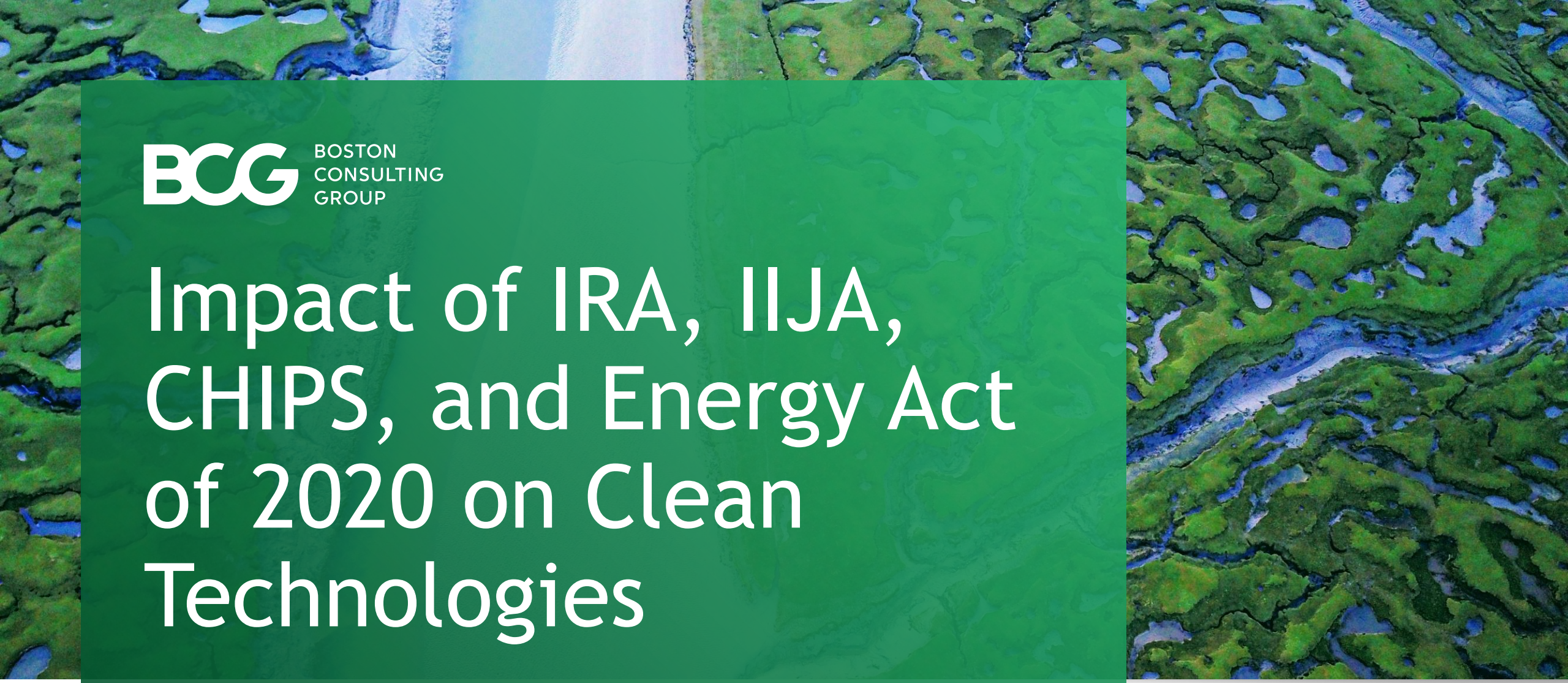


BOSTON CONSULTING GROUP

Impact of IRA, IIJA, CHIPS, and Energy Act of 2020 on Clean Technologies

Deep Dive | Advanced Nuclear Small Modular Reactors

APRIL 2023

Background | Objectives and context of this work

Objective

- Explore impacts of recent legislation[1] on U.S. opportunity and remaining challenges for emerging clean technology deployment

Stakeholders involved

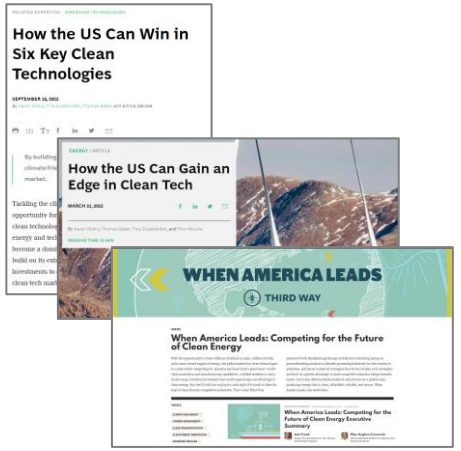
- Analysis was commissioned by Breakthrough Energy and Third Way, with input from stakeholders across the public and private sectors

Breakthrough Energy

THIRD WAY

Related publications

- BCG report | How the US Can Win in Six Key Clean Technologies
- BCG report | How the US Can Gain an Edge in Clean Tech
- Third Way publication | When America Leads: Competing for the Future of Clean Energy



1. Legislation assessed here includes Inflation Reduction Act (IRA), Infrastructure Investment and Jobs Act, CHIPS and Science Act, and the Energy Act of 2020
Source: BCG analysis

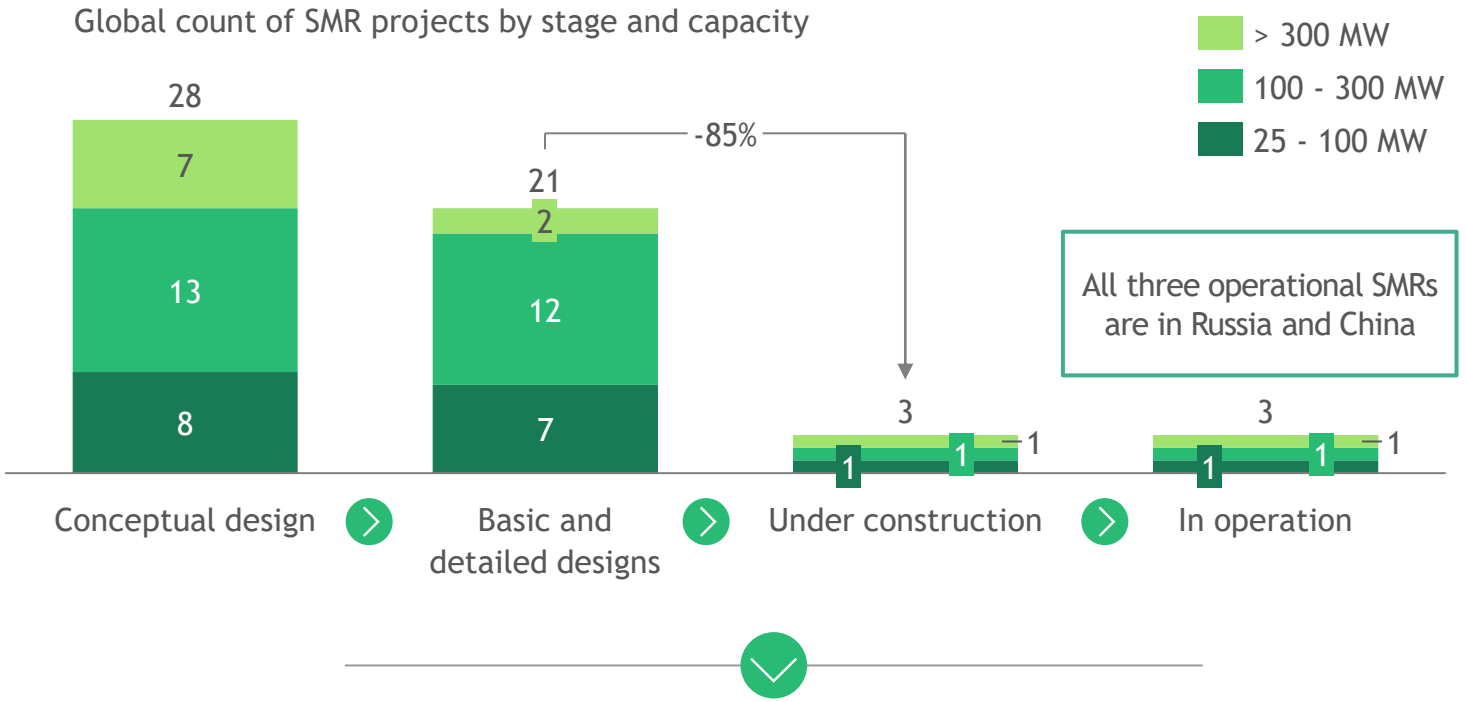
Advanced Nuclear SMRs | Executive Summary

- IRA/IIJA address historical roadblocks to advanced nuclear SMRs by allocating funding to demonstrate new technologies and build a domestic advanced reactor HALEU[1] fuel supply, helping to unlock SMR growth potential and enabling nuclear to retain a role in the clean energy transition
- IIJA authorizes $5.6B funding for advanced reactor demonstration readiness and risk reduction projects over the next 5 years to build and demonstrate commercially viable advanced nuclear SMR technologies that can be deployed at scale
- IRA funding of $700M will support the development of a domestic supply chain of HALEU[1] fuel by ~2030, enabling growth of advanced nuclear technologies, but the long-term deficit of HALEU fuel needs to be addressed through private investment
- IRA ITC and PTC incentives will support technology commercialization by reducing costs, supporting advanced nuclear SMR cost competitiveness with other firm generation sources
- This positions U.S. advanced nuclear SMR players to build advantage by testing IP and demonstrating technologies under the U.S.'s gold-standard nuclear safety regulations. Maintaining this advantage will require U.S. players to develop a strong pipeline of demand and begin reducing costs via standardized module manufacturing to capture economies of volume
- IRA/IIJA supports technology demonstration, but further initiatives to build a strong pipeline of projects, de-risk investment in manufacturing to capture economies of volume, and increasing export market access by harmonizing nuclear regulations in export markets are needed to unlock U.S. advantage

1. High-assay low-enriched uranium 2. Total number of positions created through 2050; incremental new jobs calculated as the sum of all non-negative one-year differences in # job-years (e.g., 2021 job-years minus 2020 job-years gives 2021 new jobs); incremental new jobs added to sum from prior period for cumulative calculation
Note: Numbers on the left are based on IEA's Announced Pledges (APS) scenario summed up across prioritized value chain segments from 2020-2050, except jobs which are summed up across all value chain segments
Source: IEA; BCG Analysis

Demonstration | IRA/IIJA help address significant bottleneck between design and operation, a long-standing SMR hurdle

Global number of SMR projects by status of development, 2022

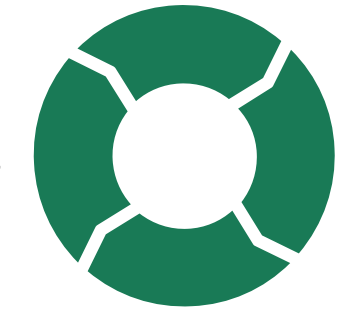


IRA/IIJA bill funding authorization of $5.6B[1] for Advanced Reactor Demonstration Program (ARDP) will support the rapid progression of SMRs from design towards construction and operations

1. $3.2B has been awarded to demonstrate 2 U.S. advanced reactors: Terrapower's Natrium reactor and X-Energy's Xe-100; $600M has been awarded for risk reduction to 5 advanced reactor teams; $56M has been awarded for advanced nuclear concept development to 3 teams
Source: IEA; DOE; BCG analysis

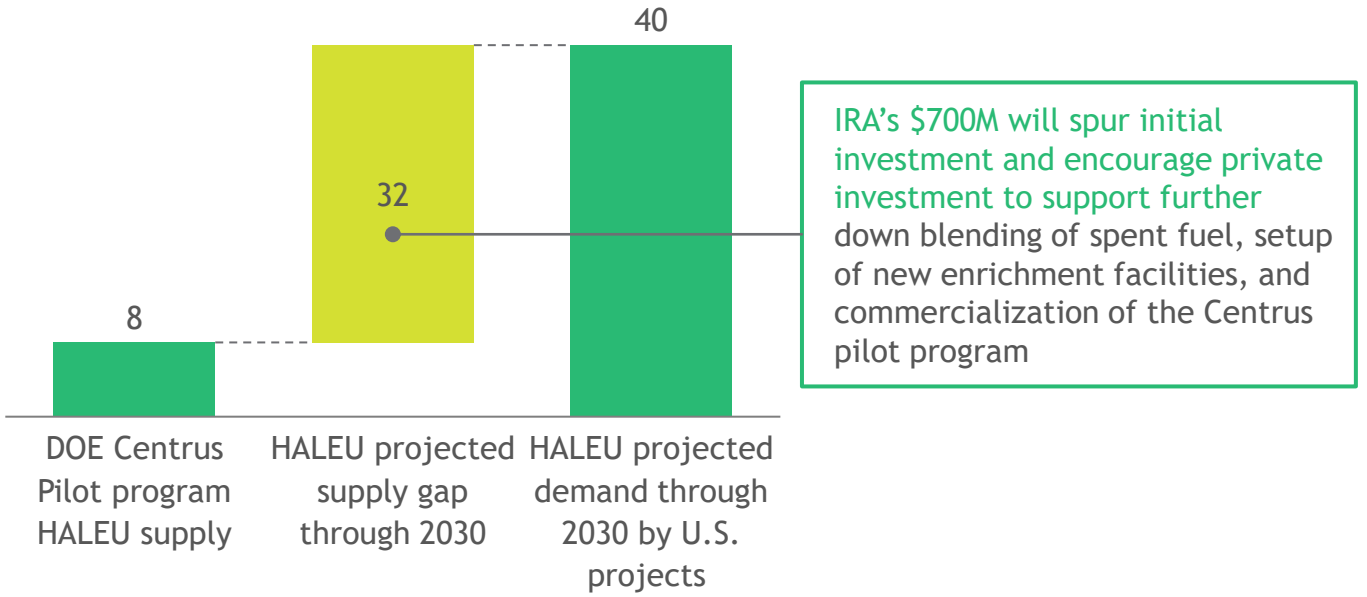
Advanced fuel | IRA funding supports availability of the advanced reactor fuel for advanced nuclear demonstration and commercialization projects

Lack of fuel creates "chicken or egg" cycle, blocking SMR commercialization



IRA helps address the HALEU "chicken or egg" cycle, but additional private investment is needed to support long-term supply

HALEU fuel projected demand and supply, 2022-2030 (MTU)



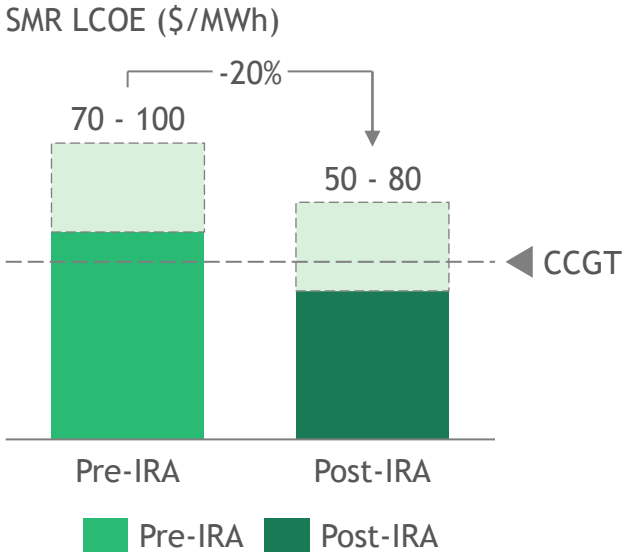
Note: HALEU = High-assay low-enriched uranium
Source: DOE; BCG Analysis

Reduced costs | IRA & IIJA support of SMRs expected to reduce LCOE[1] and increase deployment

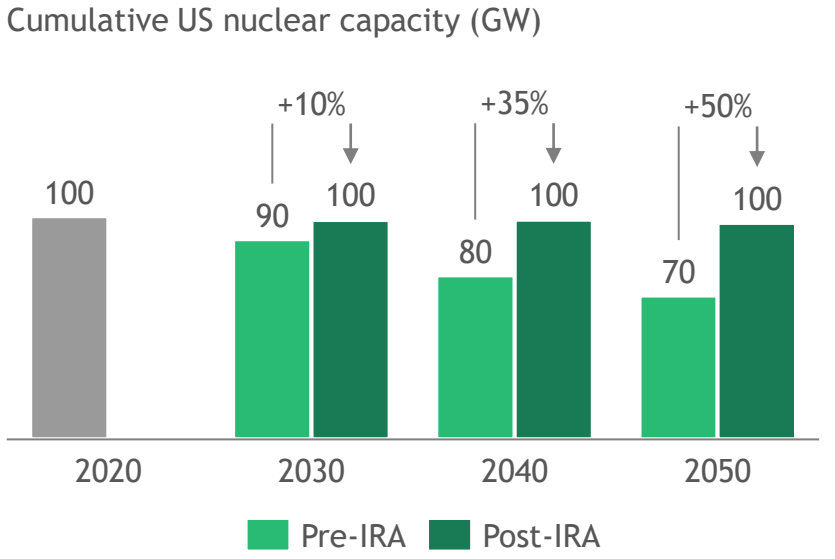
Demand-side incentives from the IRA include:

1. ITC: **6% base** with 5x multiplier for wage and apprenticeship requirements
2. PTC: **1.5 ¢/kWh** if wage and apprenticeship requirements are met
3. ITC & PTC: **10% bonus** for domestic content + **10% bonus** for plants in energy communities
4. ITC: **Additional 20%** for facilities in qualifying low-income communities

SMR LCOE expected to decrease by ~20%[2] due to IRA tax credits



Nuclear capacity expected to increase by ~50%[4] post-IRA by offsetting fleet retirements

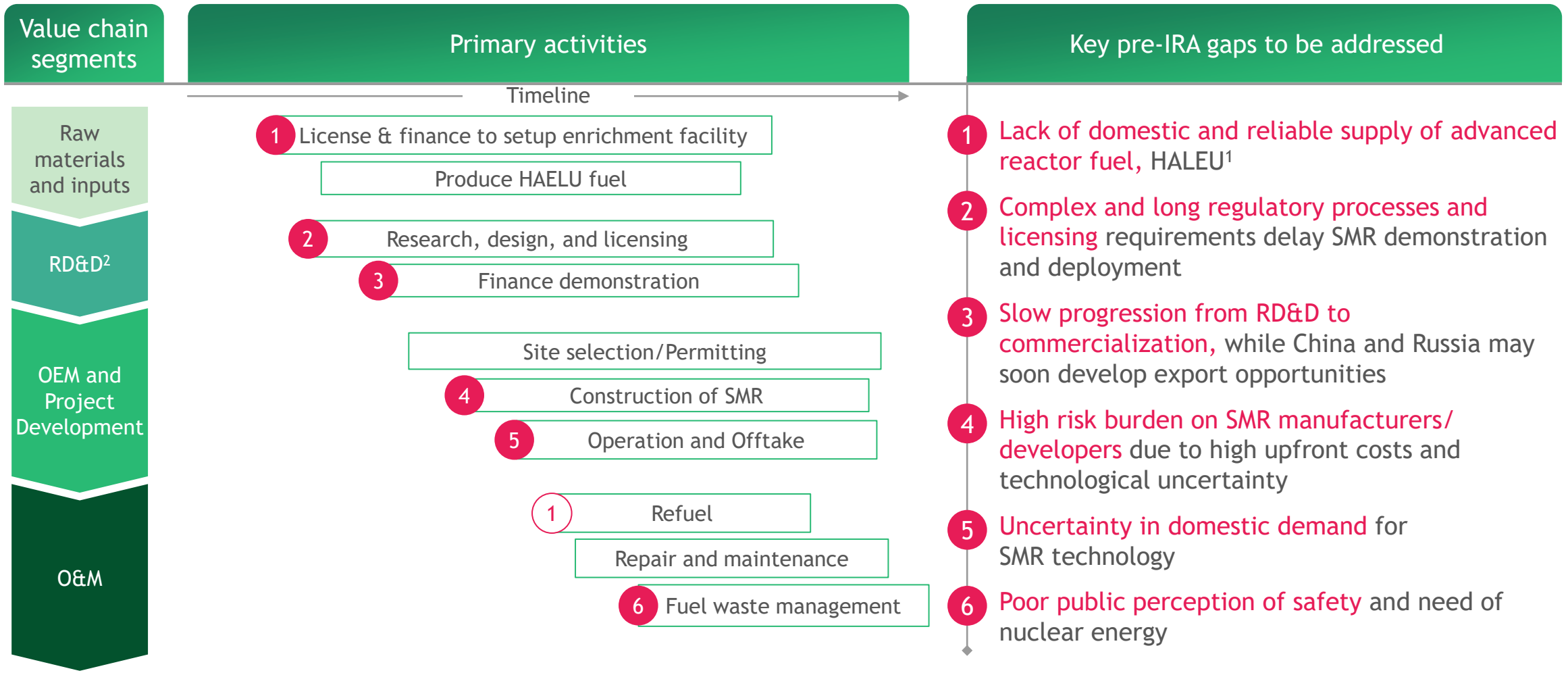


IRA arrests projected nuclear capacity decline, with existing plant extensions and new SMR capacity filling projected gap

1. Levelized Cost of Energy 2. Assumes $15/MWh incentive, inflation adjusted, and with bonuses, equal to a ~$31/MWh incentive in 2022 dollars 3. Ranges reflect high and low end of pre-IRA SMR LCOE based on PNNL analysis 4. Includes conventional and advanced nuclear reactors; calculated comparing IEA WEO STEPS data pre- and post-IRA
Source: Lazard; NREL; EIA; CPUC; IEA; BCG Analysis

Pre-legislation challenges | To support SMR deployment, several areas to be addressed to support the gap between the design and operation stages

Illustrative



1. High-assay low-enriched uranium 2. Research, development, and demonstration
Source: BCG Analysis

Remaining challenges | Additional policy could further boost U.S. competitiveness and accelerate SMR deployment

	Pre-legislation priority challenges	Changes from recent legislation (IRA, IIJA, CHIPS, and EA 2020)	Remaining areas to target with future policies
Raw materials and inputs	1 Lack of domestic and reliable supply of advanced reactor fuel HALEU1	• $700M grant to support the HALEU Availability Program	☆ Provide govt. purchasing guarantee to de-risk private investment in enrichment and build favorable trade relations with friendly countries to diversify supply chain
RD&D[2]	2 Complex and long regulatory processes and licensing requirements delay SMR demonstration and deployment		• Streamline licensing for new advanced reactors and lead development of an international standardized regulatory framework to enable export opportunities
	3 Slow progression from RD&D to commercialization, while China and Russia may soon develop export opportunities	• $150M grant for nuclear energy R&D • $5.6B grant for Advanced Reactor Demonstration Program (ARDP)	☆ Build joint RD&D programs with trusted partners who have similar SMR investments such as France, Canada, and the UK
OEM and Project Development	4 High risk burden on SMR manufacturers/ developers due to high upfront costs and technological uncertainty	• Extended ITC and PTC credits for clean energy facilities until 2032 • 48C investment tax credit of up to 30%	☆ De-risk private investment in SMR manufacturing facilities and development via loan guarantees and cost-sharing agreements
	5 Uncertainty in domestic demand of SMR technology		• Procure SMR projects for relevant govt. facilities (e.g., national labs) to incentivize private investment in SMR deployment at scale
O&M	6 Poor public perception of safety and need of nuclear energy		☆ Dispel myths and build public consensus on safety and importance of nuclear energy to U.S. energy security and engage affected communities early

☆ Priority areas

1. High-assay low-enriched uranium 2. Research, development, and demonstration
Source: IRA; IIJA; DOE; IEA; BCG Analysis

Summary | IRA provides significant support to accelerate SMR commercialization, but further action is needed to boost U.S. competitiveness

Key levers that will enable the U.S. to win the clean tech market

Build a domestic fuel supply chain

Collaborate with public and private stakeholders with existing nuclear expertise to rapidly develop domestic HALEU fuel supply

Build bilateral and multilateral agreements with trusted partners to provide necessary raw materials and build a diverse fuel supply chain

Enhance regulatory approval processes

Streamline licensing at each step including design, construction, and operations

Lead development of an international standardized regulatory framework for the new SMR technologies

Rapid commercialization of SMR technology

Continued investment in RD&D across various SMR technologies

International collaboration on RD&D with trusted partners who have SMR programs such as France, Canada, and the UK

Improve public perception

Initiate early engagements with the community where SMRs may be built

Build a stronger wider public perception highlighting the importance of nuclear energy for U.S. energy security

Source: BCG analysis

Backup | New legislation provides incentives for facilities and production of advanced nuclear small modular reactors (SMRs) (I/II)

	Provision	Summary	Type	Total investment
1	IRA Section 13701: Clean Electricity Production Credit	Creates a new clean energy production credit (PTC) for sale of electricity with no GHGs produced at qualifying facility placed in service starting in 2025[1]. Base credit amount is 0.3 cents per kWh, with 5 times increase to 1.5 cents per kWh for facilities that meet the Wage and Workforce Requirements	Production Tax Credit (PTC)	N/A
2	IRA Section 13701: Clean Electricity Investment Credit	Creates a new clean energy investment tax credit (ITC) for investment in qualifying zero-emission electricity generation at qualifying facility placed in service starting in 2025[1]. Base rate is 6%, with a five-times increase to 30% for facilitates that meet Wage and Workforce Requirements	Investment Tax Credit (ITC)	N/A
3	IRA Section 13501: 48C Advanced Energy Manufacturing Project Tax Credit[1]	Extension of the advanced energy manufacturing project credit. Base rate of 6% and 30% tax credit if wage and apprentice requirements are satisfied	Manufacturing Tax Credit	$10B
4	IIJA Section 3201: Infrastructure planning for small/micro modular nuclear reactors	Requires DOE to submit a report to congressional committees of jurisdiction about how SMRs and micro-reactors "could enhance energy resilience and reduce carbon emissions." DOE is also required to provide technical and financial assistance for feasibility studies to identify "suitable locations for the deployment of micro-reactors, small modular reactors, and advanced nuclear reactors in isolated communities."	Research Study	N/A
5	IIJA Section 41201: Office of Clean Energy Demonstration (OCED)	Establishes the OCED within DOE to conduct management and oversight of the ARDP demonstrations and other clean energy demonstration projects; designating US$2.5B for advanced nuclear	Grants	$2.5B

Producers must choose PTC or ITC

1. The credit phases out at the later of emission reduction target levels being achieved or after 2032. Emission reduction target levels are reached when greenhouse gas emissions from the electric power sector are equal to or less than 25% of the 2022 electric power sector emissions. Once phaseout begins, the full credit amount will be available to facilities that begin construction in the first following year, 75% in the second following year, 50% in the third following year and zero after that

Source: DOE; IRA; IIJA; BCG Analysis

Backup | New legislation provides incentives for facilities and production of Advanced nuclear small modular reactors (SMRs) (II/II)

	Provision	Summary	Type	Total investment
6	IIJA Section 41002: Authorizes the full amount to support the DOE's ARDP Demonstration projects	The Infrastructure Bill contains funding approvals for DOE's ARDP Demonstration projects and authorizes US$3.2 billion through FY 2027 for the advanced reactor demonstrations, which combined with the previously authorized funding from FY 2020 and 2021, makes the demonstration projects fully authorized. Note, this provision is an authorization and not an appropriation	Grants	$3.2B
7	IIJA Section 41002: Appropriates US$2.4 billion to fund ARDP awards from FY 2022 through 2025	While Congress had previously appropriated funds to support DOE's ARDP awards for FY 2020-2021, this provision of the Bill appropriates additional funds for existing ARDP awardees for FY 2022 to FY 2025. These funds are limited to "projects selected prior to the date of enactment of this Act" which would appear to reserve funds for all ARDP projects selected to date. Unlike the US$3.2B which is authorized for the advanced reactor demonstration awards, this funding may be used for the risk reduction and advanced reactor concept projects as well	Grant	$2.4B
8	IRA: Infrastructure improvements to enhance nuclear R&D	$150M in funding provided by President Biden's Inflation Reduction Act for infrastructure improvements at DOE's Idaho National Laboratory (INL) to enhance nuclear energy research and development	Grant	$150M
9	IRA: Funding to support HALEU fuel availability for advanced nuclear reactors	US$700M funding package to support the HALEU Availability Program to be conducted over the next four years by the US Department of Energy (DOE); $100M to make HALEU fuel available for RD&D, and commercial use; $500M to make HALEU available for the first advanced reactors, and $100M to assist commercial entities in the licensing and regulation of special nuclear material fuel (such as HALEU) fabrication, enrichment facilities, and transportation packages	Grant	$700M

Source: DOE; IRA; IIJA; BCG Analysis

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