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Massachusetts Roadmap for Advanced Nuclear and Fusion Energy

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Professor, Nuclear & Chemical Engineering

University of Massachusetts Lowell

Meet Sukesh Aghara

- **Education**
  - University of Texas at Austin
    - Ph.D. Nuclear Engineering, Aug. 2003
    - M.S. Nuclear Engineering, May 2001
  - Vanderbilt University, Nashville TN
    - M.S. Environmental Engineering, May 1999

- **Advance Reactors**
  - Total Energy Systems
  - Fuel Cycle and burnup
  - Spent fuel management
  - Energy economics

- **Nuclear Safeguards and Nonproliferation**
  - Nuclear Materials Accountancy
  - Inspection Planning
  - Advanced Detectors

- **Nuclear Security**
  - Cyber Threat Assessment
  - SCADA, DCS and ICS cyber vulnerability testbed for nuclear plant systems

Outline

- **Who are the Stakeholders?**
- **Schedule of webinars and stakeholder meetings**
- **The Goals, Objectives and Outcome of the Roadmap effort**
- **Motivation**
- **Timeline**

Are you a stakeholder?

If you, your organization, or your community has an interest in, or is affected by, the decisions, projects, or outcomes we're shaping in this roadmap, the answer is yes!

We want to engage - the folks who benefit, the folks who build, the folks we must protect... or all of the above

We need your partnership in reaching those whose voices must be heard as we shape Massachusetts' nuclear and fusion future

Stakeholder Groups

Stakeholder Group	Example Participants	Focus Area
Labor Unions and Workforce / Trade Associations	IBEW, UA, AFL-CIO, Building Trades	Workforce readiness, job quality, training pathways, safety standards
Local, State, and Regional Governments and New England State Regulatory Commissions	Municipalities, Regional Planning Agencies, MEMA, State Emergency Management	Permitting, siting, public safety, zoning, local engagement
Universities and Research Institutions	MIT, UMass Lowell, URI, Harvard, RPI	R&D priorities, academic programs, technology innovation, research and demonstration facilities
Community Colleges and Trade Schools	Middlesex CC, Three Rivers CC, MassBay, Vocational Institutes	Technical training, stackable credentials, inclusivity, career pathways
Utilities, ISO-NE, and Energy Companies	ISO-NE, Eversource, National Grid, Constellation Energy	Grid reliability, market integration, industrial applications
Technology Developers, Startups, and Industry	Commonwealth Fusion Systems, Rock Energy, StarCube, NuScale, EPM, Allied Power, GE Hitachi	Demonstrations, commercialization, innovation partnerships
Community, Equity, and Environmental Organizations	EJ coalitions, NGOs, town committees, public health advocates	Equity, environmental justice, transparency, local benefits
Financial and Investment Community	Green banks, venture capital firms, pension funds, investment groups	Financing mechanisms, risk reduction, ESG frameworks
Large Customer groups	Datacenters, universities, IT companies, defense industrial complex, bioprocess and pharma	Gride scale off-takers, hyper scalers, current large customers

Stakeholder Engagement Schedule

Registration & Updates
www.uml.edu/nuclearroadmap

Date	Time	Stakeholder Group and Focus
Tue, Nov 18, 2025	10 AM – 11 AM	Introductory Webinar #1
Thu, Nov 20, 2025	1 PM – 2 PM	Introductory Webinar #2
Tue, Dec 2, 2025	10 AM–11 AM	Introductory Webinar #3
Wed, Dec 10, 2025	12 PM – 1 PM	Introductory Webinar #4

Date	Time	Stakeholder Group and Focus
Tue, Dec 9, 2025	1 PM–3 PM	Community, Equity, and Environmental Organizations
Thu, Dec 11, 2025	10 AM–12 PM	Large Customer Groups
Fri, Dec 12, 2025	10 AM–12 PM	Technology Developers, Startups, and Industry
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Thu, Dec 17, 2025	10 AM–12 PM	Community Colleges and Trade Schools
Tue, Jan 6, 2026	1 PM–3 PM	Financial and Investment Community
Thu, Jan 8, 2026	10 AM–12 PM	Labor Unions and Workforce / Trade Associations
Fri, Jan 9, 2026	10 AM–12 PM	Utilities, ISO-NE, and Energy Companies

Roadmap Mission, Goals and Objectives

Mission	Engage stakeholders across academia, industry, government, and communities to develop a shared, actionable roadmap exploring how advanced nuclear and fusion energy can strengthen Massachusetts' clean energy, climate, and economic goals — grounded in innovation, equity, and responsible stewardship
Goal	Build on Massachusetts' strengths and integrate advanced nuclear and fusion energy into the Commonwealth's zero-carbon future. Create the conditions for responsible, affordable, and reliable decarbonized energy with nuclear energy in the mix.
Objectives	Produce a foundation document, the roadmap, to guide legislative, regulatory and investment decisions

Roadmap Outcomes

1. Engage stakeholders to assess capabilities, identify gaps, define opportunities

2. Outline steps to leverage innovation ecosystem, scale workforce, engage communities, coordinate regionally

3. Produce foundational roadmap to guide legislative, regulatory and investment decisions

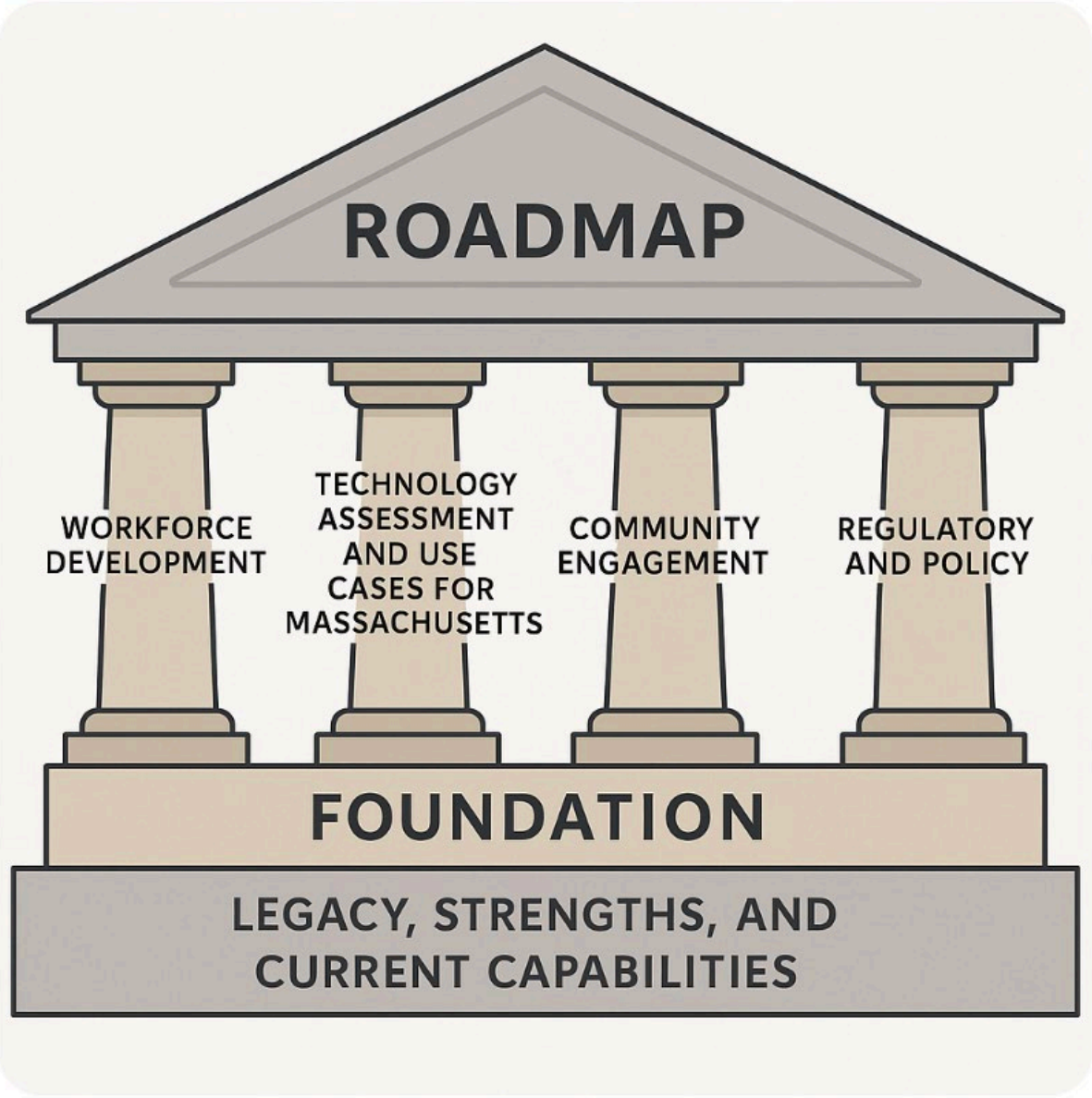
Roadmap Structure

Foundation

- Legacy
- Strengths
- Current Capabilities

Pillars

- Workforce Development
- Technology Assessment and Use Cases for Massachusetts
- Community Engagement
- Regulatory and Policy



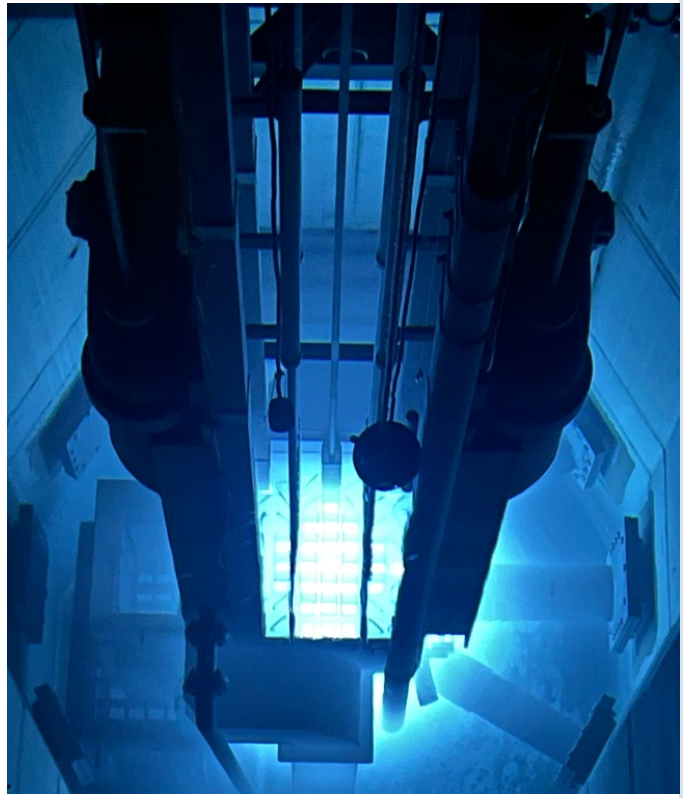
Roadmap Structure - Foundation

- **Historic Legacy**: Massachusetts' contributions to nuclear research, reactor technology, and fusion science (e.g., MIT, UMass Lowell, past partnerships, education programs), overview of R&D, facilities, and workforce assets across universities and private industry

- **Innovation Ecosystem**: Research universities, national lab collaborations, and technology startups in advanced energy

- **Industrial and Workforce Base**: Manufacturing expertise, materials science, and the clean energy workforce pipeline

- **Policy and Climate Leadership**: The Commonwealth's strong clean energy and climate mandates, bipartisan decarbonization goals, and the Governor's inclusive innovation agenda

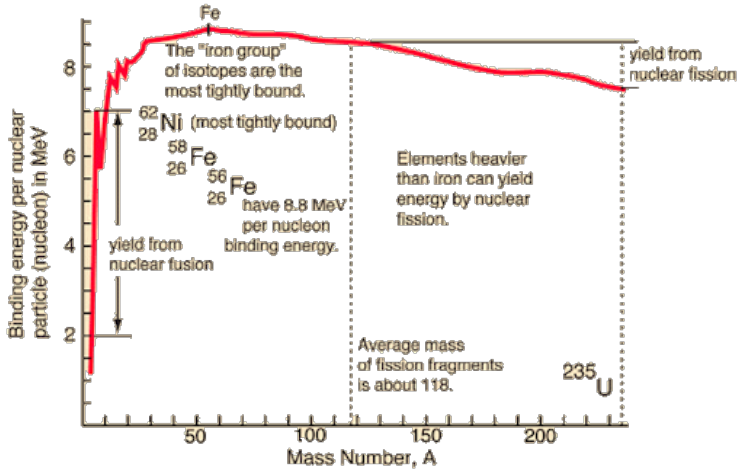


Roadmap Structure - Pillars

- **Pillar 1: Workforce**
  - Assess current educational programs and workforce pipelines
  - Identify skill gaps for advanced reactor, fusion, and fuel-cycle technologies
  - Recommend workforce pathways for both new graduates and incumbent workers
  - Explore opportunities for equitable access, reskilling, and inclusion

Roadmap Structure - Pillars

- **Pillar 2: Technology**
  - Review advanced nuclear and fusion technologies under development (e.g., SMRs, microreactors, advanced fuel cycles, fusion demonstration projects)
  - Assess commercial readiness, timelines, and supply chain implications
  - Evaluate Massachusetts-specific use cases: grid reliability, industrial heat, campus microgrids, maritime or defense applications
  - Identify R&D strengths and partnership opportunities to attract industry pilots or demonstrations



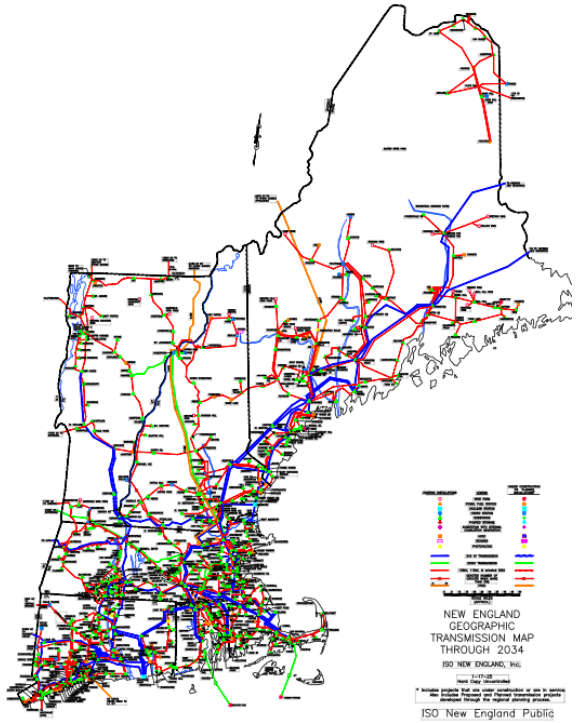
Source - Clean Air Task Force

Roadmap Structure - Pillars

- **Pillar 3: Community Engagement**
  - Develop frameworks for public engagement
  - Incorporate community perspectives early in the decision-making process
  - Identify tools for education, outreach, and trust-building around safety, environmental justice, and economic opportunity
  - Align with existing DESE and MassCEC outreach programs to sustain long-term dialogue

Roadmap Structure - Pillars

- **Pillar 4: Regulatory Modernization and Policy Framework**
  - Review existing state and federal laws affecting nuclear development (including the moratorium and siting restrictions)
  - Identify pathways for regulatory readiness
  - Define policy options to enable future consideration of advanced nuclear and fusion energy
  - Examine coordination with regional and federal agencies (NRC, DOE, ISO-NE, neighboring states)



The bipartisan Accelerating Deployment of Versatile, Advanced Nuclear for Clean Energy (ADVANCE) Act

Why Nuclear Now?

Public and plant Safety

Expensive

Nuclear Energy share going DOWN – 14% (late 2000's) to 9% (now)

Renewable and Storage is a better solution

SMR/AMR – Hype, None built

Thing of the PAST

Fusion

NOT on Time
NEVER at Cost

Nuclear Waste – NO SOLUTION

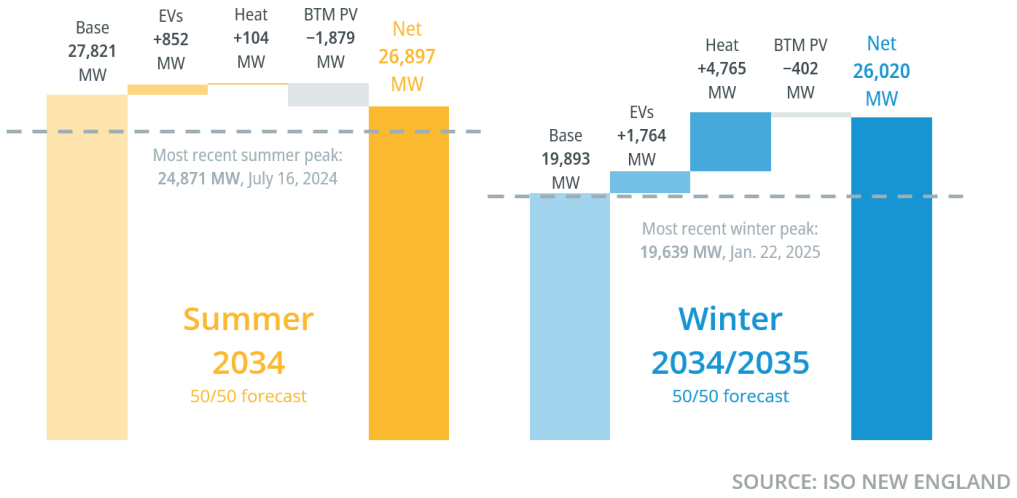
Security & Proliferation

Motivation

1. **Energy Transition**
   - Demand Shift and Growth
   - Extreme Weather
   - Energy Affordability
   - Decarbonization
2. **Nuclear Technology Maturation**
   - Bipartisan Support
   - Experience with Gen II and III – Safe Operation and Efficient Maintenance
   - Gen III+ - ready now
   - Gen IV – demonstrations

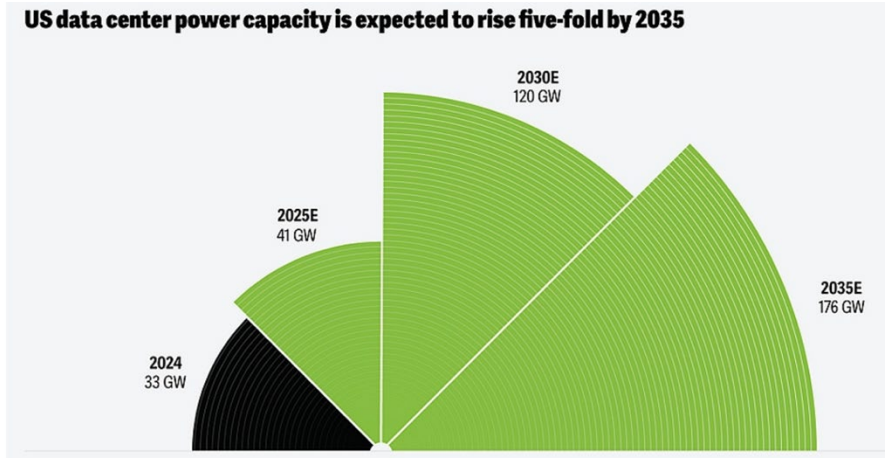
Energy Deman Growth and Shift

- Electrification, reshoring, and data-center growth are reshaping load forecasts



SOURCE: ISO NEW ENGLAND

Today, U.S. data centers use about 2% of total electricity



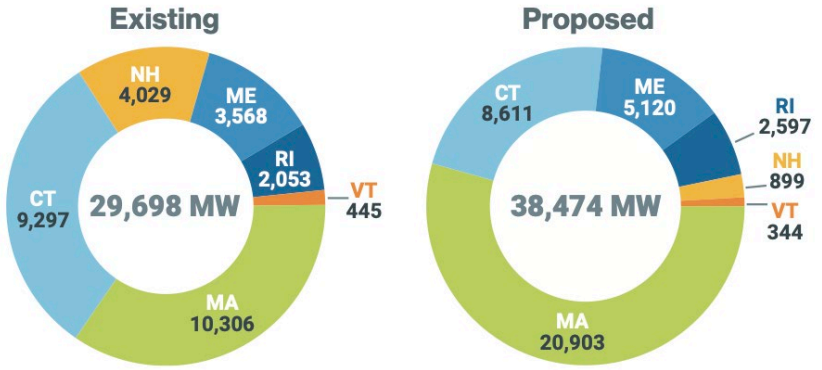
Type of Data Center	Power Usage Range
Small enterprise	100 kW – 1 MW
Medium / co-location	1 MW – 10 MW
Hyperscale (Google, AWS)	10 MW – 100+ MW

Energy Deman Growth and Shift

- ISO-NE projects 1.8–2.0% annual demand growth through 2033, reversing decades of flat load

- Exceed peak demand record:

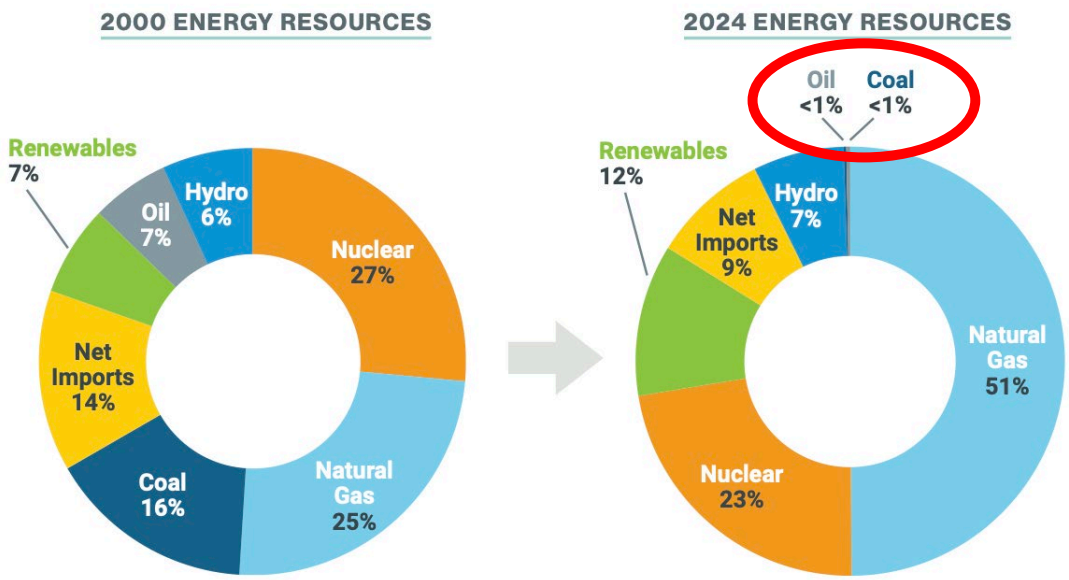
28,130 MW (Summer 2006) by 2033



Source: ISO-NE 2024 Capacity, Energy, Loads, and Transmission Report; ISO-NE Generator Interconnection Queue, January 2025

The New England Grid in Transition

- New England now operates nearly 30,000 MW of capacity



Charts show the amount of electricity produced by generators in New England and imported from other regions to satisfy all residential, commercial, and industrial customer demand in New England. This is called Net Energy for Load (NEL).

These numbers underscore a simple truth: to integrate such a variable portfolio while maintaining reliability,

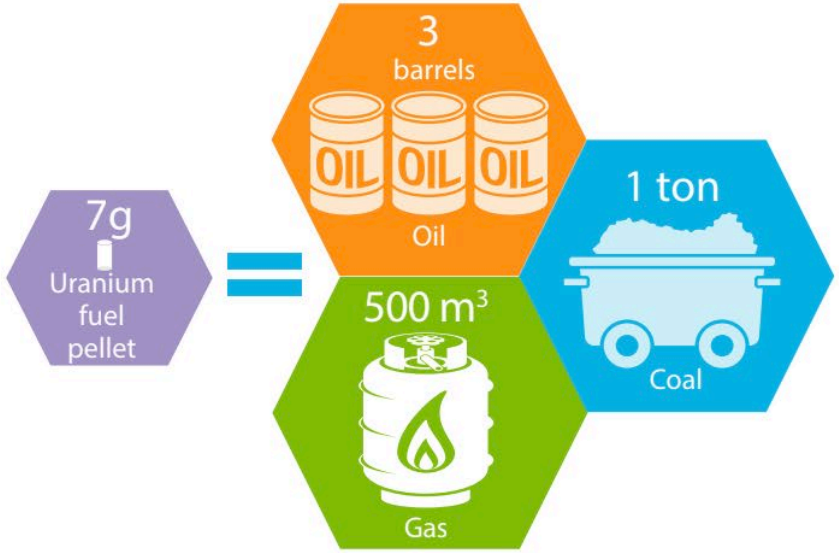
We need: firm, dispatchable, zero-carbon power

Developers have proposed 38,474 MW of new resources — nearly half in battery storage and 47% in wind

Energy Affordability

High Energy Density

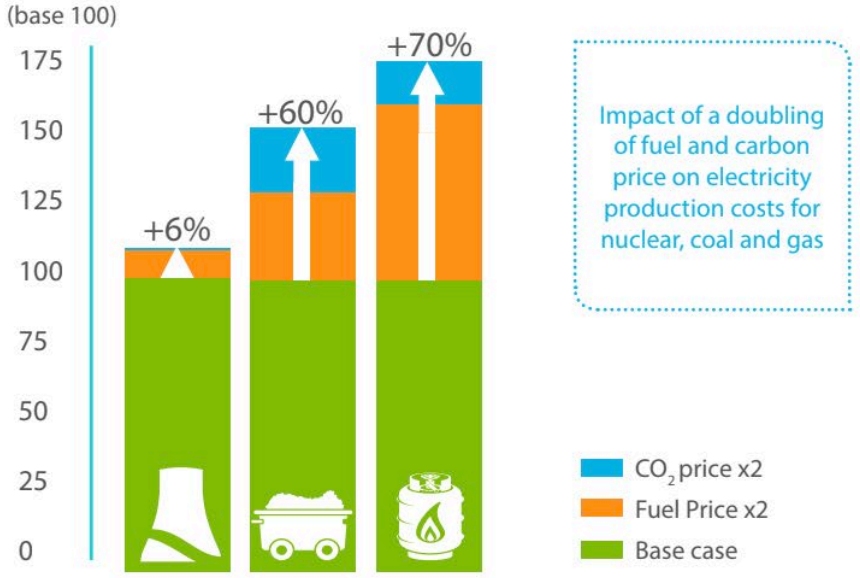
Quantity of fuel necessary to produce a given amount of electricity



Source: American Nuclear Society 2013

Low Fuel and O&M Cost

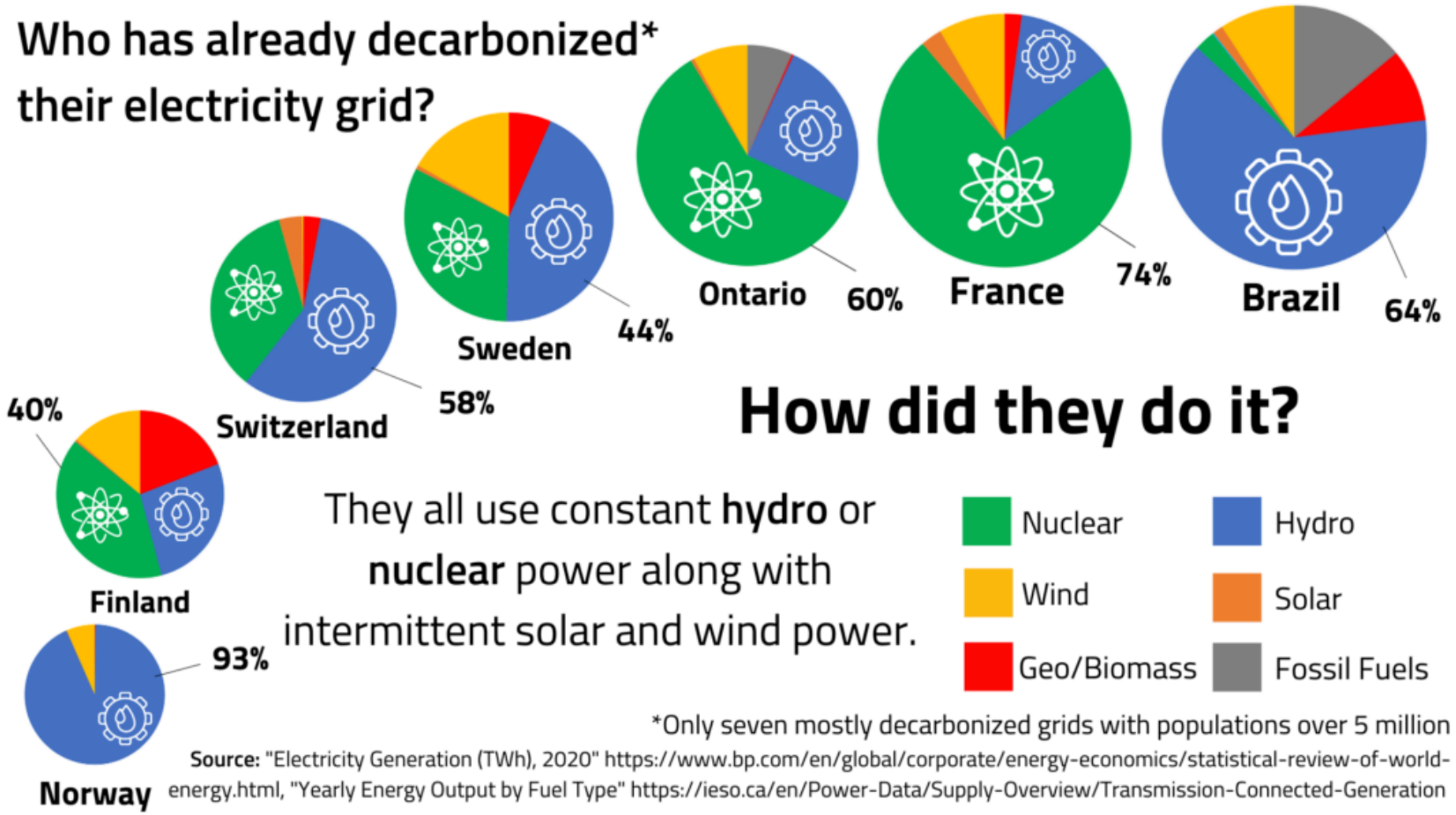
The cost of nuclear power is less vulnerable to fuel price fluctuations



Source: AREVA 2014

Gas turbine provide low capital cost energy solution but highly dependent on fuel cost fluctuation – DIFFICULT for Cost planning

Decarbonization – Path to Clean Energy



Bipartisan Support for Nuclear Policy

Act / Legislation	Year Enacted	Administration	Key Nuclear Provisions
Energy Policy Act	2009	Obama	Loan Guarantees program to support Vogel 3 & 4, **$50 billion for DOE energy programs** in support of SMR, advance reactors R&D
Blue Ribbon Commission on America's Nuclear Future (BRC)	2010	Obama	Created by Secretary of Energy Steven Chu to develop a new **consent-based strategy for nuclear waste management**
Advanced Reactor R&D Launches	2014	Obama + Trump	Established DOE's **Gateway for Accelerated Innovation in Nuclear (GAIN)** and funded early **SMR design efforts (NuScale, Holtec, mPower)**
Nuclear Energy Innovation and Modernization Act	2019	Trump	Directed the NRC to modernize its regulatory framework, establish new licensing pathways for advanced reactors, and improve fee transparency
Infrastructure Investment & Jobs Act	2021	Biden	Created the **Civil Nuclear Credit Program** ($6 billion for existing plants), funded **Advanced Reactor Demonstration Projects (ARDP)**
Inflation Reduction Act	2022	Biden	Established **production and investment tax credits** for both **existing and new clean generation (including nuclear**
ADVANCE Act	2024	Biden	Bipartisan legislation that further **modernizes NRC licensing**, expands **international nuclear cooperation**, and **extends the Price–Anderson Act** (nuclear liability protection) through 2065.

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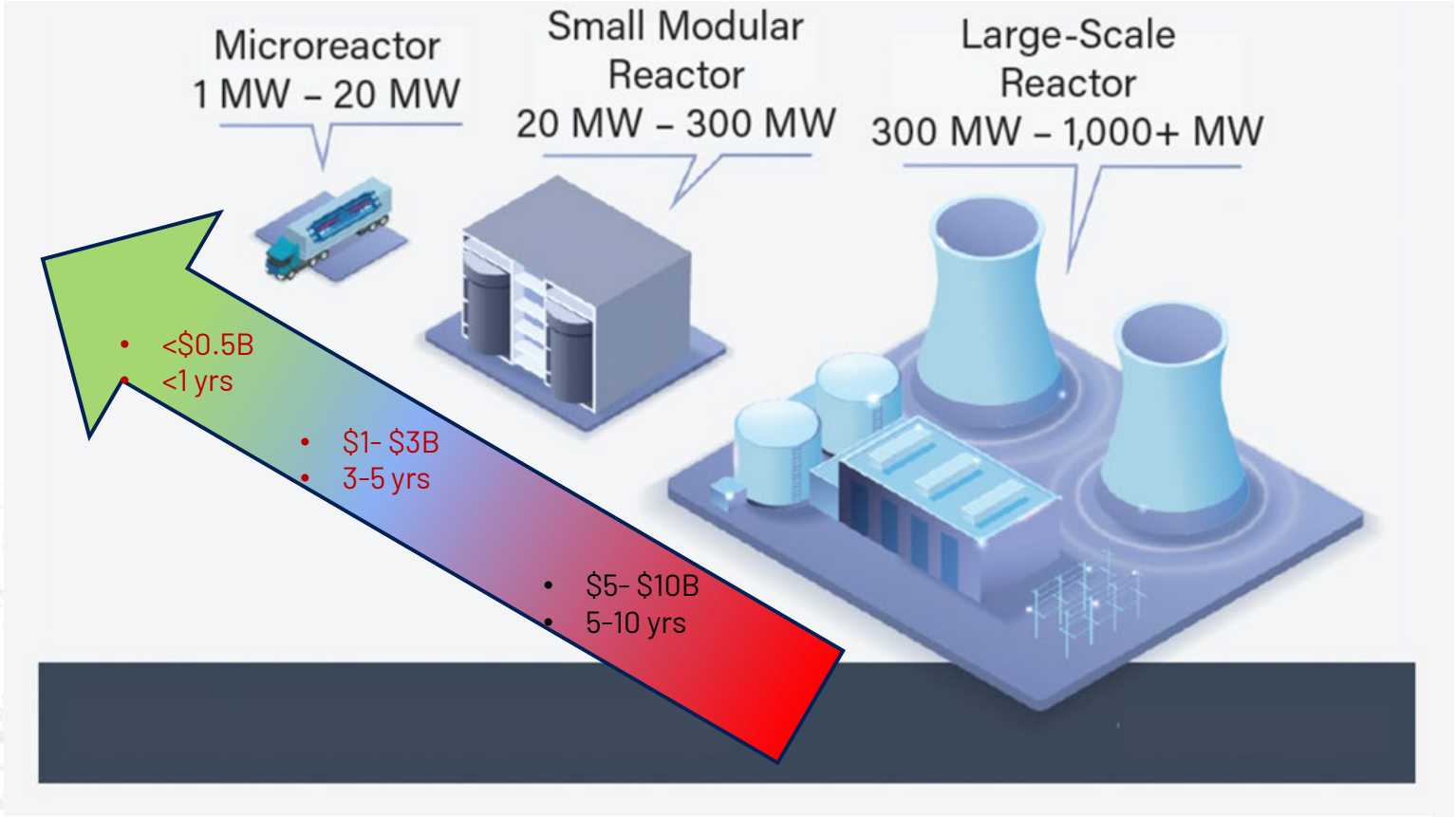
KEY DEVELOPMENTS

R&D, Build again, Loan Guarantees, ARDP, Clean Energy Credits, Data Centers, Energy Security

Power Reactor Sizes



* AP 1000 uses 50% fewer valves, 83% less pipe (safety grade), 87% less cable, 36% fewer pumps, and 56% less seismic building volumes than current Westinghouse plants.

Image courtesy of the Office of Nuclear Energy.

SMR/AMR under Deployment

Vendor	State (planned)	Power (MWe)	NRC / Licensing Status
NuScale Power	United States (various sites)	77 MWe per module (plant up to ~462 MWe)	Design approved (Standard Design Approval) by NRC for 77 MWe module.
X-energy (Xe-100)	Washington State (and Texas industrial site)	~80 MWe per module (4-unit ~320 MWe initial, up to ~960 MWe)	Construction permit application submitted; NRC published ~18-month review schedule.
Holtec International (SMR-300)	Michigan (at the site of the former Palisades Nuclear Plant)	~300 MWe (SMR-300)	Pre-licensing/deployment planning; not yet NRC certified design.
TerraPower (via SMR pathway)	United States (Kemmerer, Wyoming demonstration)	~345 MWe (with energy storage boost)	Pre-application/licensing stage with NRC; non-LWR reactor type.
Kairos Power (KP-FHR / Hermes)	Tennessee (Oak Ridge)	Demonstration (test) reactor first; commercial target ~140 MWe in 2030s.	Received NRC construction permit for the demonstration reactor; operating license pending.
Rolls-Royce plc (UK/Global AMR)	UK (but global potential)	Sub-50 MWe AMR scale (target)	Early design/AMR phase; licensing framework under development.

Microreactors under Deployment

Vendor	State (Planned)	Power (MWe)	NRC / Licensing Status
Westinghouse Electric Company – eVinci	U.S. (remote/transportable use; factory-built)	~ 5 MWe (15 MWth)	In pre-application with U.S. Nuclear Regulatory Commission (NRC); Principal Design Criteria (PDC) Topical Report approved.
Antares Nuclear, Inc. – R1 Microreactor	U.S. (remote/defense bases)	~ 0.2–0.3 MWe (200-300 kWe)	NRC engaged in pre-application interactions starting May 2025.
Oklo Inc. – Aurora Microreactor	Idaho (first site at INL)	~ 1.5 MWe (4 MWth)	NRC combined license application accepted for review in 2025 (after prior application withdrawal in 2022; resubmitted with updated design). DOE site lease approved at Idaho National Lab.
Radiant Industries, Inc. – Kaleidos Microreactor	U.S. (design for remote/edge installations)	(Design in MW-scale, < 20 MWe)	Early stage; licensing path via NRC under development.

Restart Projects

Utility / Technology Partner	Site	Power (MWe)	Status & Investment Pledge
Holtec International	Palisades Nuclear Generating Station — Covert, Michigan	~800 MWe	Plant shut down May 2022; Holtec acquired in 2022. DOE loan/guarantee of ~US$1.5 billion pledged to support restart.
Constellation Energy (with Microsoft)	Three Mile Island Unit 1 — Pennsylvania	~835 MWe	Shut down 2019. Plan to restart by ~2028 under name "Crane Clean Energy Center". Investment pledge ~US$1.6 billion.
NextEra Energy (with Googl	Duane Arnold Energy Center — Iowa	~615 MWe	Closed 2020; restart proposed with Google power-purchase agreement (PPA) targeting ~2029. Investment details emerging.

New Nuclear Energy Project Models

Reactor Restart Projects

- Palisades Nuclear Generating Station (Michigan) – Shut down May 2022; now being restarted by Holtec International with goal of late 2025 return
- Three Mile Island Unit 1 (Pennsylvania) – Closed in 2019; announced restart in 2028 under Constellation Energy with Microsoft PPA
- Duane Arnold Energy Center (Iowa) – 615 MW unit shut in 2020; partnership between NextEra Energy and Google announced in 2025 for restart by ~2029

Gigawatts and SMRs

- Advanced Reactor Demonstration Program (ARDP) (U.S. DOE) – Supports cost-shared partnerships for demonstration of advanced reactors within 7 years of award
  - X-energy "Xe-100" large SMR at Seadrift, Texas
  - TerraPower "Natrium" sodium-cooled reactor at a retiring coal plant in Wyoming
- Nuclear Reactor Pilot Program (DOE) – Selected 11 advanced reactor projects in August 2025 to build test reactors and accelerate licensing

Micro-Reactor / Small Modular Reactor (SMR) Projects & Programs

- DOE Microreactor Program – U.S. DOE program supporting microreactor (very small) technology deployment, e.g., designs for remote sites, military installations
- Advanced Nuclear Power for Installations (ANPI) (DoD/DIU) – Program for micro-reactors on military installations; eight companies selected.
- SMRs: NuScale Power (design certification), Kairos Power, Oklo, etc., are active in U.S. deployment pipelines.

New Nuclear Energy Project Models

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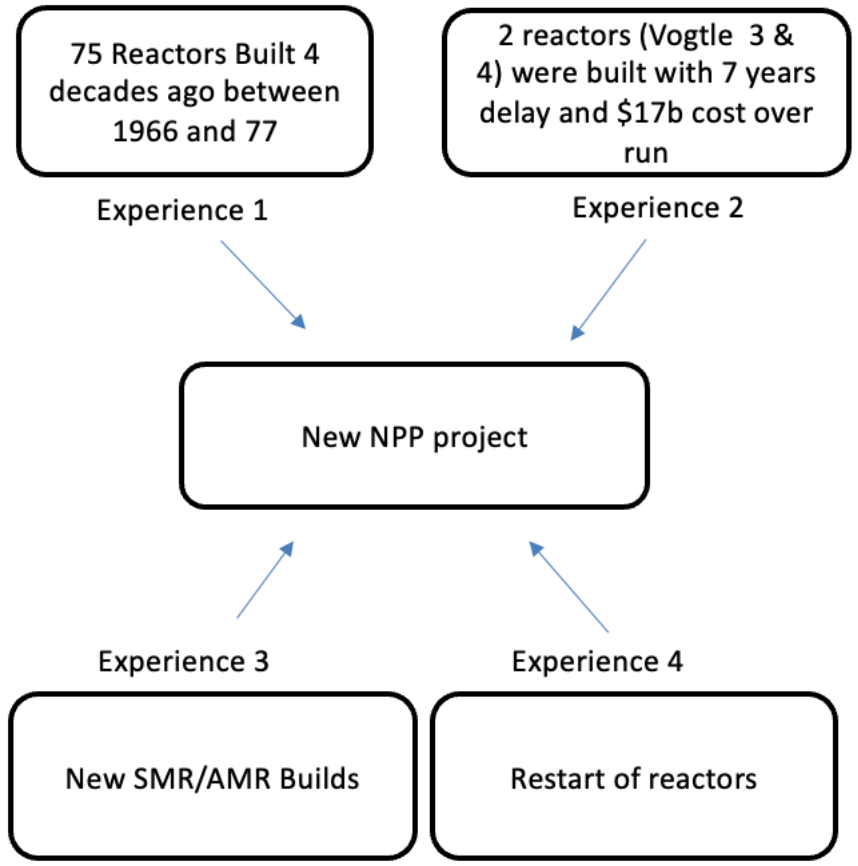

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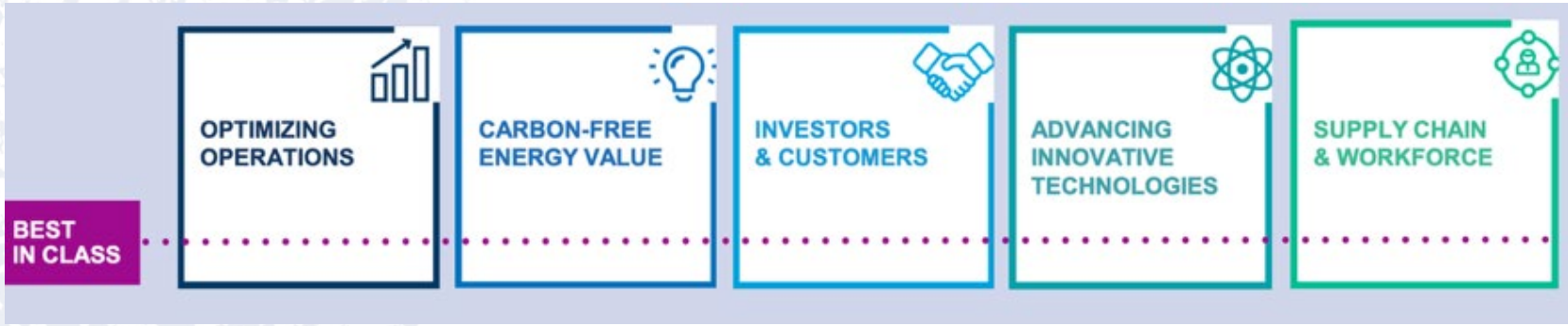
State-Level Nuclear Dialogue

- States like WY, VA, and AK lead with enabling legislation and planning
- In the Northeast, nuclear is gaining attention amid offshore wind setbacks
- NY and MA are issuing studies and RFPs mentioning nuclear explicitly
- Universities are playing a convening role for stakeholder dialogue
- Public education and regulatory readiness are key next steps

Zero and Clean Energy Production Tax Credits



(Source – NEI)

States are Investing

State	Amount	Program
Tennessee	$60 Million	Retain and attract nuclear supply chain companies to eastern TN
Tennessee	$350 Million	Tennessee Valley Authority's board has approved funding to support its continued design work and development of potentail SMDs at its Clinch River site near Oak Ridge, TN
North Carolina	Up to $75 Million	Early Site Permitting
Kentucky	$20 Million	Fund the Nuclear Authority
Wyoming	$10 Million	Micro reactor study
Wyoming	$150 Million	The state legislature appropriated $100M in 2022 + $50M in 2023 to the Emerg Matching Funds program administered by the Wyoming Energy Authority. The program is designed to spur innovation and bring transformative energy projects to WY.
Virginia	$2 Million	Nuclear Innovation Hub
Washington	$25 Million	Early Site Permitting
South Carolina	$40 Million	Battelle Alliance supporting nuclear workforce development
Ohio	$750,000	Nine-member Governor-appointed board

Massachusetts Roadmap

1. Align with North American: EPRI Roadmap pillars (Regulation, Workforce, Supply Chain)
2. Invest in Massachusetts Strengths: Academic institutions, fusion, green tech industry, workforce programs
3. Four Pillars of the MA Roadmap: Regulation, Technology, Workforce, Engagement
   - Planned Stakeholder Sessions: Labor, Industry, Regulators, Finance, Communities
   - Expected Outcomes: Policy reform, civic engagement, workforce hub, pilot deployments

Goal: From legacy reactors to demonstration and deployment

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Universities and Research Institutions	MIT, UMass Lowell, URI, Harvard, RPI	R&D priorities, academic programs, technology innovation, research and demonstration facilities
Community Colleges and Trade Schools	Middlesex CC, Three Rivers CC, MassBay, Vocational Institutes	Technical training, stackable credentials, inclusivity, career pathways
Utilities, ISO-NE, and Energy Companies	ISO-NE, Eversource, National Grid, Constellation Energy	Grid reliability, market integration, industrial applications
Technology Developers, Startups, and Industry	Commonwealth Fusion Systems, StarCube, NuScale, Allied Power	Demonstrations, commercialization, innovation partnerships
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Financial and Investment Community	Green banks, venture capital firms, pension funds, investment groups	Financing mechanisms, risk reduction, ESG frameworks
Large Customer groups	Datacenters, universities, IT companies, defense industrial complex, bioprocess and pharma	Gride scale off-takers, hyper scalers, current large customers

Registration & Updates
www.uml.edu/nuclearroadmap

Stakeholder Engagement Schedule

- Structure (2 hours = 120 min):
  - 15 minutes – Welcome and introductions
  - 5 minutes – Discussion of common questions (Quick poll across all stakeholders)
  - 90 minutes – Open dialogue and breakout discussions guided by key questions
  - 10 minutes – Summary of findings, synthesis across groups, and capture key priorities

- Expected outcomes from each stakeholder session are the following:
  - Executive summary with 3–5 key insights per roadmap pillar.

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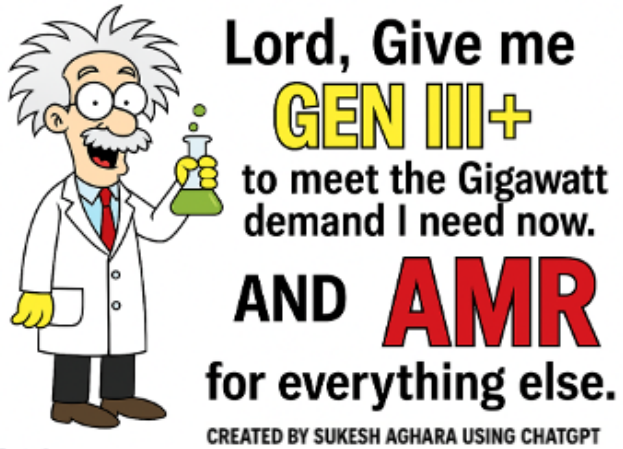
Thank You

Registration & Updates: www.uml.edu/nuclearroadmap

Inquires about Roadmap: nuclearroadmap@uml.edu

Inquires about Nuclear Engineering Program : nuclear@uml.edu



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