EPRI | ELECTRIC POWER RESEARCH INSTITUTE

Introduction and Kickoff

Andrew Sowder
Sr. Technical Executive, Advanced Nuclear Technology

Innovation Network for Fusion Energy (INFUSE) Workshop
December 1, 2020

Electric Power Research Institute…Born in a Blackout

- Mission: advancing ***safe***, ***reliable***, ***affordable*** and ***environmentally responsible*** electricity for society

- Independent, nonprofit center for ***collaborative*** public interest energy and environmental research

- Major offices in Palo Alto, CA, Charlotte, NC, and Knoxville, TN
  - Laboratories in Knoxville, Charlotte and Lenox, MA
  - In-country presence around the world

New York City: The Great Northeast Blackout, 1965

- International membership and reach:
  - International members > 25% of EPRI research (~50% for nuclear)
  - EPRI members generate > 90% of the electricity in the United States (100% of US nuclear)
  - EPRI programs engage > 75% of nuclear operators globally

A Research Portfolio Spanning Entire Electricity Sector

Generation

- Advanced Coal Plants, Carbon Capture and Storage
- Combustion Turbines
- Environmental Controls
- Major Component Reliability
- Materials and Chemistry
- Operations and Maintenance
- Power Plant Water Management
- Renewable Energy

Nuclear

- Advanced Nuclear Technology
- Chemistry, Low-Level Waste and Radiation Management
- Equipment Reliability
- Fuel Reliability
- Long-Term Operations
- Materials Degradation/Aging
- Nondestructive Evaluation and Material Characterization
- Risk and Safety Management
- Used Fuel and High-Level Waste Management

Energy & Environment

- Environmental Sciences: Air and Multimedia
- Strategic Analysis and Technology Assessments
- Environmental Sciences: Groundwater and Land Management
- Workforce and the Public: Health Assessment and Safety
- Environmental Sciences: Water and Ecosystems

Power Delivery and Utilization

Distribution Utilization

- Distribution
- Energy Utilization
- Information, Communication, and Cyber Security

Transmission

- Grid Operations and Planning
- Transmission and Substations

EPRI Focus on Advanced (Fission) Reactors

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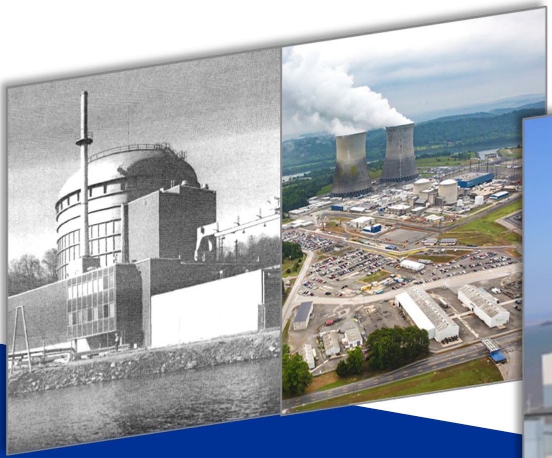
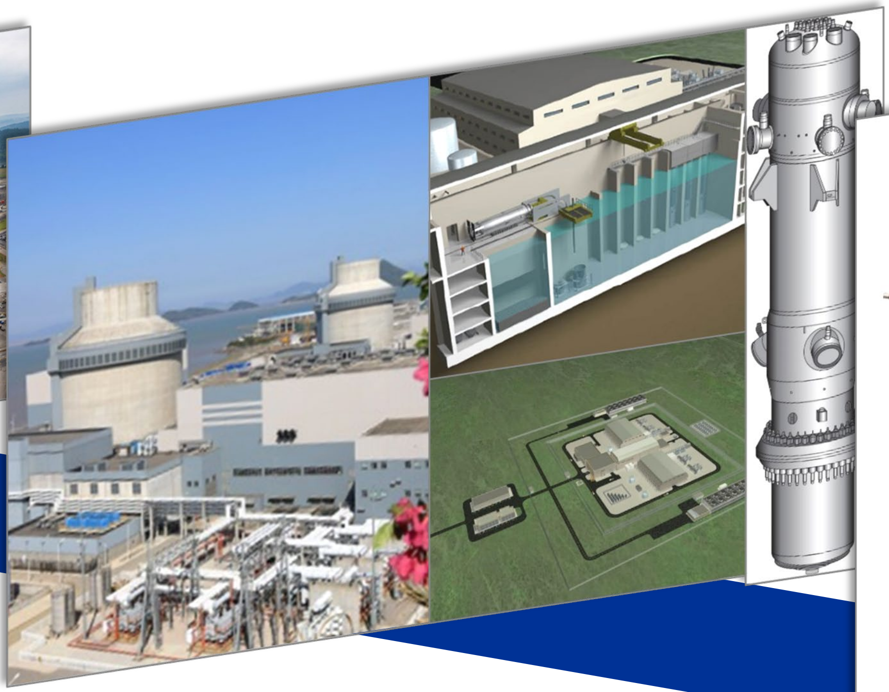
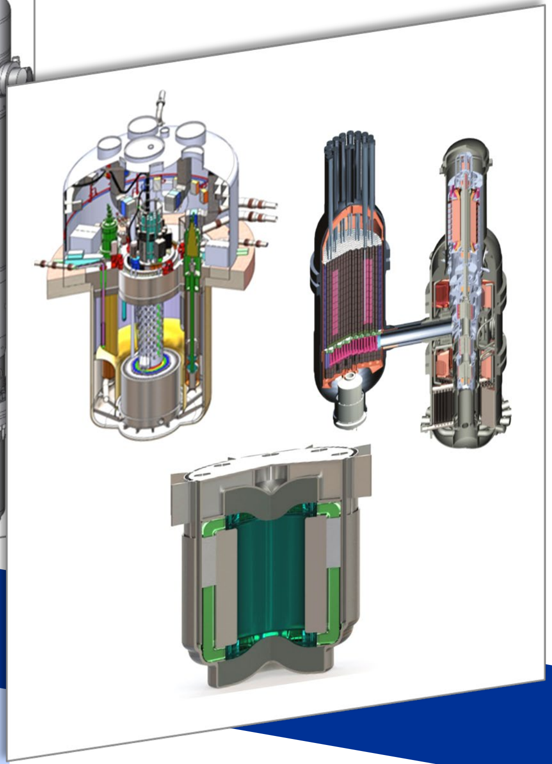
Evolving Technologies, Markets, and Missions for Nuclear



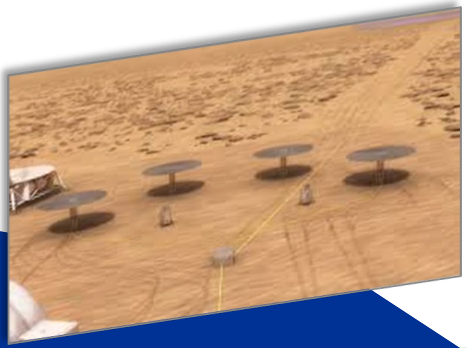




Microreactors

MWe-scale expands technology options

- Heat pipe cooling
- Remote deployment
- New markets
- Competition with diesel



GEN I & II

Early demonstrations through GW-scale commercial fleets

- Diversity of designs
- Diversity of vendors
- Diversity within vendors
- Limited standardization
- Aggressive build rates
- Evolving regulations

GEN III/III+

Evolutionary designs, GW-scale +

- Convergence on ALWRs
- Passive safety
- Standardization
- Integration with licensing
- Emergence of SMRs

EPRI and European utilities establish LWR-centric requirements

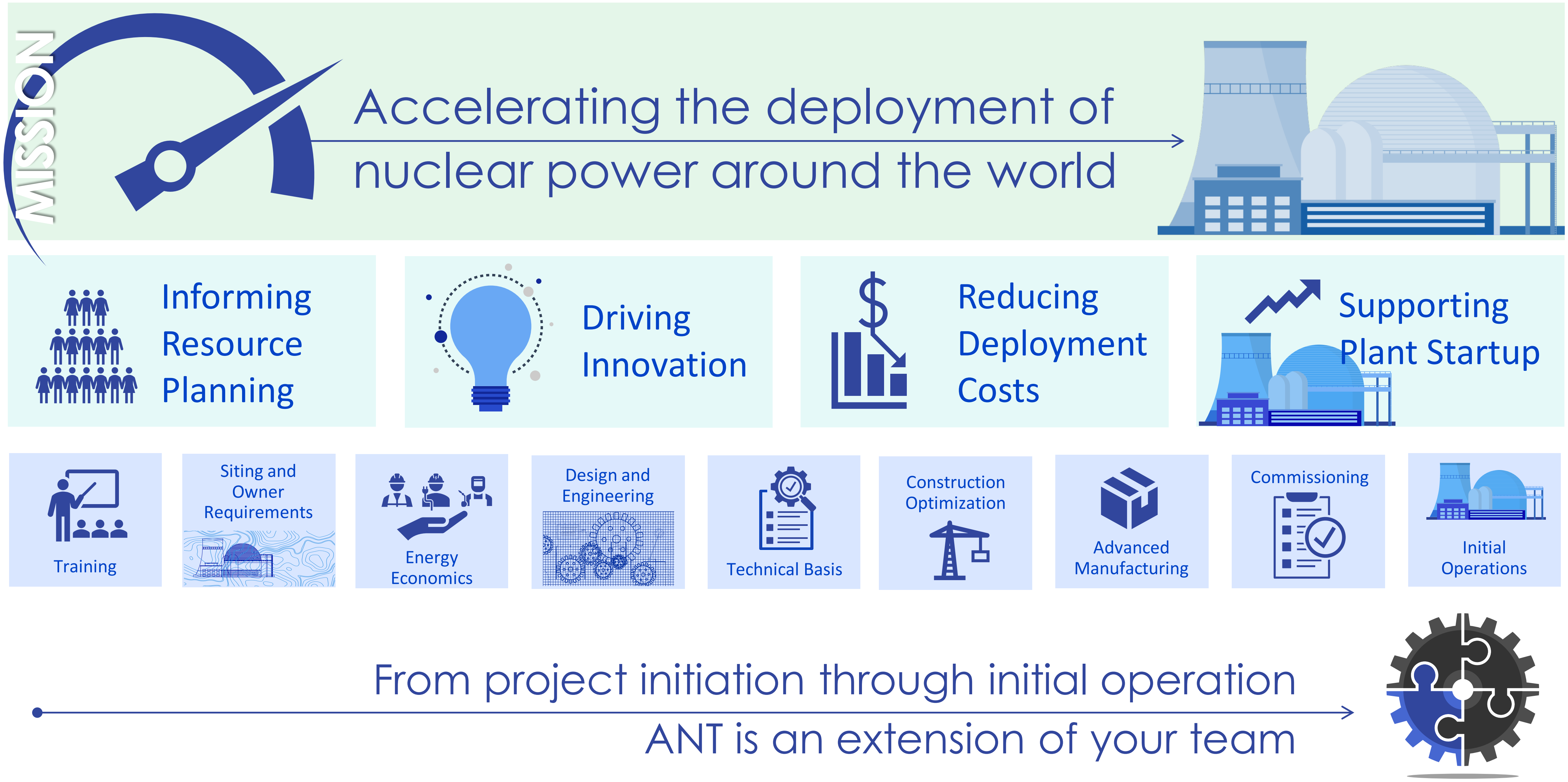
Advanced Reactors

Beyond large LWRs: GEN IV, non-LWRs, lwSMRs

- Aggressive cost and schedule targets
- Competitiveness via new missions and customers
- Focus on innovation, tension with standardization?
- Evolving regulatory frameworks

EPRI launches AR Owner-Operator Requirements

Advanced Nuclear Technology (ANT) Program Focus



Expanding AR Community Engagement in EPRI

BECHTEL

KHNP
KOREA HYDRO & NUCLEAR POWER CO., LTD

CFE
COMISIÓN FEDERAL DE ELECTRICIDAD

مؤسسة الإمارات للطاقة النووية
Emirates Nuclear Energy Corporation

Exelon

ONTARIO POWER GENERATION

FLUOR
Marine Propulsion

GE HITACHI

HITACHI GE

SRP

NIPPON STEEL & SUMITOMO METAL

Rolls-Royce

SOUTHERN COMPANY

NUCLEAR AMRC

NUSCALE™

Westinghouse

TVA

国家核电 SNPTC 上海核工程研究设计院
SHANGHAI NUCLEAR ENGINEERING RESEARCH & DESIGN INSTITUTE

TerraPower

Full ANT Members

Xcel Energy®

Kairos Power

ENGIE

Studsvik

NEIL

Dominion Engineering, Inc.

Concrete Engineering Consultants, Inc.

New in 2020

Advanced Reactor Supplemental Members

Renewed ANT Program for the Next Generation Plants

Needs of New Plants

- Flexible
- New Materials
- Resilient Supply Chain
- Reduced Construction Costs
- Efficient Startup

EPRI Focus Areas

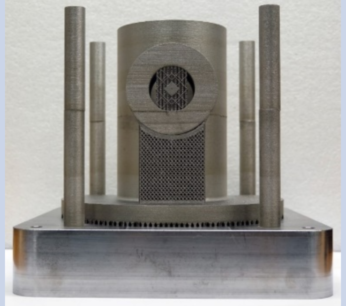
- Advanced Reactors
- Advanced Reactor Material Development
- Advanced Manufacturing
- Engineering and Construction Innovation
- Commissioning and Initial Operations

Advanced Manufacturing

Goal: Identify, develop, qualify and implement more economical manufacturing technologies that enable:

Higher Quality Components • Reduced Lead Times • Alternative Supply Chains • Cost Competitiveness

Additive Manufacturing



316L LPBF Code Case & Data Package (submitted to ASME August 2020)

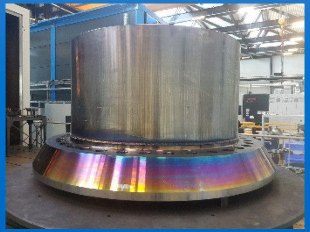
Additive Manuf. Roadmap for Nuclear Applications *(Q3 2020)*

DED-AM Component Demonstration

Advanced Manuf. Demonstration Project

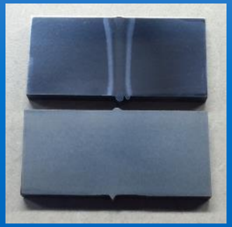
PM-HIP

EB Welding



DLC

Heat Treat

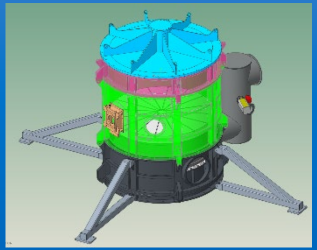


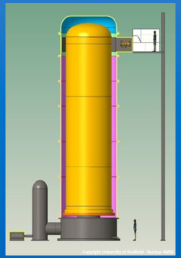
Advanced Welding Techniques

Adaptive Feedback Welding

ANT
+
WRTC

Modular In-Chamber EBW



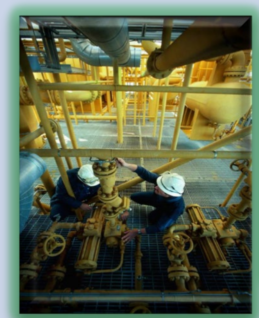


Engineering and Construction

Goal: Identify, develop, qualify engineering and construction technologies that enable:

Reduced Cost • Increased Quality • Improved Efficiency

Automated Technologies



3D Scanning of Embedded Items in Concrete

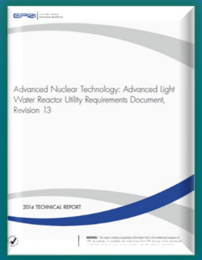
Digital Twin for Structure Life Cycle

Smart Structural Monitoring

Engineering Solutions

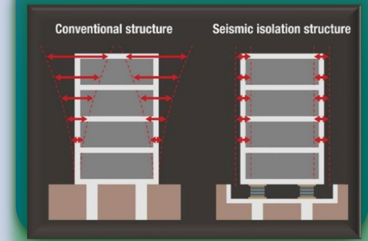
Siting Guide

URD


Advanced Nuclear Technology: Advanced Light Water Reactor Utility Requirements Document, Revision 13

2014 TECHNICAL REPORT

Design

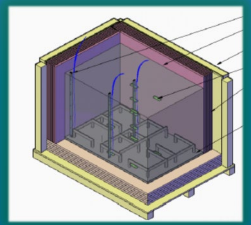


Field Guides

High Strength Concrete and Reinforcement

Experimental Testing and NDE

Concrete Optimizations

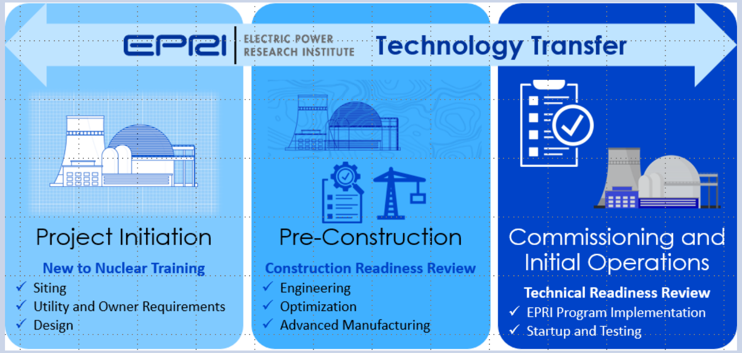


Commissioning and Initial Operations

Goal: Ensure a smooth transition from construction to commissioning, and then to initial operations by:

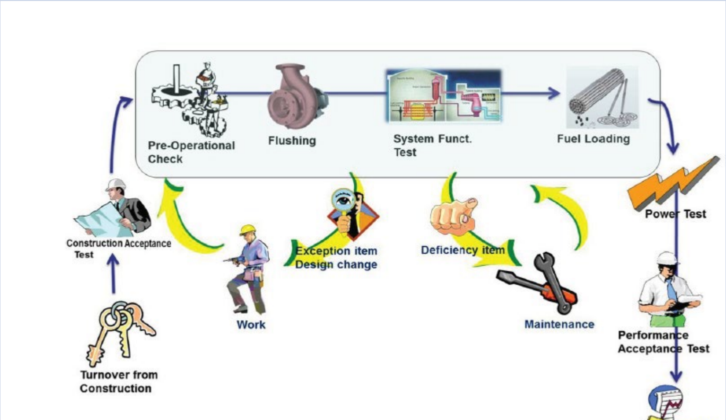
New Plant Startup • Lessons Learned • Technology Transfer

New Plant Technical Assistance



Develop detailed guidance for all phases of a new plant project: Project Initiation, Pre-construction Commissioning and Initial Operations

New Products



Source: IAEA Nuclear Energy Series No. NP-T-2.10

Guidance and Best Practices for Construction Tests

Analysis of Recent Startups

Existing Needing Updates

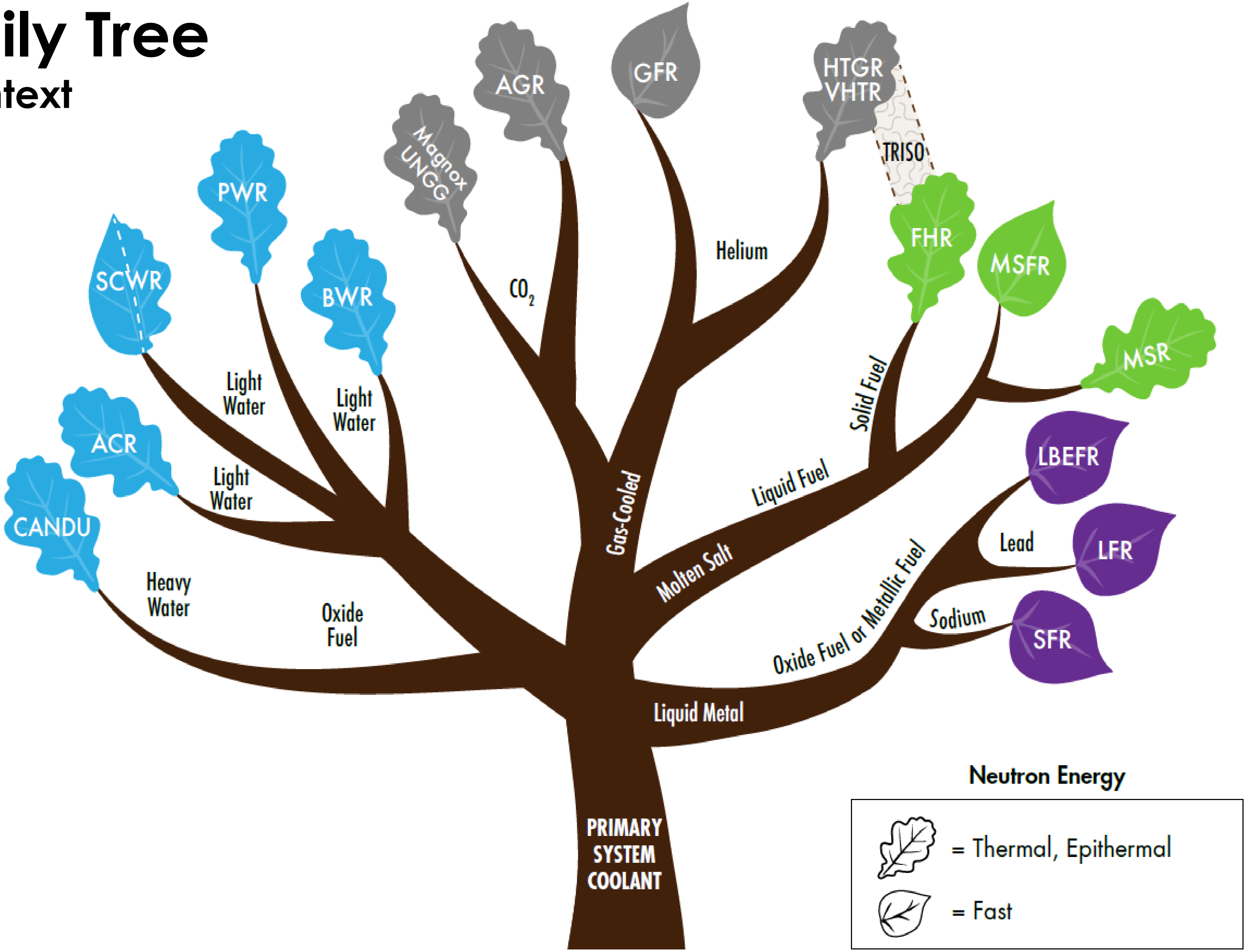
Startup Program Guidelines

Establishing a Maintenance Program for New Builds

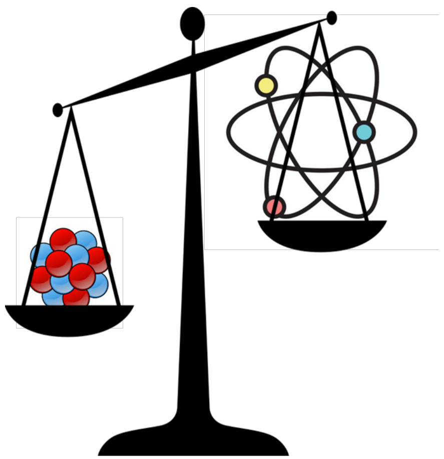
The Nuclear Family Tree

Advanced Reactors in Context

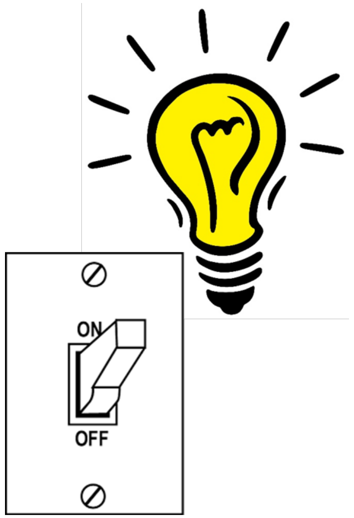
- Small Modular Light Water Reactor (SMR)
- Gas-cooled Fast Reactor (GFR)
- Lead-cooled Fast Reactor (LFR)
- Sodium Fast Reactor (SFR)
- Supercritical-water-cooled Reactor (SCWR)
- Molten Salt Reactor (MSR)
- High-temperature Gas-cooled Reactor (HTGR)



Fission Offers a Unique Bundle of Energy Attributes
(Fusion Too!)



energy dense



dispatchable

non-emitting

scalable

Other low carbon options co-dependent on maturity of auxiliary technologies.

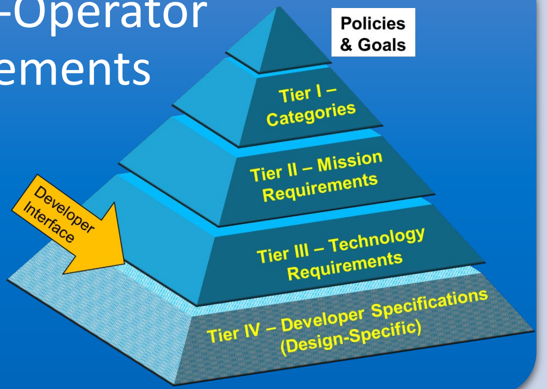
Advanced Reactors

Goal: Enable and accelerate commercialization of advanced reactors by:

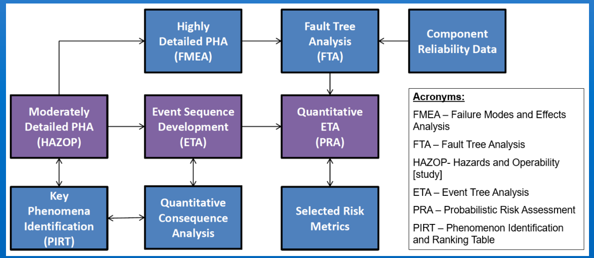
Aligning Design Attributes with End-User Needs • Increasing Understanding • Addressing Technology Gaps

Requirements & Guidance

Owner-Operator Requirements

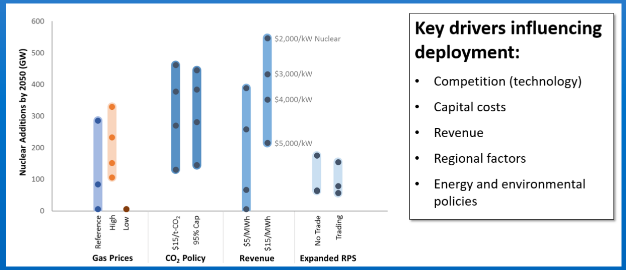


Safety-in-Design



Strategic Analysis and Technology Assessment

Economics and Markets



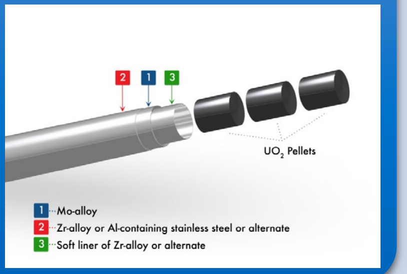
Expanded Flexibility Concept

Attribute	Sub-Attribute	Benefits
Operational Flexibility	Maneuverability	Load following
	Compatibility with Hybrid Energy Systems and Polygeneration	Economic operation with increasing penetration of intermittent generation, alternative missions
	Diversified Fuel Use	Economics and security of fuel supply
	Island Operation	System resiliency, remote power, micro-grid, emergency power applications
Deployment Flexibility	Scalability	Ability to deploy at scale needed
	Siting	Ability to deploy where needed
	Constructability	Ability to deploy on schedule and on budget
Product Flexibility	Electricity	Reliable, dispatchable power supply
	Process Heat	Reliable, dispatchable process heat supply
	Radioisotopes	Unique or high demand isotopes supply

Technology Development and Transfer

TRISO Fuel Qualification

AR Material Gap Analysis



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AR (Gen IV) Material Gap Analyses Published 2019 - 2020

Downloadable at EPRI.com for Free

Austenitic Stainless Steels

316H SS	Extend BPV-III Div 5. Code properties to include time dependent behavior (Creep. Creep fatigue) Development and demonstration of cladding (Mo rich) for protection
316FR SS	Code qualification properties for ASME code Sec III Div 5 for 316FR including time dependent properties
Type 15-15Ti SS	Verification of swelling resistance Development of code properties for 15-15Ti material design
Alumina Forming SS	Demonstration of adequate resistance to irradiation/swelling at expected high dpa Development of processing and joining of alumina forming austenitic stainless steels
D9 Stainless Steel	Development of for ASME Code Sec III Div 5 properties (including time dependent properties) for D9 Development of swelling behavior at long times under realistic conditions – demonstrate adequacy

Ferritics-Martensitics and Low Alloy Steels

Ferritic-Martensitic--9Cr	Demonstration of adequate resistance to swelling at high fluence range. Time dependent properties for ASME Code Sec III Div 5. Development of fabrication and effective joining methods
Ferritic-Martensitic--12Cr	Demonstration of adequate resistance to swelling at high fluence range. Time dependent properties for ASME Code Sec III Div 5. Development of fabrication and effective joining methods
Ferritic Martensitic	Validation of commercial reliability – Properties sensitivity to heat treatment/local microstructures Response to fabrication processes – welding practices
LAS	Time dependent and fatigue properties for ASME code Sec III Div 5

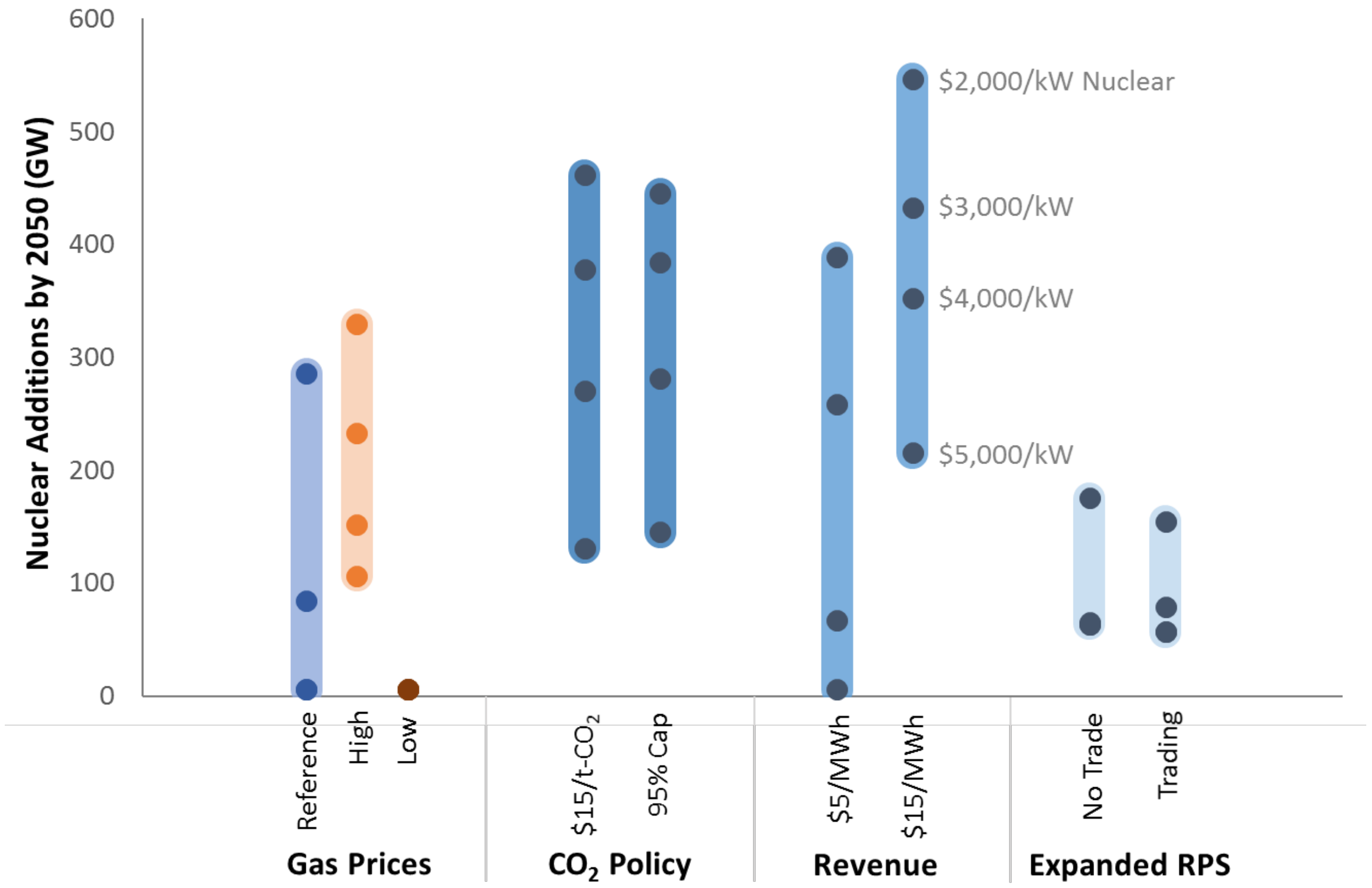
Nickel-Based Alloys

Hastelloy N	Demonstration of radiation tolerance of Hast N variants (Proper understanding of chemistry→ microstructure properties Development of properties for ASME Code Sec III Div 5 certification
800H and 617	Summary Document of Properties

- Identify candidate materials for major AR families:
  - SFRs - 3002016949
  - HTGRs/GFRs - 3002015815
  - LFRs - 3002016950
  - MSRs - 3002010726
- Review available data for implementation into designs
- Outline development and validation programs

Economics and Competitiveness of Advanced Nuclear

U.S. example: Exploring the Role of Advanced Nuclear in Future Energy Markets. March 2018, Report 3002011803



Key drivers influencing deployment:

- Competition (technology)
- Capital costs
- Revenue
- Regional factors
- Energy and environmental policies

Cumulative nuclear additions through 2050 (GW) across a range of sensitivities (horizontal axis) and nuclear capital costs (dots)

Fusion and fission look the same to current capacity expansion models.