & Renewables

- What is the current outlook in the US for advanced reactors with passive safety systems? (**Can costs and time to build be reduced?**)
- Do we know how many SMRs and other advanced reactor concepts will be operational? (**How long will it take to assess success?**)
- What is the **path forward to increase the capacity of advanced reactors / SMRs** by in 2050?
- Is the **electrical capacity of renewables** under or over predicted? (**30-year estimates are questionable**)
- Can we predict the size of a carbon tax? **(not likely)**



What are the LBE unknowns (1)?

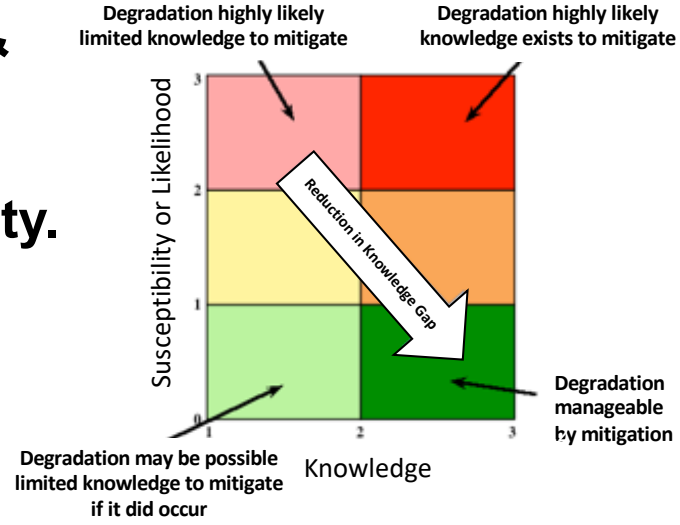
- **Degradation modes** that are **already occurring and may grow more severe** during extended lifetimes
- **Degradation modes** at LBE for which **there is a limited mechanistic understanding** and for which **long-term research is needed**
- **Degradation modes** for which there is **little or no supporting data** and that **may be problematic for extended lifetimes**

What are the LBE unknowns (2)?

- **Future advances** in **NDE technologies and methods:**
  - Improved **sensors**
  - Real time **monitoring**
- **Future advances in mitigation methods and materials**
  - **Advanced replacement materials**
  - **Weld repair techniques**
- **What are the options / path forward**

Establish Research Needs Assessment for LBE Based on an Expert Panel Consensus

- In FY 22, initiate a Subsequent or Second Expanded Materials Degradation Assessment (SEMDA) and publish a gap analysis report by 2024:
- Expert panel from the nuclear community (industry, EPRI, national labs, universities, international, & NRC)
- Address gaps but will not rank in terms of priority.
- SEMDA: RPV, Internals, Concrete, Cables, Mitigation, NDE / On-line Monitoring



Establishing an LBE path forward:

- Identity knowledge gaps (SEMDA?)
- Review and identify key priorities and timelines to reach goals
- Continue engagement with stakeholders (EPRI, NRC, PWROG, BWROG, utilities, universities, and vendors) to develop research plans that address key issues and sustainability of the US NPP fleet
- Predicting the future is not easy but planning for the future makes it easier to prepare for the future.

Session 2 Presentation

Reactor Pressure Vessel Aging at Extended Operation - Thermal Annealing of Reactor Pressure Vessels

Mikhail A. Sokolov

Materials Science and Technology Division,
Oak Ridge National Laboratory

Session 2 Presentation

Potential materials issues to monitor for stainless steel reactor internals during extended plant life to 80-100 years*

Frank A. Garner and Lin Shao
Nuclear Engineering Department
Texas A&M University

Maxim Gussev
Reactor and Nuclear Systems Division
Oak Ridge National Laboratory

*Maximum dose of 200-250 dpa in PWRs, but much less in BWRs

Session 3 Presentation

Life Beyond 80: Concrete Aging

Yann Le Pape, T. M. Rosseel, Elena Tajuelo Rodriguez, Amani Cheniour, Yujie Li, Paula Bran Anleu

Nuclear Structures and Construction Group

Nuclear Energy and Fuel Cycle Division

Oak Ridge National Laboratory

Session 4 Presentation

Reliable Use of Cables at Extended Operation

Leo Fifield
Pacific Northwest National Laboratory