LWR Fleet Capacity Expansion Scenarios and Acceleration Pathways

Report SL-021967

Revision 0

October 29, 2025

Project No.: 14248.021

S&L Nuclear QA Program Applicable:

☐ Yes

☒ No

55 East Monroe Street
Chicago, IL 60603-5780 USA
312-269-2000
www.sargentlundy.com

Sargent & Lundy

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REVISION HISTORY

Revision History:

Revision	Issue Date	Notes
0	10/29/2025	Initial Issuance

ISSUE SUMMARY AND APPROVAL PAGE

This is to certify that this document has been prepared, reviewed and approved in accordance with Sargent & Lundy's Standard Operating Procedure SOP-0405, which is based on ASQ/ANSI/ISO 9001:2015: Quality Management Systems–Requirements.

Contributors

Prepared by:

Name	Signature	Date
Henry Fidlow	Henry Fidlow	10/29/25

Reviewed by:

Name	Signature	Date
Thomas Bartoski	Thomas Bartoski	10/29/25
Steven Malak	Steven Malak	10/29/25

Approved by:

Alan J Wilson
Digitally signed by Alan J Wilson
Date: 2025.10.29 15:17:56 -05'00'

Alan J. Wilson
Sr. Vice President

Date

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ACRONYMS AND ABBREVIATIONS

Acronym/Abbreviation	Definition Clarification
BOP	Balance of plant
BWR	Boiling water reactor
CLTP	Current Licensed Thermal Power
CO	Commercial Operation
EO	Executive Order
EPU	Extended Power Uprate
EPU+	Extended Power Uprate Plus
FL	Fuel Loading
GAIN	Gateway for Accelerated Innovation in Nuclear
GWe	Gigawatt-electric
HP	High-pressure
INPO	Institute of Nuclear Power Operations
LAR	License Amendment Request
LP	Low-pressure
LWR	Light water reactor
MSR	Moisture separator reheater
MUR	Measurement Uncertainty Recapture
MWe	Megawatt-electric
MWt	Megawatt-thermal
NEI	Nuclear Energy Institute
NRC	United States Nuclear Regulatory Commission
NSSS	Nuclear steam supply system
OLTP	Original Licensed Thermal Power
PWR	Pressurized water reactor
SPU	Stretch Power Uprate
U.S.	United States

1. BACKGROUND AND OBJECTIVES

United States (U.S.) nuclear energy capacity has remained largely stagnant, at around 100 gigawatts-electric (GWe), over the past 30 years. Competition in the marketplace, regulatory uncertainty, long construction durations, and large capital investments have all played a part in stifling the prospect of new nuclear projects.

Despite these challenges, recent years have seen multiple positive tailwinds driving a resurgence in nuclear power. Increasing renewable penetration and coal plant retirements have increased grid supply-side variability, emphasizing the importance of baseload generation. Projected load growth through the rapid adoption of artificial intelligence has provided a new market driver particularly well-suited to the reliability of nuclear power plants. New reactor technologies have implemented decades of lessons learned to optimize designs for faster construction durations and inherent safety. Meanwhile, public sentiment and bipartisan support for nuclear continue to grow.

The current presidential administration has set out several Executive Orders (EO) calling for increased nuclear power production as both a short term and long term solution to domestic energy needs. EO 14302 calls for 5 GWe of power uprates to existing reactors by 2030, with an additional 10 new large reactors under construction. EO 14300 develops a target of 400 GWe in nuclear power plant capacity by 2050.

From these strategic goals, the need for increased nuclear power production is readily apparent. The focus of this study is to define pathways, barriers, incentives, and methods that can be employed to meet or exceed the near-term EO goal of 5 GWe by 2030.

Three (3) scenarios are considered.

- Scenario 0: Base Case (5 GWe by 2030)
- Scenario 1: Moderately Accelerated
- Scenario 2: Highly Accelerated (2.5 GWe by July 2027, 5 GWe by 2029)

2. SCENARIO DEFINITIONS

The three (3) scenarios outlined are intended to explore the opportunities for increased U.S. power capacity expansion through greater incentives and methods that can accelerate project implementation. There are a variety of pathways by which nuclear capacity can be increased. The pathways considered herein include:

- Thermal Power Uprates
  - MUR
  - PWR SPU/EPU
  - BWR EPU
  - EPU+
- Efficiency Power Uprates
  - Moisture Separator Reheater (MSR) Modifications
  - High Pressure (HP) / Low Pressure (LP) Turbine Modifications
- Capacity Factor Increases
  - Operational Excellence
  - 18-to-24 Month Fuel Cycle
- Plant Restarts
- New Reactors

2.1. SCENARIO 0: BASE CASE

In the base case Scenario 0, current and anticipated industry project data was reviewed to determine the magnitude of capacity expansion pathways and timeline for planned implementation. Scenario 0 credits current incentives and enabling methods to overcome barriers. The base case provides a path to meet the EO provided a few key assumptions are met. These include a fleet-wide 1% capacity factor improvement beyond 2024 levels (92.3%), which is representative of approximately 1 GWe capacity expansion, as well as the successful planned restart of three (3) previously shutdown reactors to realize an additional 2.2 GWe by 2030.

Figure 1 illustrates projected incremental capacity expansions year-by-year under each of the scenarios.

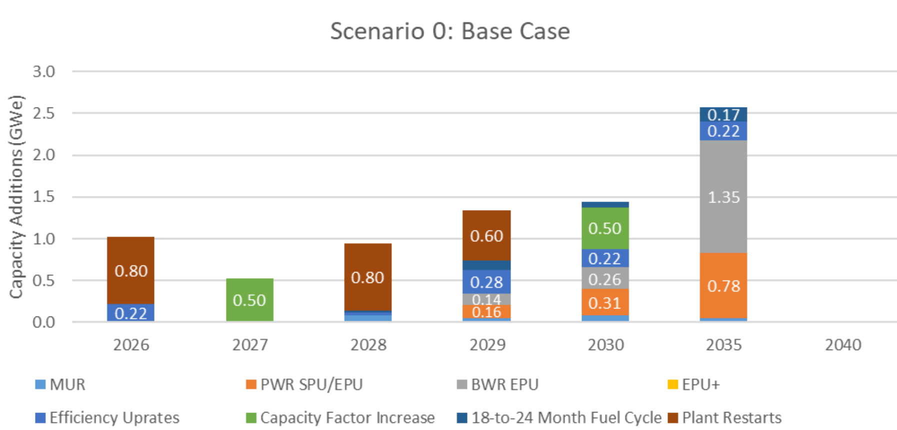

Figure 1. Incremental capacity additions (excluding new reactors) for base case

2.2. SCENARIO 1: MODERATELY ACCELERATED

Scenario 1 considers additional incentives which would moderately accelerate project timelines. Minor adjustments to project timelines are assumed to help support nearer-term targets for capacity expansion prior to 2030. A combination of government incentives and acceleration methods is expected to be required to facilitate these changes. Figure 2 depicts incremental capacity additions under this scenario.

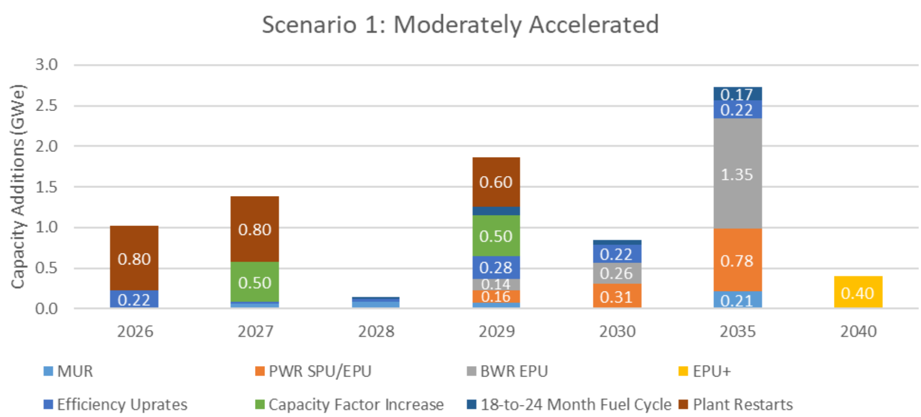

Figure 2. Incremental capacity additions (excluding new reactors) for moderately accelerated scenario

2.3. SCENARIO 2: HIGHLY ACCELERATED

Scenario 2 accelerates project timelines even more aggressively to support +2.5 GWe and +5 GWe total capacity expansions targets by July 2027 and 2029, respectively. A combination of government incentives and acceleration methods, beyond those employed under the moderately accelerated scenario, would be required to meet these targets. Figure 3 below depicts incremental capacity additions for this scenario.

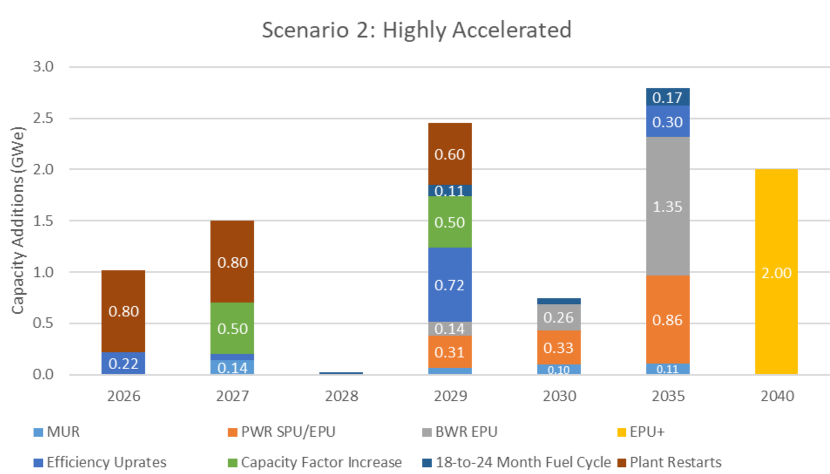

Figure 3. Incremental capacity additions (excluding new reactors) for highly accelerated scenario

2.4. SCENARIO COMPARISON

Figure 4 below illustrates how these employing these enabling factors would accelerate capacity expansion in the near term, over the next five (5) years. The base case scenario is able to realize 5 GWe of capacity expansions by 2030. Meanwhile, the highly accelerated scenario is just on target for 2.5 GWe by 2027 and 5 GWe by 2029 in capacity expansions.

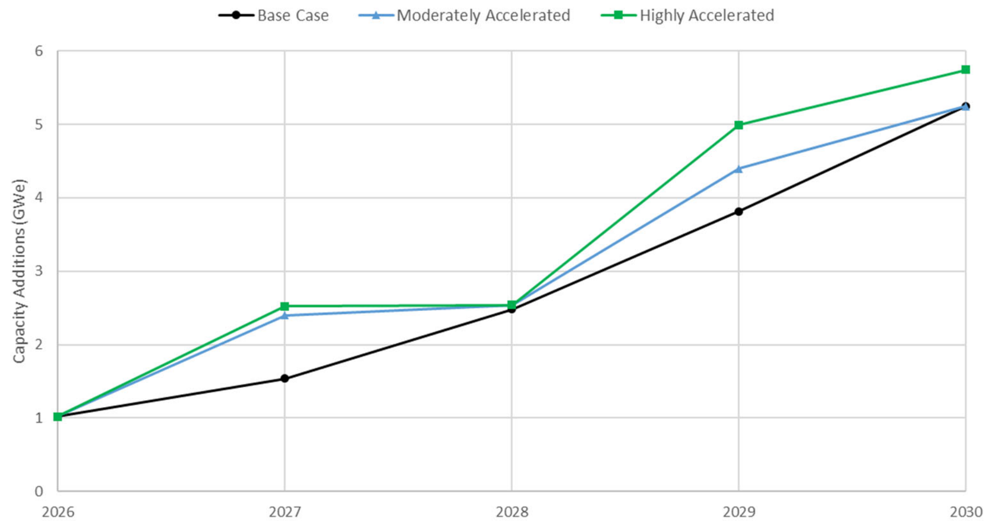

Figure 4. Stacked comparison of cumulative capacity additions for base case, moderately accelerated, and highly accelerated scenarios through 2030

To meet the moderately and highly accelerated scenarios, enabling methods and incentives should focus on the pathways with schedule flexibility. For the 2027 accelerated EO target of 2.5 GWe in capacity additions, it is suggested to focus incentives on plant restarts, capacity factor improvements, MURs, and efficiency uprates. The restart of Palisades (publicly announced for 2026) and Crane Clean Energy Center (publicly announced for 2027) units would provide a combined 1.6 GWe, which would capture more than 60% of the 2.5 GWe goal. Given the complexity, large scope, and uniqueness of these projects, employing various methods and incentives can help ensure plant restarts remain on schedule. Specific milestones prior to commercial operation (CO), including Fuel Loading (typically 1-2 months prior to CO) or NRC Operating License Reauthorization (typically 3-6 months prior to CO), may be considered as an alternative to CO to represent substantial project completion. On the capacity factor front, emphasizing INPO guidance and other existing initiatives can help the industry improve capacity factors, which would account for a large remainder of the 2027 goal.

To support the 5 GWe target for 2029, incentives should continue to focus on plant restarts and capacity factor improvements, while also accelerating PWR stretch power uprates (SPUs) and efficiency uprates. Although the larger extended power uprate (EPU) projects planned for 2030-2032 are largely inflexible to schedule accelerations (due to a combination of factors including multi-outage implementation, modification completion, NRC review timelines, and equipment lead times), some of the PWR SPUs with smaller modification scope could be accelerated with sufficient incentives. In parallel, MSR and HP/LP turbine modifications to support efficiency uprates have the potential to be accelerated if supply chain limitations can be addressed.

Figure 5 depicts cumulative capacity expansion under these three (3) scenarios for the existing, operating LWR nuclear fleet through 2040. While the difference is rather small in the near term, greater capacity for existing reactors through EPU+ uprates is envisioned in the 2040 timeframe, which represents an expected 30% increase in capacity additions to the existing LWR nuclear fleet beyond the base case.

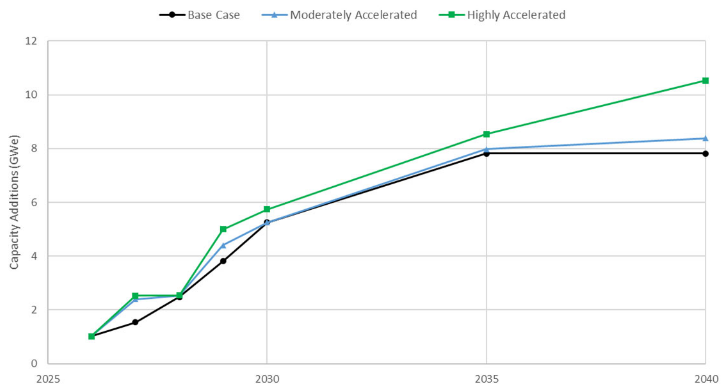

Figure 5. Stacked comparison of cumulative capacity additions (excluding plant restarts and new reactors) for base case, moderately accelerated, and highly accelerated scenarios through 2040

The more pronounced difference is illustrated in Figure 6, which includes capacity expansion from plant restarts and new large reactors through 2040. Through the implementation of incentives and enabling methods that would provide regulatory streamlining, supply chain certainty, and financial justification, there is an increase and acceleration in new reactors projects by virtue of supporting currently planned power uprate projects in the near term. This represents nearly a doubling in LWR fleet capacity additions through 2040, with greater projected differences beyond and through 2050. It should also be noted that small modular reactors were not considered in this study, but would benefit from these same enablers.

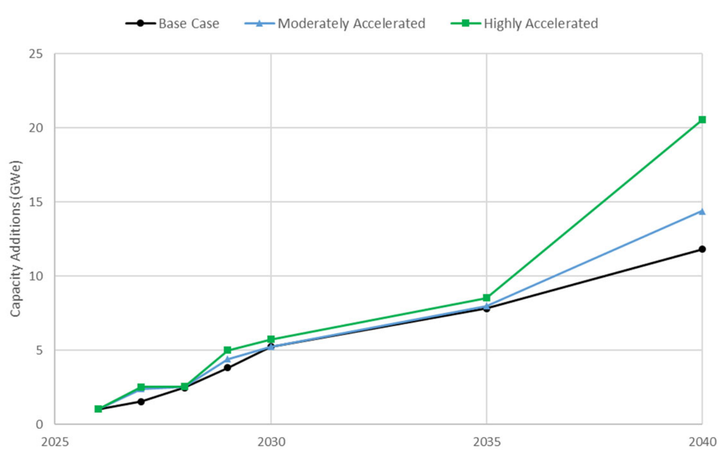

Figure 6. Stacked comparison of cumulative capacity additions for base case, moderately accelerated, and highly accelerated scenarios through 2040

Table 1 and Table 2 below provides a detailed summary of expected capacity expansions based on year (through 2040) and pathway.

Table 1. Incremental and cumulative capacity growth summary

Year	Incremental Capacity Growth (GWe)			Cumulative Capacity Growth (GWe)		
	Scenario 0 Base Case	Scenario 1 Moderately Accelerated	Scenario 2 Highly Accelerated	Scenario 0 Base Case	Scenario 1 Moderately Accelerated	Scenario 2 Highly Accelerated
2026	1.02	1.02	1.02	1.02	1.02	1.02
2027	0.52	1.38	1.50	1.54	2.40	**2.52**
2028	0.94	0.14	0.02	2.48	2.54	2.54
2029	1.34	1.86	2.45	3.82	4.40	**4.99**
2030	1.44	0.85	0.75	**5.25**	5.25	5.74
2035	2.57	2.73	2.79	7.82	7.98	8.53
2040	4.00	6.40	12.00	11.82	14.38	20.53

Table 2. Cumulative capacity expansion potential by pathway through 2030 and 2040

Pathway	Cumulative Capacity Expansion Potential by 2030 (GWe)			Cumulative Capacity Expansion Potential by 2040 (GWe)		
	Scenario 0 Base Case	Scenario 1 Moderately Accelerated	Scenario 2 Highly Accelerated	Scenario 0 Base Case	Scenario 1 Moderately Accelerated	Scenario 2 Highly Accelerated
MUR	0.21	0.21	0.31	0.26	0.42	0.42
PWR SPU/EPU	0.47	0.47	0.64	1.25	1.25	1.50
BWR EPU	0.40	0.40	0.40	1.75	1.75	1.75
EPU+	0.00	0.00	0.00	0.00	0.40	2.00
Efficiency Uprates	0.78	0.78	1.00	1.00	1.00	1.30
Capacity Factor Increase	1.00	1.00	1.00	1.00	1.00	1.00
18-to-24 Month Fuel	0.19	0.19	0.19	0.36	0.36	0.36
Plant Restarts	2.20	2.20	2.20	2.20	2.20	2.20
New Large Reactors	0.00	0.00	0.00	4.00	6.00	10.00
Total	**5.25**	**5.25**	**5.74**	**11.82**	**14.38**	**20.53**

3. BARRIERS, INCENTIVES, AND METHODS FOR IMPLEMENTATION

Each capacity expansion pathway has associated barriers to adoption, which may be broadly categorized as:

- Design/Technical
- Regulatory/Operational
- Supply Chain
- Market/Financial

Incentives primarily target the financial challenges to a project, while enabling methods can help to overcome items such as, but not limited to, time constraints and project uncertainty barriers associated with design, regulation, operation, supply chain, and market conditions.

General incentives suggested for consideration include:

- Funding of Generic Design and Feasibility Studies for specific uprate projects and capacity factor improvements
- Subsidies for capital equipment purchases
- Subsidies for domestic manufacturing
- Extending and expanding tax incentives
- Providing tariff relief for select foreign manufacturing
- Potential incentives for plant restart milestone accomplishments

Methods to derisk and accelerate project timelines include:

- Standard modification and design guidance for key equipment (i.e., MSRs, HP/LP turbines, etc.) to support thermal and efficiency uprates
- Standard approach to NRC reviews for power uprates
- NEI survey of required equipment to facilitate power uprates, plant restarts, and new reactors
- Government-backed demand certainty for major equipment suppliers
- Government guaranteed equipment reserves for utilities
- Secure equipment pool for long-lead items through bulk reservations
- Additional funding and staffing of NRC
- Risk-informed NRC review method for LARs
- Materials research to support 100-year licensing certainty
- NSSS vendor research investigating EPU+ pinch points and modifications
- GAIN Voucher Program to support utility uprates

4. CONCLUSIONS

This report details three (3) scenarios under which the US LWR nuclear fleet can expand its capacity to support short term and long term growth. Scenario 0 represents the base case, leveraging current project announcements and government incentives to target 5 GWe of capacity growth by 2030. Scenarios 1 and 2 illustrate moderately and highly accelerated growth scenarios, respectively, under which additional enablers would be required to reach 2.5 GWe of growth by July 2027 and 5 GWe total by 2029.

Capacity growth will be realized through a variety of pathways including thermal power uprates (MURs, SPUs, and EPUs), efficiency power uprates, capacity factor improvements, plant restarts, and new reactors. Enabling methods and incentives should be tailored for each pathway to overcome unique implementation challenges.

To realize accelerated capacity expansion in the next year-and-a-half, the focus should be on plant restarts and capacity factor improvements. There are two (2) restart projects with the potential to meet the 2027 target (with a third in the 2029 timeframe). Additional financial support to facilitate increased staffing for these projects can help accelerate project milestones and reduce project success uncertainties. On the capacity factor front, existing INPO guidance and operating experience should be further emphasized, along with the pursuit of potential subsidization for maintenance projects to improve equipment reliability for long term plant health.

In realizing growth objectives in the 2029 and 2030 timeframes, enablers should focus more on the developing the regulatory and supply chain conditions required to yield exponential long term development of nuclear power. Large power uprates will face similar barriers to new build projects. The NRC will require proper staffing and efficient review processes to support dozens of License Amendment Requests and new operating license applications in parallel. A nationally secured equipment pool for large, long-lead items can provide certainty for suppliers to develop their manufacturing capabilities, which will subsequently reduce demand side lead times. Tariff relief, subsidies for domestic manufacturing, investment tax credits, and awards for successful capacity expansion project milestone completions within target timeframes will also help strengthen the financial case for these projects while accelerating implementation schedules.

With EO 14300 outlining an aggressive 2050 goal of 400 GWe of domestic nuclear capacity, strong federal support and long term strategic planning of the nuclear industry is a necessity. It is suggested that all of the incentives and methods outlined herein be considered to help ensure nuclear capacity expansion project success. These enablers will not only accelerate project implementation within the 2030 timeframe but will also increase investor confidence and develop the regulatory, supply chain, and workforce foundations necessary for rapid adoption of nuclear power over the next two and a half decades.

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