INL/CON-24-76294

LWRS
LIGHT WATER REACTOR SUSTAINABILITY

Svetlana Lawrence
Risk-Informed Systems Analysis Pathway Lead

March 13, 2024

Enabling Sizable Power Uprates

NRC's Annual Regulatory Information Conference 2024

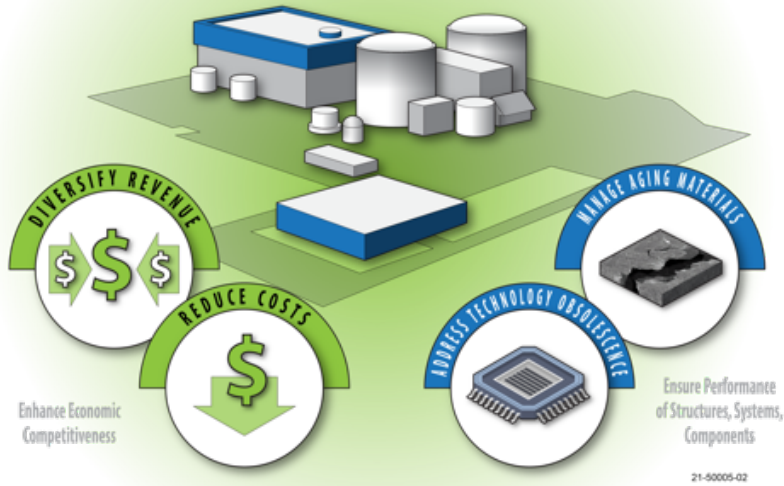
W9: Use of Accident Tolerant Fuel to Safely Increase Reactor Output

Strategic Goals for Nuclear Energy

- DOE Office of Nuclear Energy Vision[1]
  - A thriving U.S. nuclear energy sector delivering clean energy and economic opportunities
    - Goal: Enable continued operation of existing U.S. nuclear reactors.
- Light Water Reactor Sustainability (LWRS) Program
  - Goal:
    - Enhance the safe, efficient, and economical performance of our nation's nuclear fleet and extend the operating lifetimes of this reliable source of electricity
  - Objectives
    - Enable long term operation of the existing nuclear power plants
    - Deploy innovative approaches to improve economics and economic competitiveness of LWRs in the near term and in future energy markets
    - Sustain safety, improve reliability, enhance economics

DOE Goal: 550-770 GW of additional clean capacity

"U.S. will need ~550–770 GW of additional clean, firm capacity to reach net-zero; nuclear power is one of the few proven options that could deliver this at scale"[2]

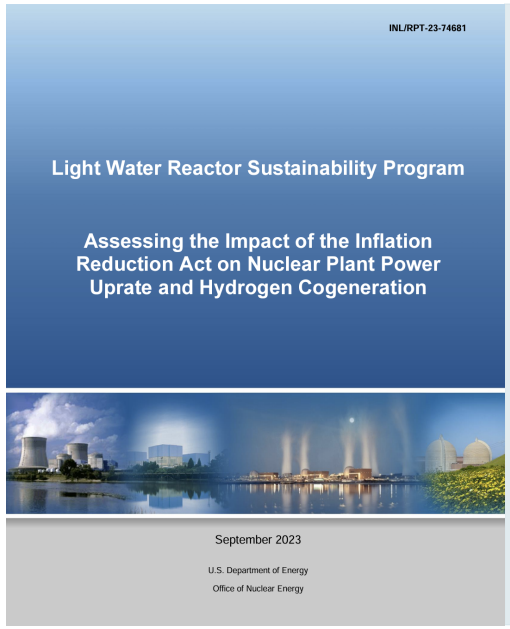


[1] DOE Office of Nuclear Energy Strategic Vision

[2] U.S. Department of Energy (2023), Pathways to Commercial Liftoff: Advanced Nuclear

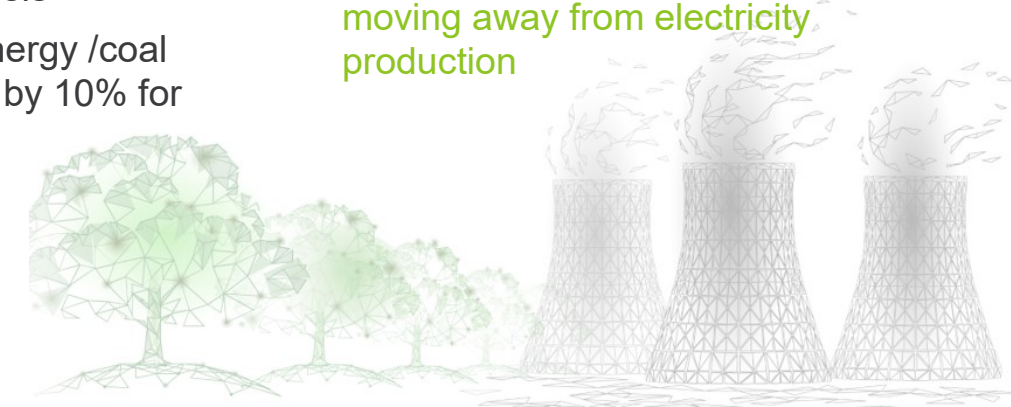
IRA Incentives for Nuclear

Production Tax Credit (PTC) for Operating Nuclear Plants (§45U)	PTC (§45Y) or Investment Tax Credit (ITC) (§48E) for Carbon-Free Generation	PTC for Carbon-Free Hydrogen (§45V)
Up to $15/MWh	PTC: At least $30/MWh for the first 10 years of operation; indexed to inflation ITC: Credit for 30% of construction expenses when plant enters service Applies to all carbon-free generators Plants entering service in 2025 or later Select the PTC (§45Y) or the ITC (§48E), not both Lasts until CO_2 emissions from electricity are 75% below 2022 levels Increases by 10% for energy /coal communities; increases by 10% for domestic content	$3/kg of H_2 for the first 10 years of operation; indexed to inflation Applies to all low-carbon generators (with lifecycle emissions below 0.45 kg of CO_2 / kg of H_2) Size of the credit based upon emission intensity Plants beginning construction in 2033 or sooner Credit significant enough to consider moving away from electricity production



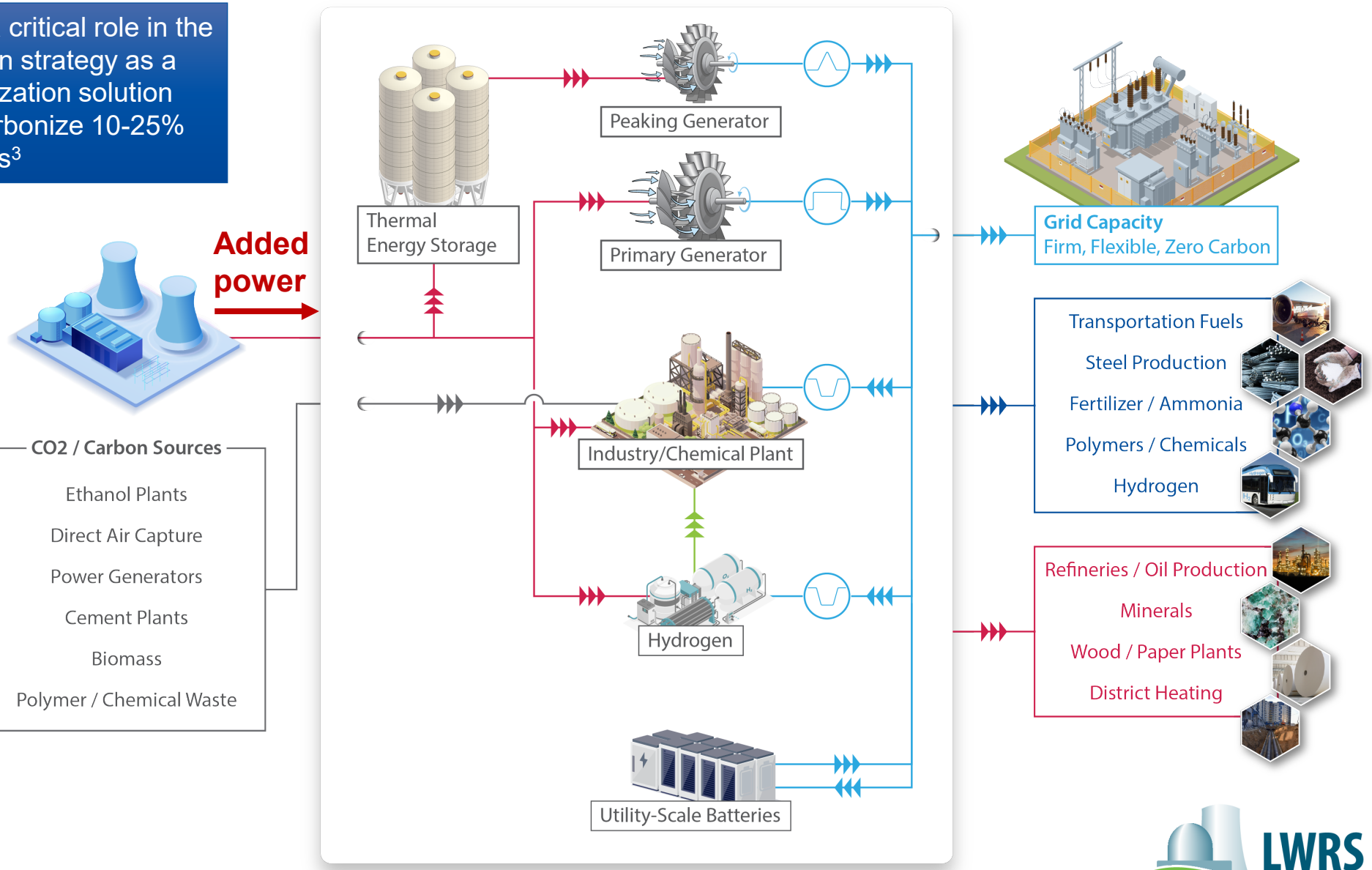
- LWRS' Feasibility Study
  - Business case assessment of practicality of power uprate with consideration of IRA credits
- Results:
  - Positive and competitive levelized cost of electricity (LCOE) supporting the business case for power uprates
  - A stronger business case if added power is used to produce clean hydrogen

Project Report Link



Nuclear Power and Industry Integration – Clean Hydrogen

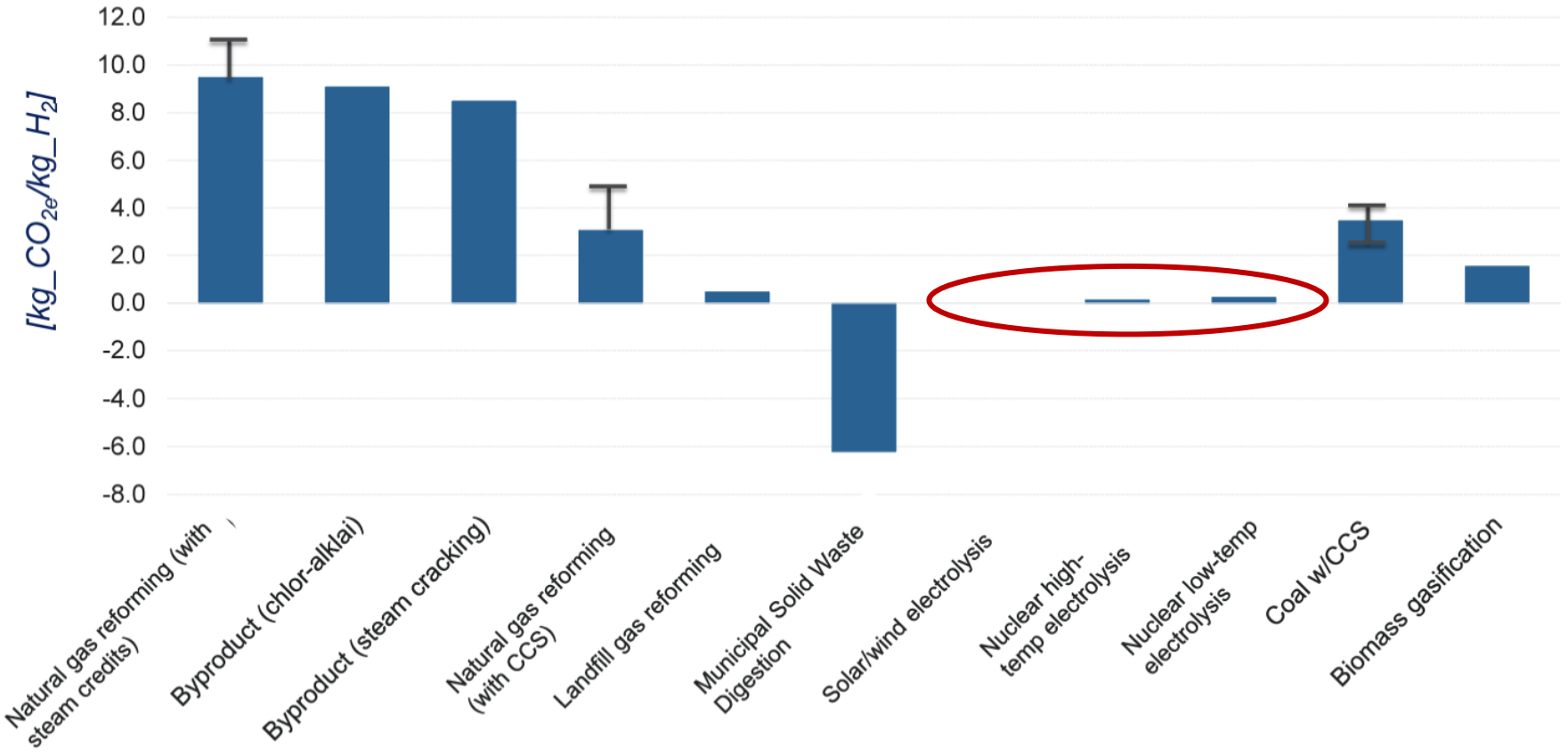
Clean hydrogen plays a critical role in the Nation's decarbonization strategy as a multi-faceted decarbonization solution with a potential to decarbonize 10-25% of global CO2 emissions[3]



[3]U.S. Department of Energy (2023), Pathways to Commercial Liftoff: Clean Hydrogen

CO_2 Emissions from Hydrogen Production Pathways

WTG GHG emissions of Key Hydrogen Production Pathways



Ranges shown reflect potential variability in upstream methane leak rates, plant energy efficiency, and CO_2 capture rates. Baseline assumes 90% capture rate

Nuclear-based energy source has the distinct advantage of **24/7 production rain or shine**.

A highly important attribute for large industrial applications (e.g., refineries, chemical production, steel manufacturing).

The Department of the Treasury draft rule[4] recognizes power uprates as a qualified energy source for §45V hydrogen production credit

WTG: well-to-gate (lifecycle)
CCS: Carbon Capture and Sequestration
GHG: Green House Gas
GREET: Greenhouse gases, Regulated Emissions, and Energy use in Technologies Model

Source: GREET Model for Emissions Lifecycle Analysis

[4]U.S. Department of the Treasury, Internal Revenue Service, proposed regulations relating to the credit for production of clean hydrogen, https://www.federalregister.gov/d/2023-28359

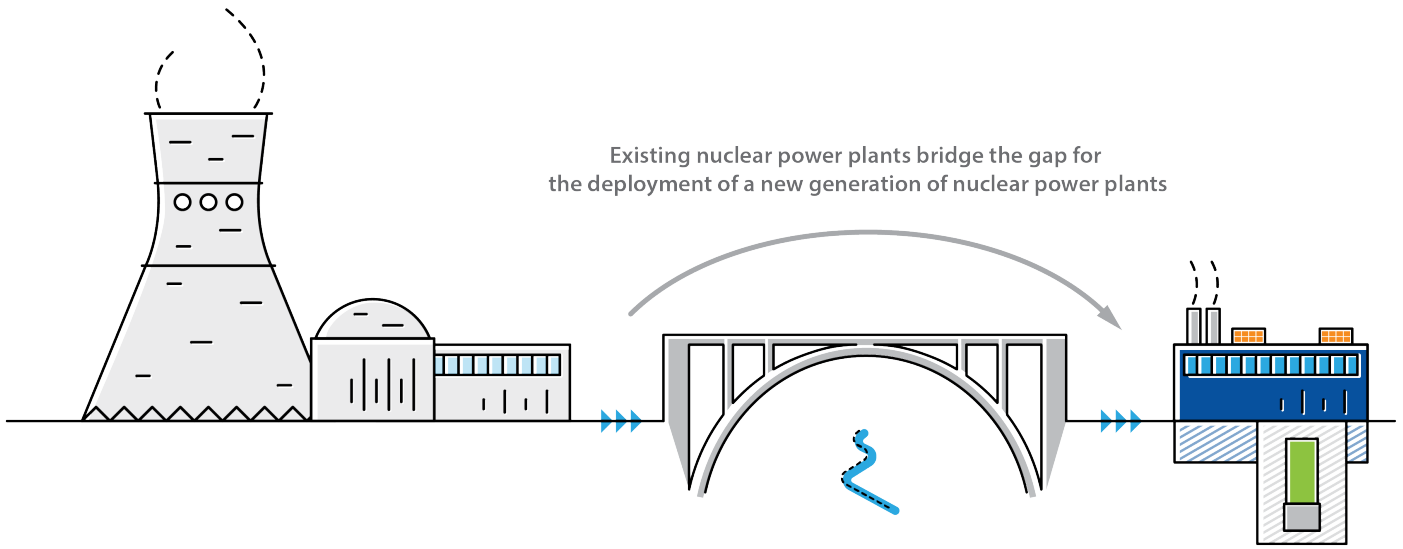
Value of Sizable Power Uprates

- Near-term delivery of substantial amount of clean power. Untapped available power:
  - BWRs: ~ 5,500 MWt, equivalent to ~3 large LWRs, or 20 – 30 small modular reactors
  - PWRs: ~13,000 MWt, equivalent to ~ 7-8 large LWRs, or 50 – 70 small modular reactors
- Sustainability of existing nuclear fleet
  - Added profitability as soon as new power is produced
  - Improved economics of plant lifetime extension for another 20 years
  - An opportunity to modernize
- Added power can be used to produce clean hydrogen
  - Explicitly allowed in the draft rule* for §45V hydrogen production credit
  - Hydrogen credits further strengthen the business case for power uprates

* "Proposed § 1.45V–4(d)(3)(i)(B) would provide an alternative test for establishing incrementality for electricity generating facilities that undergo an uprate. Proposed § 1.45V–4(d)(3)(i)(B) would provide that an EAC satisfies this alternative test if the electricity represented by the EAC is produced by an electricity generating facility that had an uprate no more than 36 months before the hydrogen production facility…."

Value of Sizable Power Uprates (cont'd)

- **Bridging the gap to new nuclear**
  - U.S. nuclear fleet to scale from ~100GW to ~ 300GW by 2050[5]
    - Scaled capacity of existing nuclear plus added new nuclear – need to triple the current capacity
  - Re-establishing U.S. Nuclear Sector Capabilities:
    - Workforce
    - Supply chain
    - Nuclear-grade systems and components
    - Nuclear-grade materials
    - Scaled capacity of regulatory framework
    - Enterprise risk mitigation
      - Reducing uncertainties related to completion of large nuclear projects on-time and on-budget increasing public and investors trust



[5]U.S. Department of Energy (2023), Pathways to Commercial Liftoff: Advanced Nuclear

Enabling Sizable Power Uprates

SSC – Systems, structures, and components
LB LOCA – Large break loss of coolant accident
TaT – Time at temperature
DNB – Departure from nucleate boiling
ATF – Accident-tolerant fuel

- Understand what limits the size of power uprates
  - Real limits – non-negotiable limits based on SSCs capacity
  - Imposed limits based on
    - Bounding scenarios with intentionally high conservatisms
    - Intentionally conservative safety limits
- Identify opportunities to remove or reduce imposed limits, e.g.,
    - Risk-informed performance-based approaches
    - TaT safety criterion instead of DNB for fuel performance during normal operation
    - Safety limits specific to ATF to be used with power uprates
- Perform R&D to improve safety margins
  - Planned joint Utilities / NEI / DOE / EPRI workshop in May 2024
    - Identify and prioritize R&D activities to support expedited sizable power uprates
    - Develop a roadmap

Sustaining National Nuclear Assets

lwrs.inl.gov