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License Renewal and Long Term Operation for the US Nuclear Power Plants

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Electric Power Research Institute (EPRI)

Presented to

Spanish Nuclear Society

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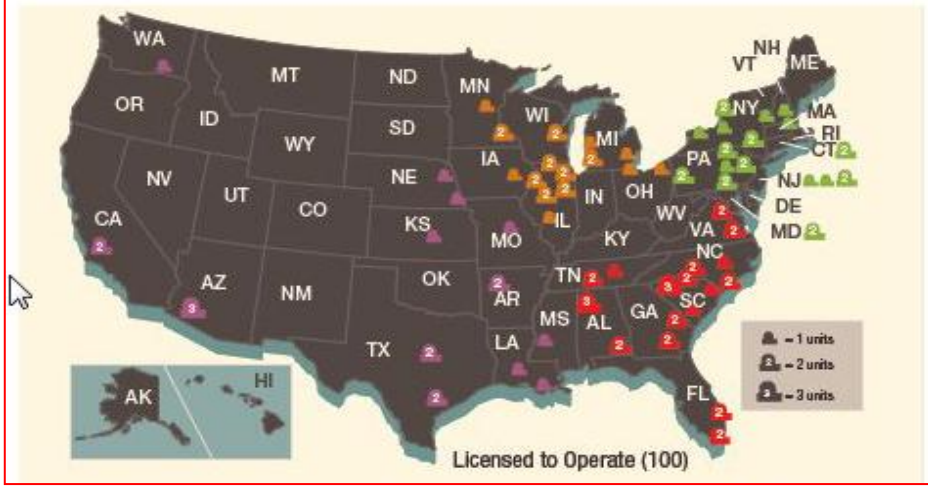
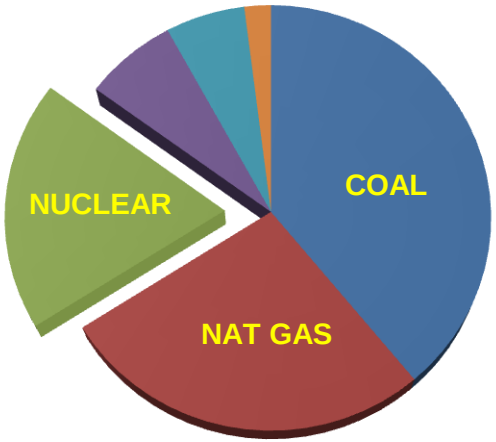
Status of US Nuclear Fleet

- 99 operating nuclear reactors on 62 sites
  - 64 PWRs (64.5 GWe)
  - 35 BWRs (34.5 GWe)
- 5 Reactors under construction
- 20 Reactors decommissioned
- Average age: 35 years
- 99 GWe installed capacity (~27% of world's capacity)
- 19.4% of US electric production (789 TWh)



Electric Power Generation



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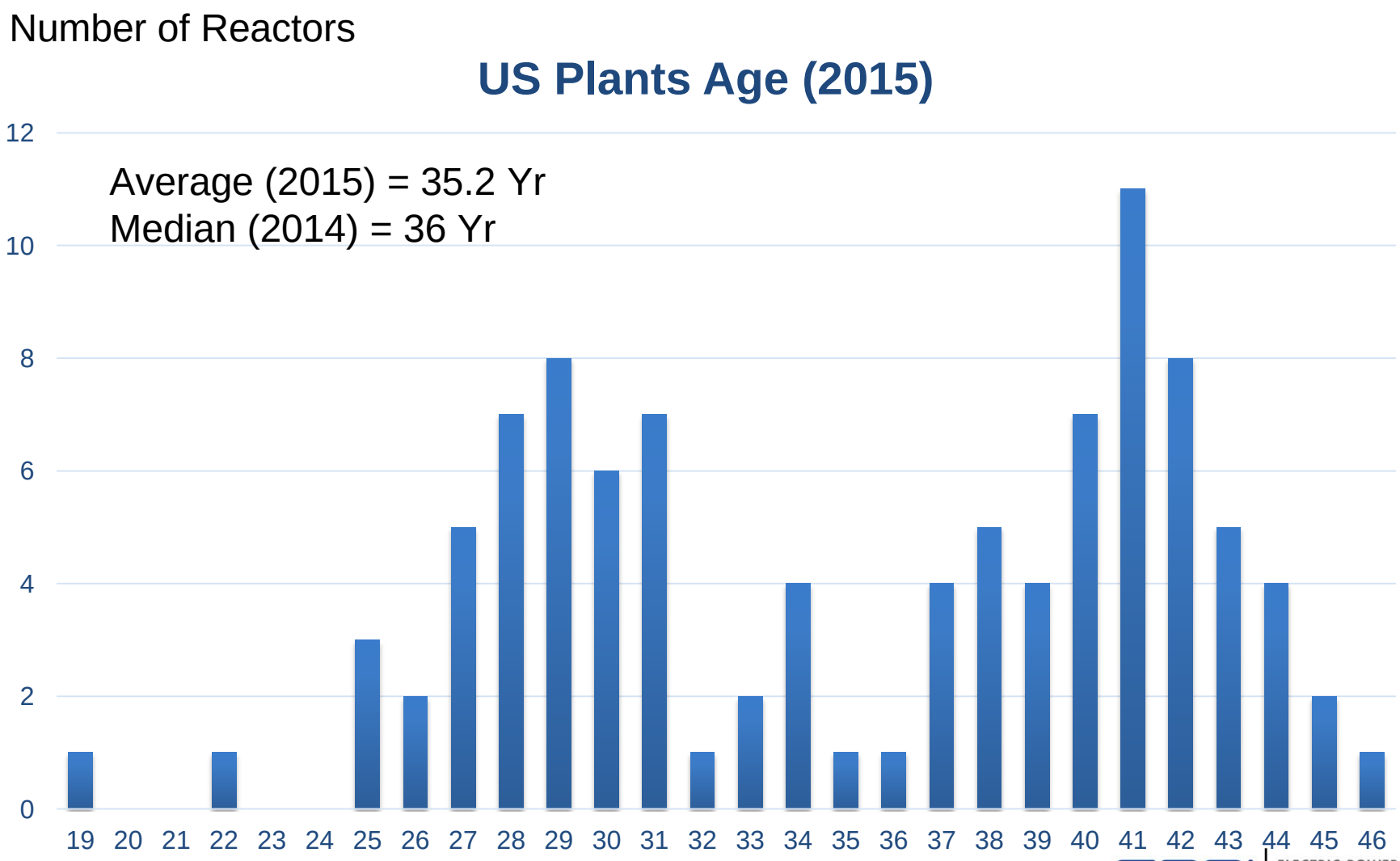
US Fleet's Age (2015)



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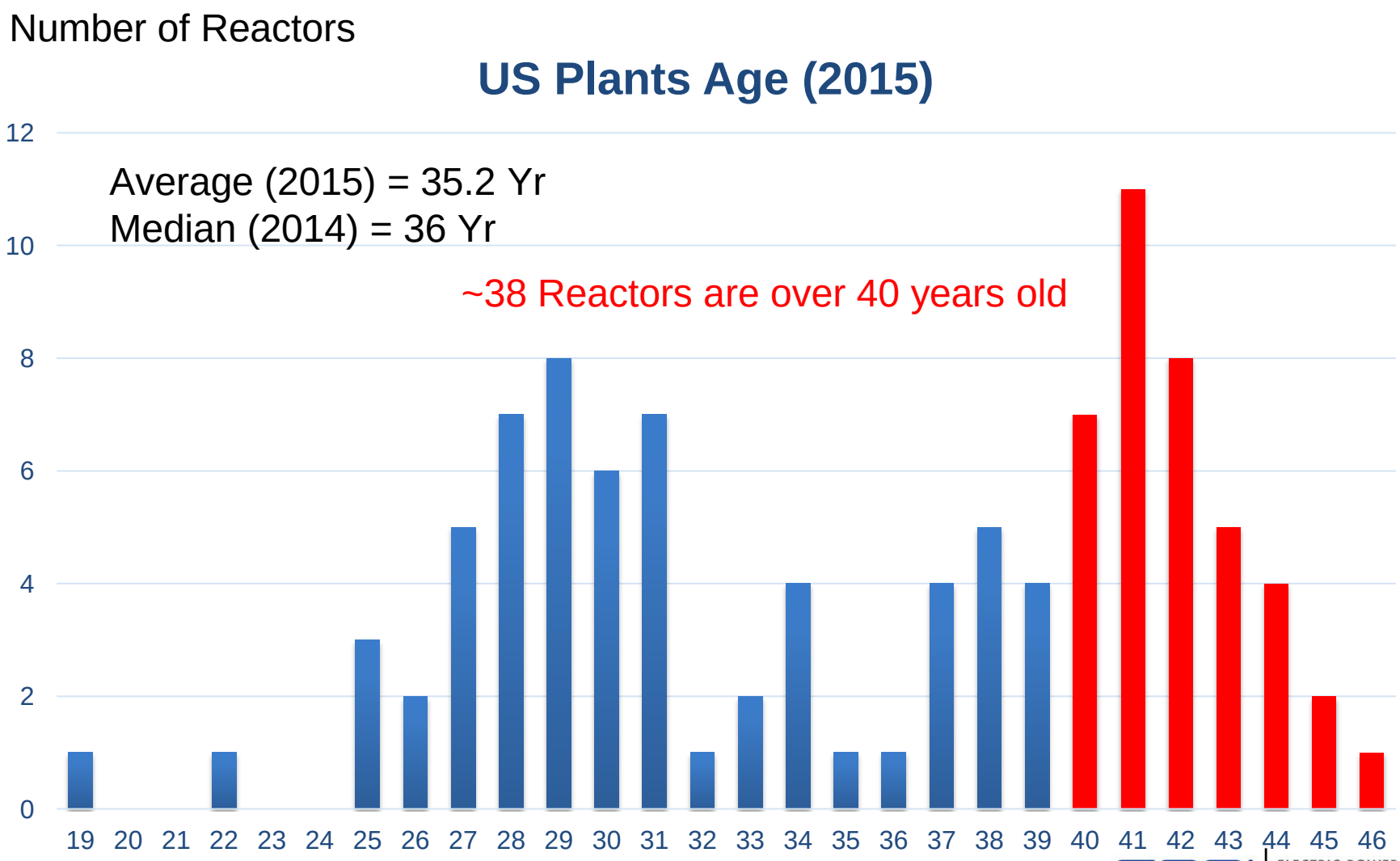

License Renewal Regulatory Requirements (40 60 years)

- **Technical information to support application**
  - Integrated Plant Assessment
    - Current Licensing basis changes
    - Time Limited Aging Analysis (TLAA)
    - Final Safety Analysis Report (FSAR)
  - Technical Specifications (changes & additions)
- **Environmental Review**
  - Generic Environmental Impact Statement
  - Scoping Process
  - Standard Review Plan and Regulatory Guide
  - High-Level Waste
- **Inspection Program**

The Generic Aging Lessons Learned (GALL) report

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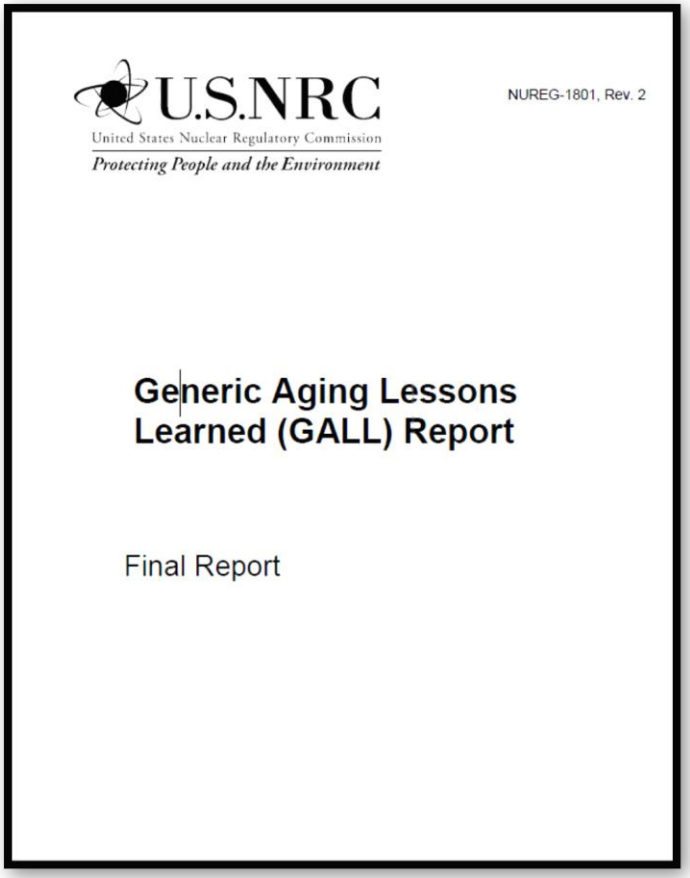
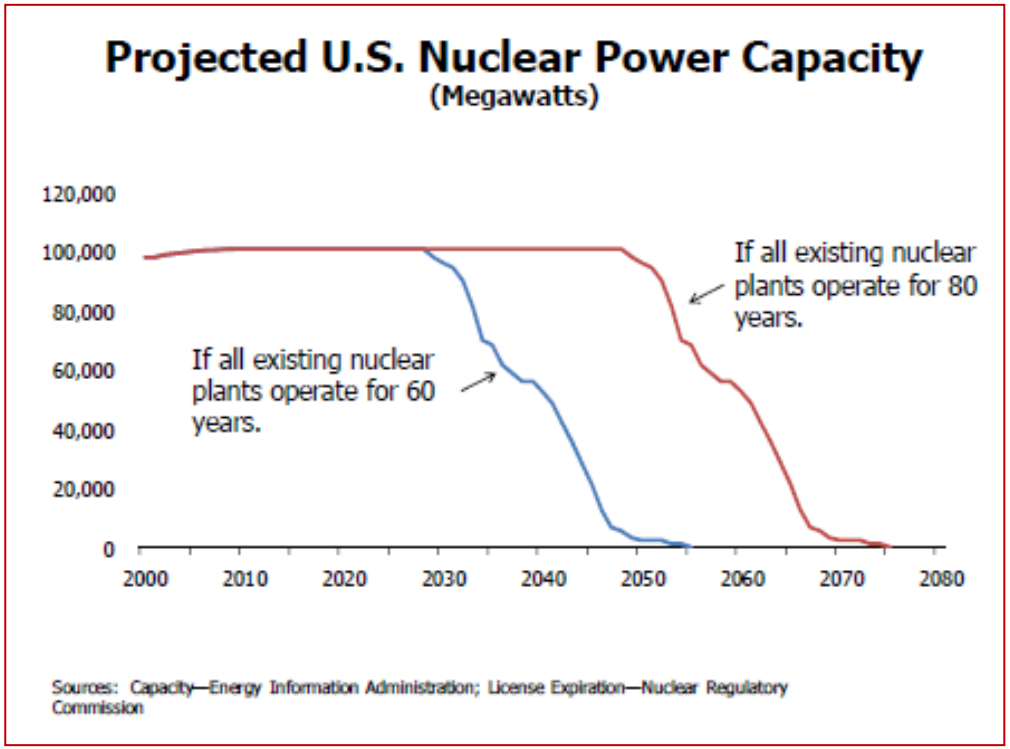
Objectives of Generic Aging Lessons Learned (GALL) Report

- The GALL Report contains
  - **The technical basis** for determining where existing programs are adequate without modification and where existing programs should be augmented for the period of extended operation
  - **The Aging Management Programs (AMP):** prescribe inspections, monitoring, testing, and evaluations to assure that SSCs subject to aging degradation continue to satisfy their intended functions.



Subsequent License Renewal (60 – 80 years)

- First reactors will achieve 60 years operation in 2029
- Companies must plan either to replace power or extent life several years ahead
  - Long lead time for replacement of some components
  - Regulatory clarity
  - Financial planning
  - Maintenance, repair and replacement strategies
  - Research
- DOE, NRC and EPRI have MOU to cooperate on this topic
- NRC is preparing framework for further extension (GALL 3)



Regulations and guidance must be ready at least a decade in advance

LTO Considerations

Economics

- Future electricity prices
- Country's energy policy for carbon and renewables
- Upgrades and refurbishments
- Equipment Obsolescence\

Regulatory Framework

- 'License Renewal' – US approach
- 'Periodic Safety Review' – EU approach
- Some countries use elements of both
- Duration of license renewal varies

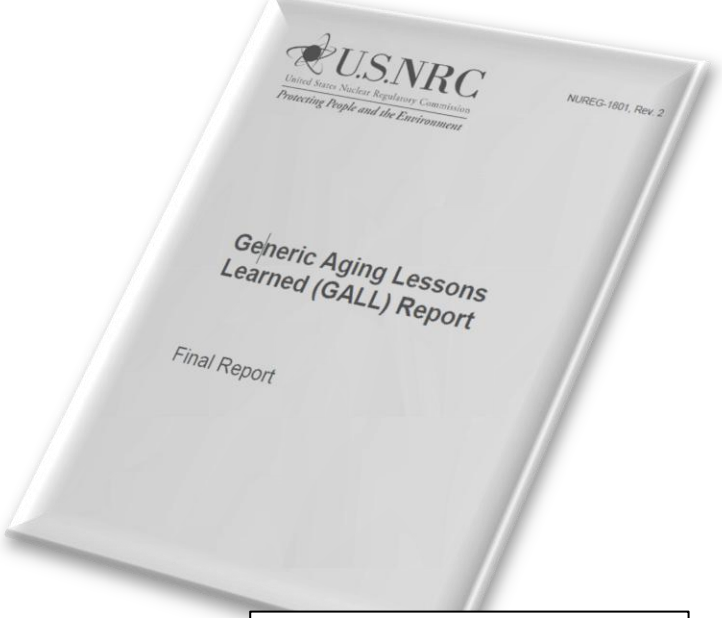
Potential Life Limiting Factors

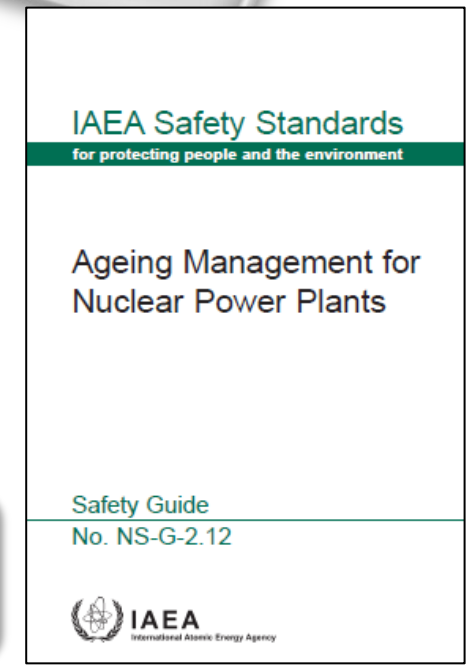
- Reactor Coolant System metals
- Reactor pressure vessel
- Electrical cables
- Containment and concrete structures

Regulatory Process

- Generic Aging Lessons Learned (GALL) - NRC
  - GALL, rev 2 for 40 to 60 years
  - GALL, rev 3 in development for 60 to 80 years

- International-GALL - IAEA
  - Developed by international working groups
  - Passive and some active components that are safety or important to safety
  - Added a Technical Obsolesce Program
  - PWR, VVER, BWR, CANDU and PHWR





IAEA has a group working on updates and revisions to the IGALL.

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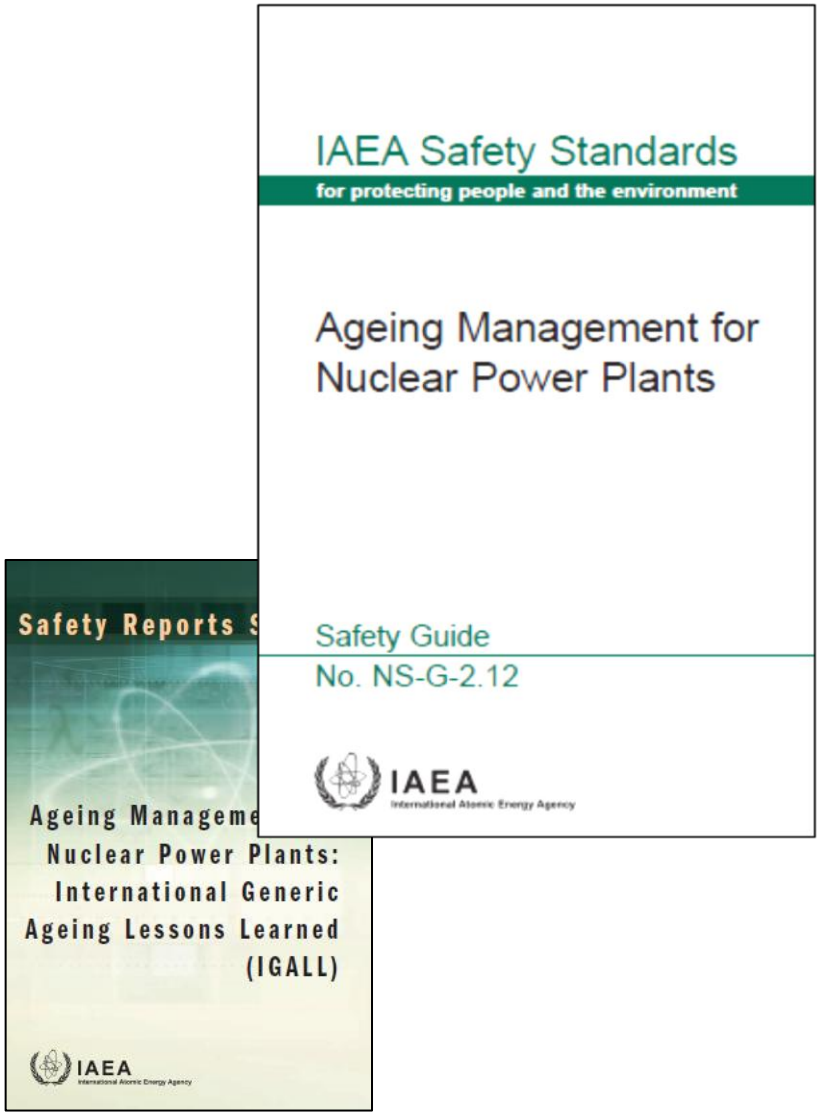
IGALL Background

More than 120 experts representing 23 Countries have already contributed to IGALL's development and are actively involved in the implementation and further development of IGALL.

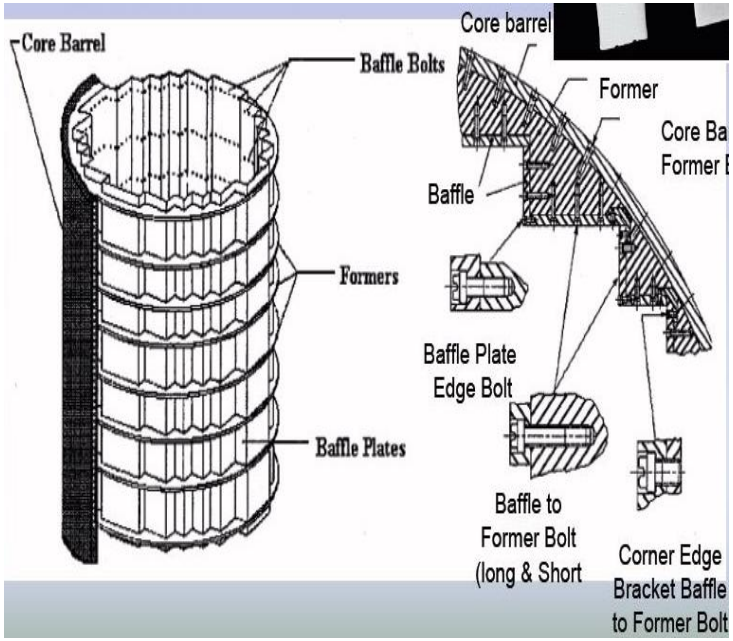
Objectives:

- Basis for implementation of recommended AMPs for NPPs with diverse technologies: PWR, BWR, VVER, CANDU, PHWR
- Fundamental document supporting a systematic approach to managing of aging as described in IAEA Safety Guide NS-G-2.12



EPRI LTO Program Goals and Objectives

- Technical basis for ***decision*** to operate through extended life time
  - Supports business case for life extension and refurbishments
- Technology to ***manage*** plant assets throughout the lifetime
  - Aging management, asset management and risk management
  - Addresses safety, performance and costs

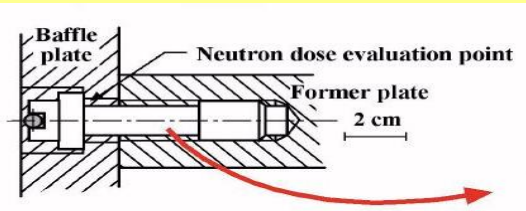


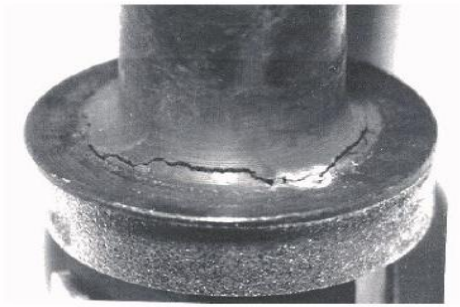
Research projects are leveraged within EPRI, and with external R&D partners

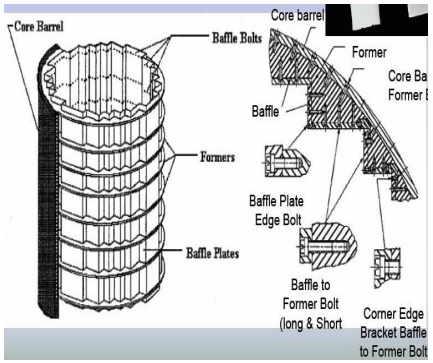
Prioritization of R&D for LTO

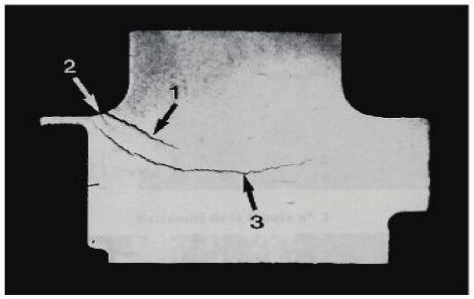
- High Priority:
  1. Reactor pressure vessel
  2. Primary system metals, welds and piping
  3. Electrical cables
  4. Concrete and containment structures

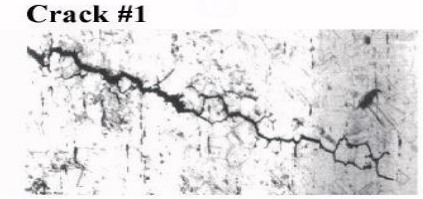
- Aging Impacts:
  - Increased thermal exposure
  - Increased radiation exposure
  - Stress corrosion cracking
  - Fatigue usage
  - Wear
  - Etc…..











EPRI R&D Projects to Support AMPs Implementation

- R&D to understand aging degradation
  - Mechanism and failure modes
  - Initiation and growth rates
  - Inspection and Evaluation GLs
- Inspection methods
  - Detection and measurement
  - Non destructive examination and qualification
- Mitigation strategies
  - Chemistry
  - Stress relieving techniques
- Condition Monitoring
  - On-line monitoring
  - In-field detection
- Prediction of Remaining Useful Life
  - Health Monitoring software and algorithms
- Repair & Replacement Decisions
  - Life Cycle Management GLs
  - Integrated Life Cycle Management (ILCM)

RCS Metals and Reactor Pressure Vessel

- Key R&D products
  - Vessel internals inspection guidelines
  - Flaw evaluation guidelines
  - Coordinated reactor vessel surveillance capsule program
  - Improved crack growth rate trend correlations
  - Fatigue degradation
  - Stainless steel degradation

- On-going and future R&D
  - Test harvested materials, Zorita baffle plates, baffle bolts and core shroud boat sample
  - Develop mitigation strategies

OBJECTIVE

Enhance knowledge and control of aging mechanisms, inspection methods and repair strategies

Jose Cabrera NPP “Zorita”
1968 – 2006 (~26 EFPY)

Mapping IGALL Aging Management Programs to EPRI Reports (EPRI Report # 3002005485)

AMP103	Water Chemistry	EPRI, PWR Primary Water Chemistry Guidelines, EPRI 1014986, Revision 6, Volumes 1 and 2, EPRI, Palo Alto, CA, December 2007.	1014986	3002000505 (Rev 7, 2014)	CHEM
AMP103	Water Chemistry	EPRI, PWR Secondary Water Chemistry Guidelines, EPRI 1016555, Revision 7, EPRI, Palo Alto, CA, February 2009.	1016555		CHEM
AMP103	Water Chemistry	EPRI, BWR Vessel and Internals Project: BWR Water Chemistry Guidelines, BWRVIP-190 (EPRI 1016579), 2008 Revision, EPRI, Palo Alto, CA, October 2008.	1016579	3002002623 (Rev 1, 2014)	BWRVIP
AMP104	Reactor Head Closure Stud Bolting	EPRI, Degradation and Failure of Bolting in Nuclear Power Plants, Volumes 1 and 2, EPRI, Palo Alto, CA, May 1988,	NP-5769-V1 and NP-5769-V2		PE
AMP104	Reactor Head Closure Stud Bolting	EPRI, Nuclear Maintenance Application Center: Bolting Guides Consolidation Review, EPRI, Palo Alto, CA, November 2006.	1013550		NMAC
AMP105	BWR Vessel ID Attachment Welds	EPRI, BWR Vessel and Internals Project, Vessel ID Attachment Weld Inspection and Flaw Evaluation Guidelines, BWRVIP-48-A (EPRI 1009948), EPRI, Palo Alto, CA, November 2004	1009948		BWRVIP
AMP106	BWR Feedwater Nozzle	BWR OWNERS' GROUP, Alternate BWR Feedwater Nozzle Inspection Requirements, GE-NE-523-A71-0594, Rev. 1, BWROG, August 1999	GE-NE-523-A71-0594, Rev. 1		
AMP107	BWR Stress Corrosion Cracking in Coolant Pressure Boundary Components	EPRI, BWR Vessel and Internals Project, Technical Basis for Revisions to Generic Letter 88-01 Inspection Schedules (NUREG-0313), BWRVIP-75-A (EPRI 1012621), EPRI, Palo Alto, CA, October 2005	1012621		BWRVIP
AMP108	BWR Penetrations	EPRI BWR Vessel and Internals Project, Instrument Penetration Inspection and Flaw Evaluation Guidelines, BWRVIP-49-A (EPRI 1006602), EPRI, Palo Alto, CA, April 2002.	1006602		BWRVIP
AMP108	BWR Penetrations	EPRI, BWR Vessel and Internals Project, BWR Standby Liquid Control System/Core Plate ΔP Inspection and Flaw Evaluation Guidelines, BWRVIP-27-A (EPRI 1007279), EPRI, Palo Alto, CA, August 2003.	1007279		BWRVIP
AMP108	BWR Penetrations	EPRI, BWR Vessel and Internals Project, BWR Lower Plenum Inspection and Flaw Evaluation Guidelines, BWRVIP-47-A (EPRI 1009947), EPRI, Palo Alto, CA, November 2004.	1009947		BWRVIP
AMP108	BWR Penetrations	EPRI, BWR Vessel and Internals Project, Instrument Penetration Repair Design Criteria, BWRVIP-57-A (EPRI 1012111), EPRI, Palo Alto, CA, September 2005.	1012111		BWRVIP

R&D Cooperation with Spain

- **EPRI is benefiting from strong collaboration and support in Spain**
- Zorita Internals Research Project (ZIRP)
- BWR Channel Distortion Program
- BWR Mark III Containment analysis (for filtered vents)
- Analysis of Spain Spent Fuel Pools under MAAP 5
- Spain PWRs Secondary Water Chemistry improvement
- GRUVAL NDE Qualification
- Spanish PWRs Pressurizer Safety Valves O&M
- Alloy 690 crack initiation
- Jose Cabrera site characterization Ground Water
- UNESA's participation in the EPRI Nuclear Power Council and Technical advisory committees

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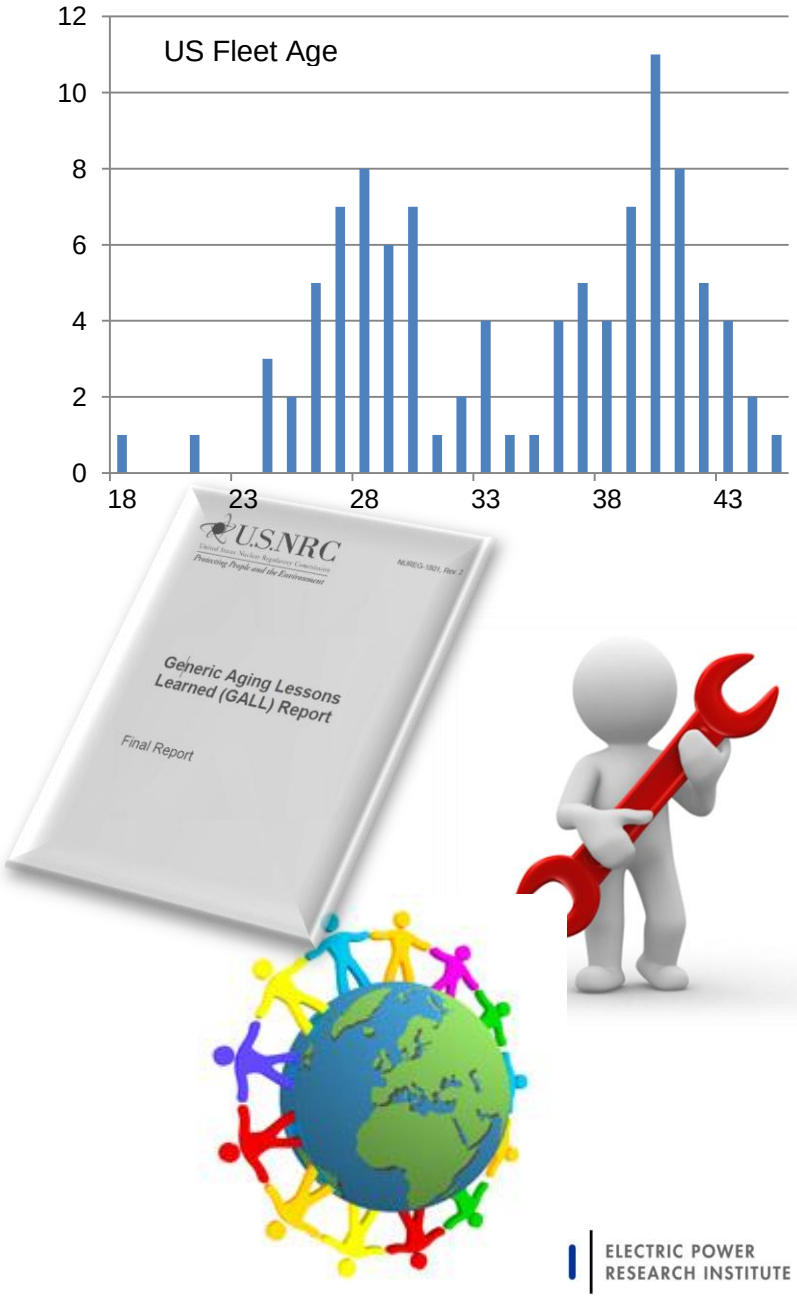
Summary

- Nuclear License Extension in the US is an economic necessity
- Technical basis is established and in use for aging management in increasing number of plants
- Continuous improvements based on research results, inspections and operating experience underway for extension to 80 yrs.
- EPRI considers that coordination and collaboration with research partners in the US and Internationally are critical to success.



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