Colstrip Power Plant Feasibility Study: Colstrip Public Meeting

May 2, 2025

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GAIN
Gateway for Accelerated Innovation in Nuclear

INL/MIS-18-50189

GAIN Presentation Agenda

- Nuclear Overview
- Research Project Overview
  - NorthWestern Energy Regional Siting Assessment
  - Deployment Scenario Comparison
  - Economic Impact Assessment
- Relevant News in Surrounding States / Intermountain West

Nuclear Overview

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GAIN's Areas of Expertise

- Department of Energy Office of Nuclear Energy initiative
- Focus on initiating and completing projects that support commercial deployment of advanced reactors and technologies

2024 HIGHLIGHTS

- Awarded 16 ***GAIN Nuclear Energy Vouchers*** at a value of nearly $5.4 million
- Published the ***advanced reactor cost study*** developed cost ranges for modeling and energy planning and provided the data for NREL's Annual Technology Baseline, which is used by utility planners and grid operators when planning their energy investments
- Worked with ***coal communities*** in Kentucky, Arizona and Montana to conduct nuclear feasibility studies
- Worked with ***states and communities*** across the U.S. to provide them with advanced nuclear information through conversation and testimony and connect them with Department of Energy financial and technical resources

Advanced Nuclear Versatility

SPECTRUM OF SIZES AND OPTIONS

Micro
(10s of MW)

Small
(100s of MW)

Large
(1,000+ MW)

Small Town: 1 Megawatt
750k to 1M Homes: 1 Gigawatt
The U.S.: 1,000 Gigawatts

VARIETY OF OUTPUTS

Electricity

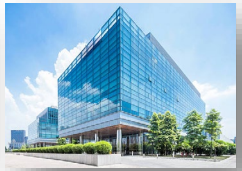
Hydrogen

Process Heat

MULTITUDE OF END USES

Homes

Vehicles



Businesses

Aviation

Rail

Shipping

Concrete

Steel

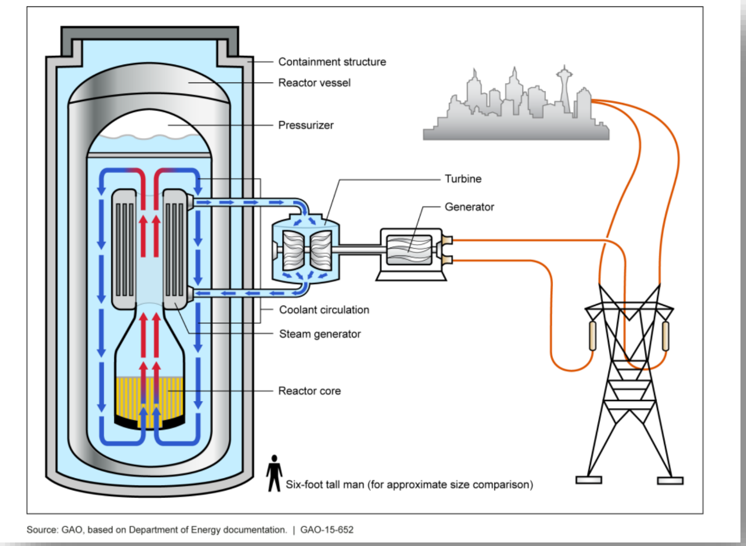
Factories

Desalinization

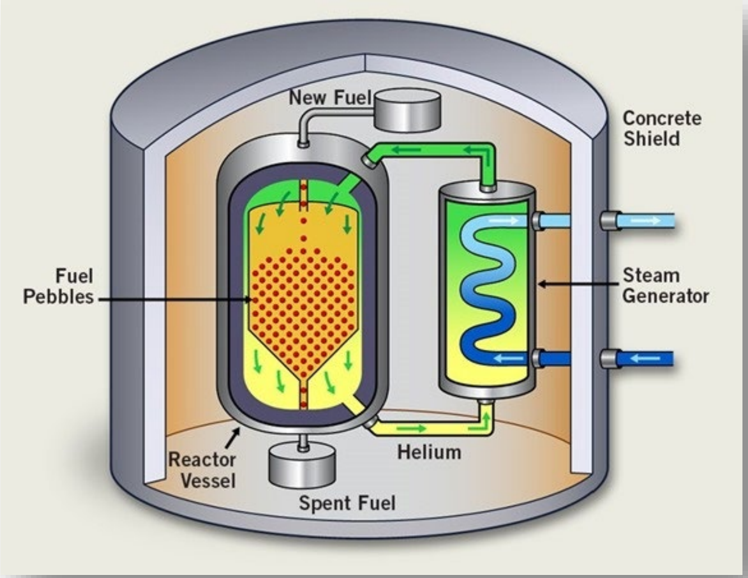
Space

Advanced Reactor Types

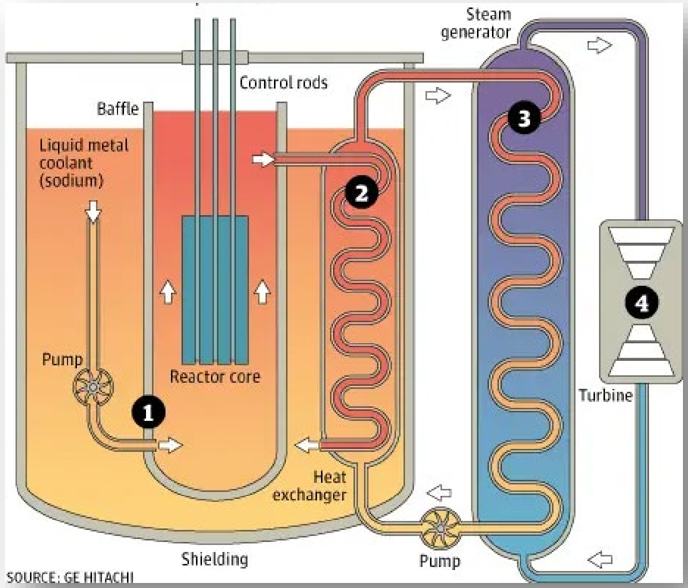
LIGHT WATER REACTORS IN SMALL MODULAR REACTOR FORM



HIGH-TEMPERATURE GAS REACTORS



LIQUID METAL FAST REACTORS / MOLTEN SALT



Active vs. Passive vs. Inherent Safety

ACTIVE	PASSIVE	INHERENT
Requires an external input to function	Relies on natural forces, property of materials, or internally stored energy	Relies on fundamental properties or design choices
A valve needs an electrical current to operate or a pump needs electricity to operate	Long term decay heat removal to heat sink using density changes and gravity heads	Design achieves reactor shutdown by negative power reactivity feedback (self limiting reaction)
Current plants	Advanced reactors (light water and non-light water)	Advanced reactors (light water and non-light water)
Example: Air Bag	Example: Self-Retracting lifeline	Example: Quick Disconnect Shutoff Valve

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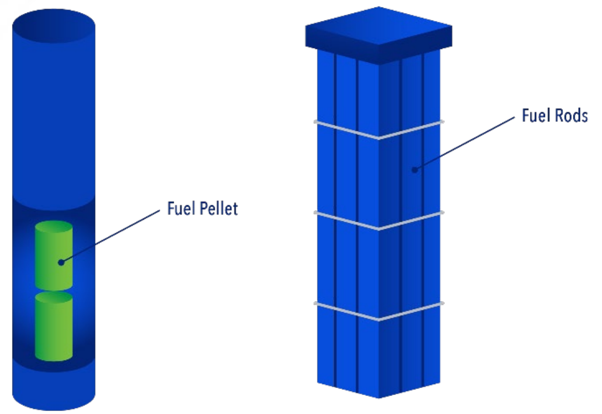
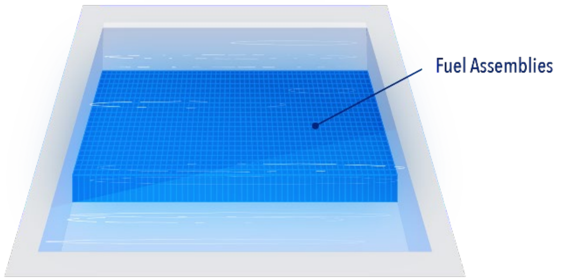
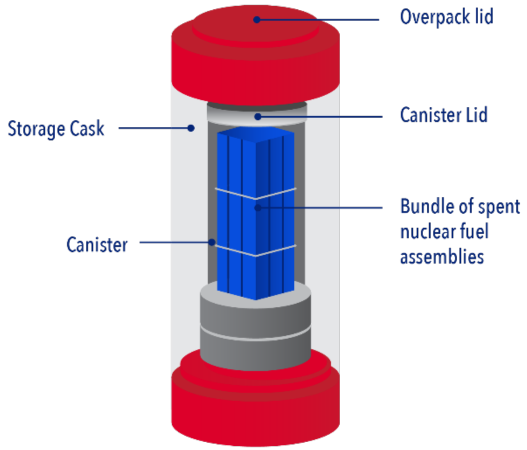
Spent Nuclear Fuel







IN THE REACTOR

- Small ceramic uranium pellets are stacked inside metal tubes, called fuel rods.
- Fuel rods are bundled together into fuel assemblies that are placed inside the nuclear reactor.

AFTER USE

- Assemblies are moved underwater from the reactor to a storage pool located inside or next to the reactor building.
- While the fuel cools, the water in the pool shields workers from radiation emitted from the spent nuclear fuel.

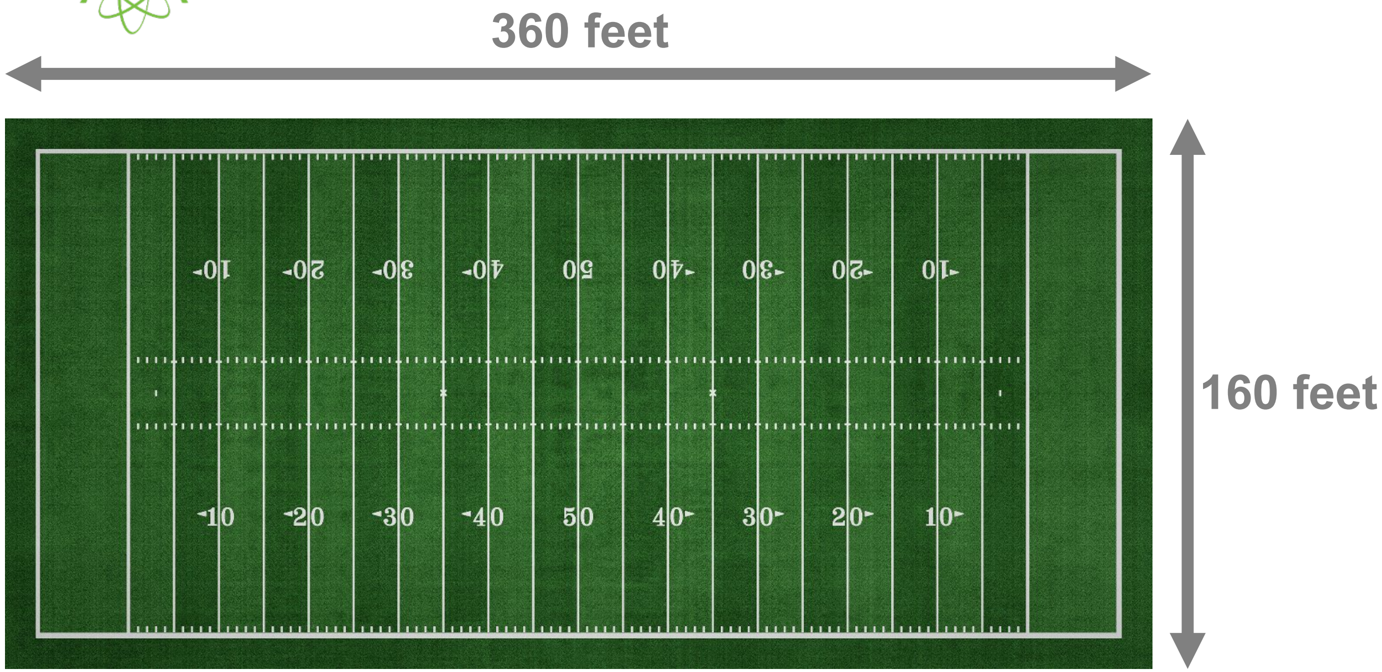
FIVE+ YEARS LATER

- Spent nuclear fuel assemblies are transferred from the pool to dry storage casks.
- The casks are designed and certified by the Nuclear Regulatory Commission to provide radiation shielding.

Spent Nuclear Fuel

- Spent nuclear fuel is a solid material composed of uranium and fission products.
- The total amount of commercial spent nuclear fuel accumulated in the U.S. since the first reactor started up in 1957 would fit in an area the size of a football field stacked ~10 yards high.

A spent nuclear fuel pellet
(about the size of a gummy bear)



Developers and Reactors

- Currently tracking over 30 developers with over 40 reactor designs in the U.S.
- Includes all varieties (water, gas, sodium, lead, salt) and sizes (from 100s kWe to 100s MWe)

U.S. NUCLEAR REGULATORY COMMISSION ACTIVITIES

Design Pre-Application Engagement

16 NON-WATER MODERATED DESIGNS

5 WATER MODERATED DESIGNS

Project Licensing

2 COMMERCIAL

3 RESEARCH/TEST

Current Projects

- GE Hitachi's BWRX-300 for Ontario Power Generation (Application Submitted)
- Tennessee Valley Authority – Clinch River (Pre-Application Construction Permit Development)
- Duke – Belews Creek (Preparing Early Site Permit)
- TerraPower Natrium – Kemmerer 1 (Construction Permit Under Review)
- DOW/X-Energy – Seadrift (Construction Permit Under Review)

Advanced Nuclear in North America

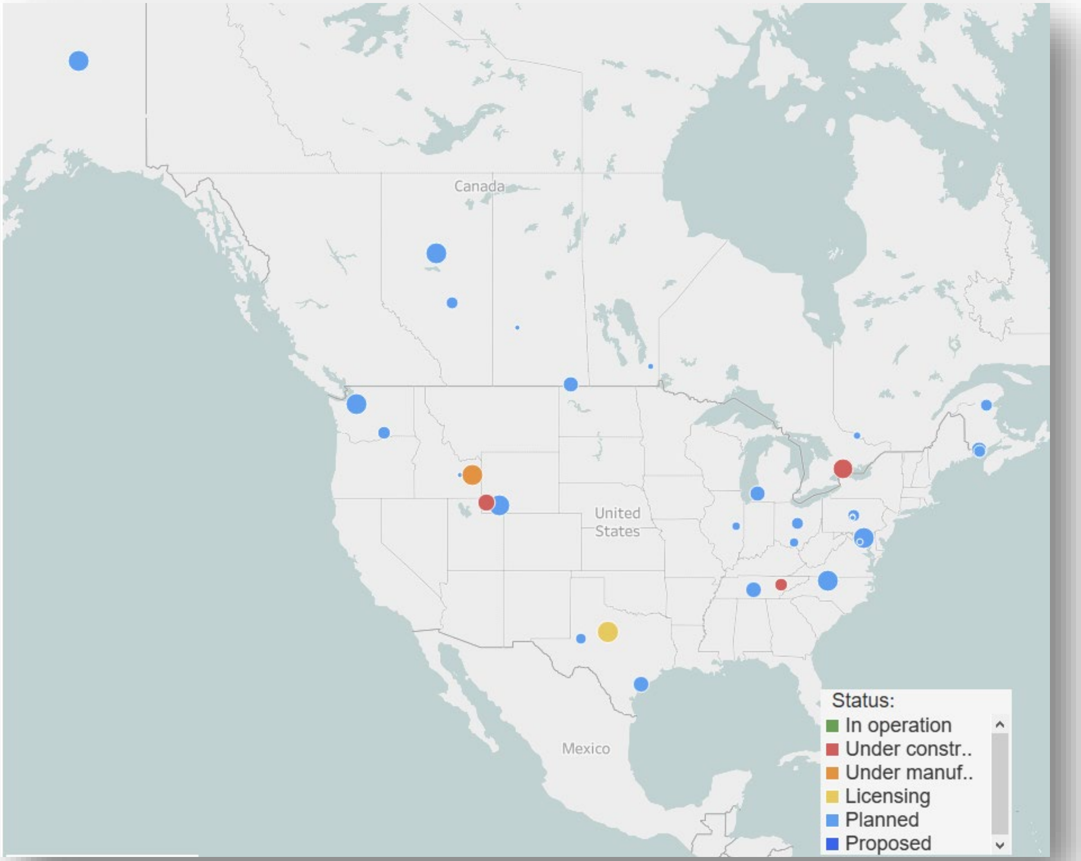


Image Source: Nuclear Innovation Alliance, 2024

- 32 active projects that includes a mix of reactor demonstrations, commercial demonstrations, and commercial reactors
- 12 deployment dates prior to 2030
- Variety of agreements, 7 are firm contracts

14

MICROREACTORS

- **4** HIGH TEMPERATURE GAS REACTOR
- **3** SODIUM FAST REACTOR
- **2** MOLTEN SALT REACTOR
- **3** SOLID CORE HEAT PIPE
- **2** TBD

18

SMALL MODULAR REACTORS

- **4** HIGH TEMPERATURE GAS REACTOR
- **3** SODIUM FAST REACTOR
- **3** MOLTEN SALT FAST REACTOR
- **7** LIGHT WATER REACTOR
- **1** FLUORIDE SALT-COOLED HIGH-TEMPERATURE REACTOR

What's driving load growth across the world and how does it impact the U.S.?

- AI, data centers and crypto are driving energy demand at the equivalent of the 6th largest country in 2026.
- Additional demand is estimated at 26,900 TWh by 2050, or the equivalent of adding the six times more than United States' power consumption.
- 84% of new electricity demand will occur in countries current projected to be ready for nuclear by 2030.
- Around 71% of new demand will be outside of high-income countries.
- Potential to grow our U.S. supply chain for advanced reactors and export our technology to support increased demand.

AI Consumption (TWh) (2022)

Countries	Total Consumption
China	8,849
United States	4,277
India	1,852
Russia	1,119
Japan	1,036
Brazil	679
Canada	636
Korea, Rep.	607
Germany	561
France	470
AI/Data center/Crypto	460
Saudi Arabia	399
Mexico	348
Indonesia	332
United Kingdom	326

Source: International Energy Agency. Electricity 2024. Organisation for Economic Co-operation and Development (OECD). January 2024. https://www.iea.org/reports/electricity-2024. Accessed October 2024.

THIRD WAY

AI Consumption (TWh) (2026)

Countries	Total Consumption
China	9,231
United States	4,591
India	2,113
Japan	1,083
Russia	1,064
AI/Data center/Crypto	800
Brazil	706
Germany	640
Canada	628
Korea, Rep.	603
France	527
Indonesia	438
Saudi Arabia	415
United Kingdom	414
Mexico	397

Source: International Energy Agency. Electricity 2024. Organisation for Economic Co-operation and Development (OECD). January 2024. https://www.iea.org/reports/electricity-2024. Accessed October 2024.

THIRD WAY

Google turns to nuclear to power AI data centres

Three Mile Island nuclear plant will reopen to power Microsoft data centers

NorthWestern Energy Regional Nuclear Siting Assessment

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NorthWestern Energy Regional Nuclear Siting Assessment

Scope: Evaluate viability of nuclear deployment in NorthWestern Energy's service territory

- Perform initial siting evaluation for Colstrip Power Plant and several sites in South Dakota, focused on criteria specific to siting a nuclear power plant.
  - Screen for exclusionary and avoidance factors (i.e., factors that could preclude nuclear or increase cost/risk)
  - Identify pros and cons associated with each site
  - Determine applicability of federal funding opportunities
- Leverage best-in-class industry siting guidance, publicly available information, and data from NorthWestern Energy (NWE).

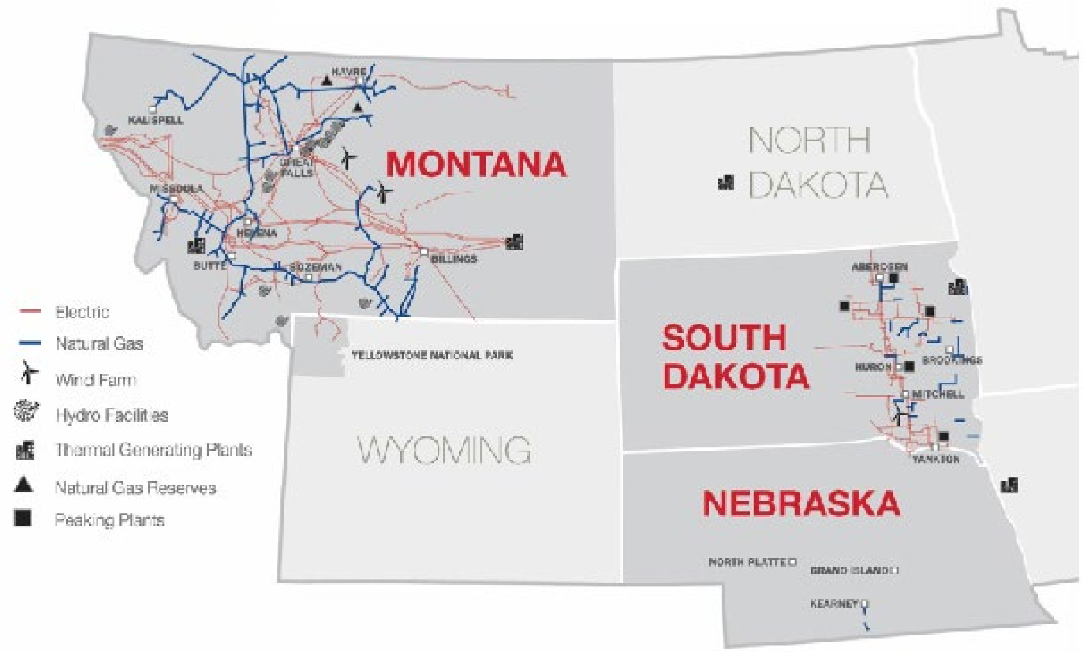

Image Source: NorthWestern Energy

Scope and Results: South Dakota LOIs

GAIN evaluated the suitability of several Locations of Interest (LOIs) in South Dakota to host a nuclear power plant

Scope

- NWE identified several LOIs that are large plots of land spread across the eastern part of South Dakota
- GAIN evaluated each South Dakota LOI separately due to the unique features of each plot of land

Results

- Several LOIs in eastern South Dakota are suitable to host a nuclear power plant.
- Common risks that require additional investigation:
  – Infringement on wetlands
  – Farmland use
  – Cooling water supply

Image Source: NorthWestern Energy

Scope and Results: Montana LOIs

GAIN evaluated several parcels near Colstrip Power Plant, based on input from NWE.

Scope

- NWE identified several parcels of land surrounding Colstrip
- GAIN evaluated a representative parcel due to the similarities between each parcel

Results

- Land surrounding Colstrip is suitable to host a nuclear power plant
  - No exclusionary or avoidance factors were identified
- Favorable aspects of Colstrip include:
  - Access to existing transmission infrastructure, water pumping infrastructure, and workforce.

Image Source: NorthWestern Energy

Summary and Potential Next Steps

- No exclusionary or avoidance factors were identified at Colstrip or at several LOIs in South Dakota. Construction of a nuclear power plant within NWE's service territory is feasible based on the results of this analysis.

- GAIN study is the first step of many required to make decision regarding the addition of nuclear.

- Should NWE decide to continue the nuclear siting process, initial next steps could include:
  - Align NWE's business objectives with selected sites
  - Identify parcels of land within the LOIs and reassess site-specific criteria using technology specific inputs
  - Conduct more detailed engineering analyses to quantify the site development costs
  - Engage with local/state stakeholders to assess support and identify potential mutual benefits.

Based on the results of this initial screen, no exclusionary or avoidance factors were identified at Colstrip or several of the LOIs in South Dakota.

Deployment Scenario Comparison

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Deployment Scenario Comparison - Overview

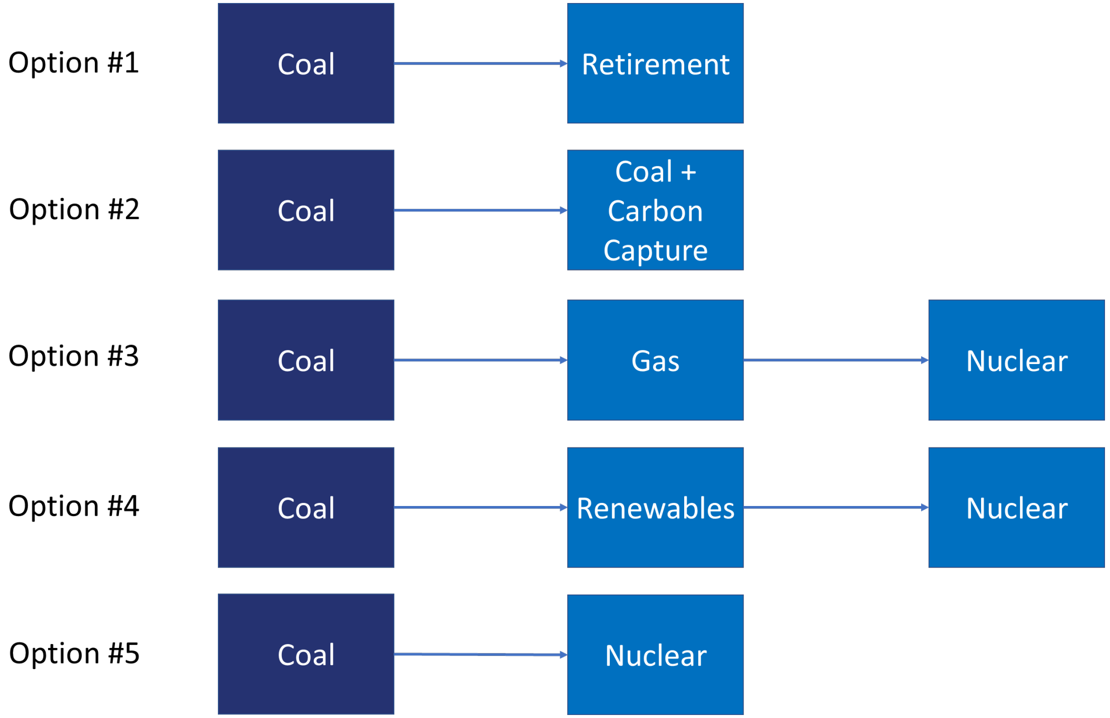
Scope: Assess the feasibility of different technologies at Colstrip Power Plant (CPP). Baseline case is continued coal plant operations.

Identify advantages and challenges associated with different technologies at CPP

- Consider potential deployment windows

Build out high-level scenarios to ensure they will be useful in the future

- Coal with Carbon Capture
- Natural Gas with/without Carbon Capture
- Wind with Battery Storage
- Solar with Battery Storage
- Nuclear



Colstrip Deployment Options

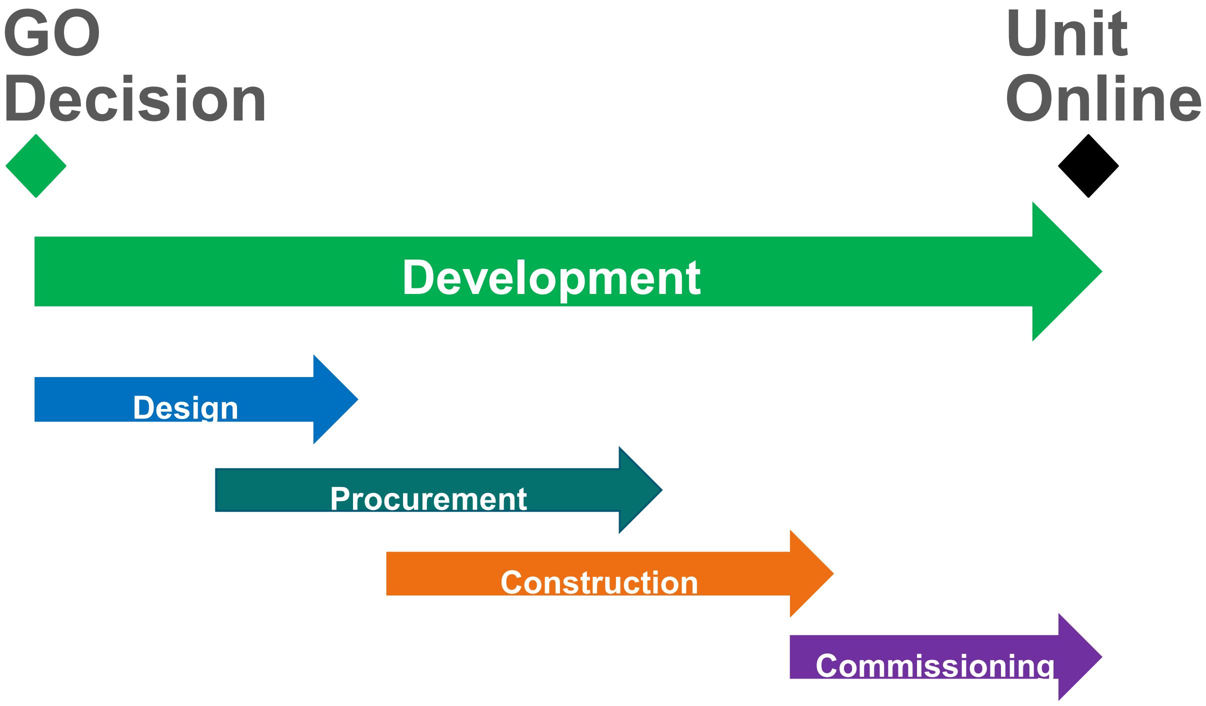
Deployment Scenario - Decision to Proceed

A **"GO"** decision is a significant investment that requires up-front feasibility studies to increase confidence in path forward.

GAIN's efforts provide independent data to help NorthWestern Energy narrow options.

Key factors that contribute to "GO" decision:

- Project cost (and associated impact to rate payers)
- Project deployment timeline
- Lifetime of generating asset
- Site compatibility
- Fit in generation portfolio / integrated resource plans
- Alignment between communities and states
- Confidence in project deployment and risk tolerance



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Deployment Timelines

- Deployment timelines range based on the technology(ies) selected and timing of the "GO" decision.
  - Less than 6 years
    - Wind with Battery Storage
    - Solar with Battery Storage
  - 6 to 10 years
    - Natural Gas without Carbon Capture
    - Natural Gas with Carbon Capture
    - Coal with Carbon Capture
  - 10+ years
    - Nuclear

Note – Durations could be impacted by project and technology specific risks (e.g., interconnection queue delays) and opportunities.

Deployment Scenario Comparison

Technology Type	Key Risks	Key Opportunities
Coal with Carbon Capture (CC)	• Maturing Technology, New Supply Chain with High Demand • Licensing/Permitting Timelines • CO2 Pipeline and Geological Storage	• Interconnection Agreement Modification • Leverage Existing CPP Infrastructure
Natural Gas with CC		
Natural Gas without CC	• Licensing/Permitting Timelines • Natural Gas Transmission Line	• Mature Technology, Developed Supply Chain • Interconnection Agreement Modification • Leverage Existing CPP Infrastructure
Wind with Battery Storage	• Interconnection Agreement Studies • Land Availability • Additional Substations/Switchyards and Network Upgrades	• Mature Technology, Developed Supply Chain • Licensing/Permitting • Leverage Existing CPP Infrastructure
Solar with Battery Storage		
Nuclear	• Advanced Nuclear Technology and Supply Chain in Development • Interconnection Agreement • Licensing/Permitting Timelines • Infrastructure Upgrades	• Regulatory Opportunities

Summary and Potential Next Steps

- Several technology futures are possible at Colstrip.
  - GAIN study is the first step of many required to make a “GO” decision

- Should NWE decide to continue to assess different technology futures, initial next steps could include:
  - More detailed feasibility studies, leveraging the information provided by GAIN to guide areas of focus
  - Assess fit of each technology future into NWE's broader resource plans and mission/ business objectives
  - Refine schedules and risk registers with technology and project specific information by engaging with vendors and/or construction contractors

Regional Economic Impact Assessment

Will Jenson
Energy Economist, INL

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Economic Impact Assessment - Overview

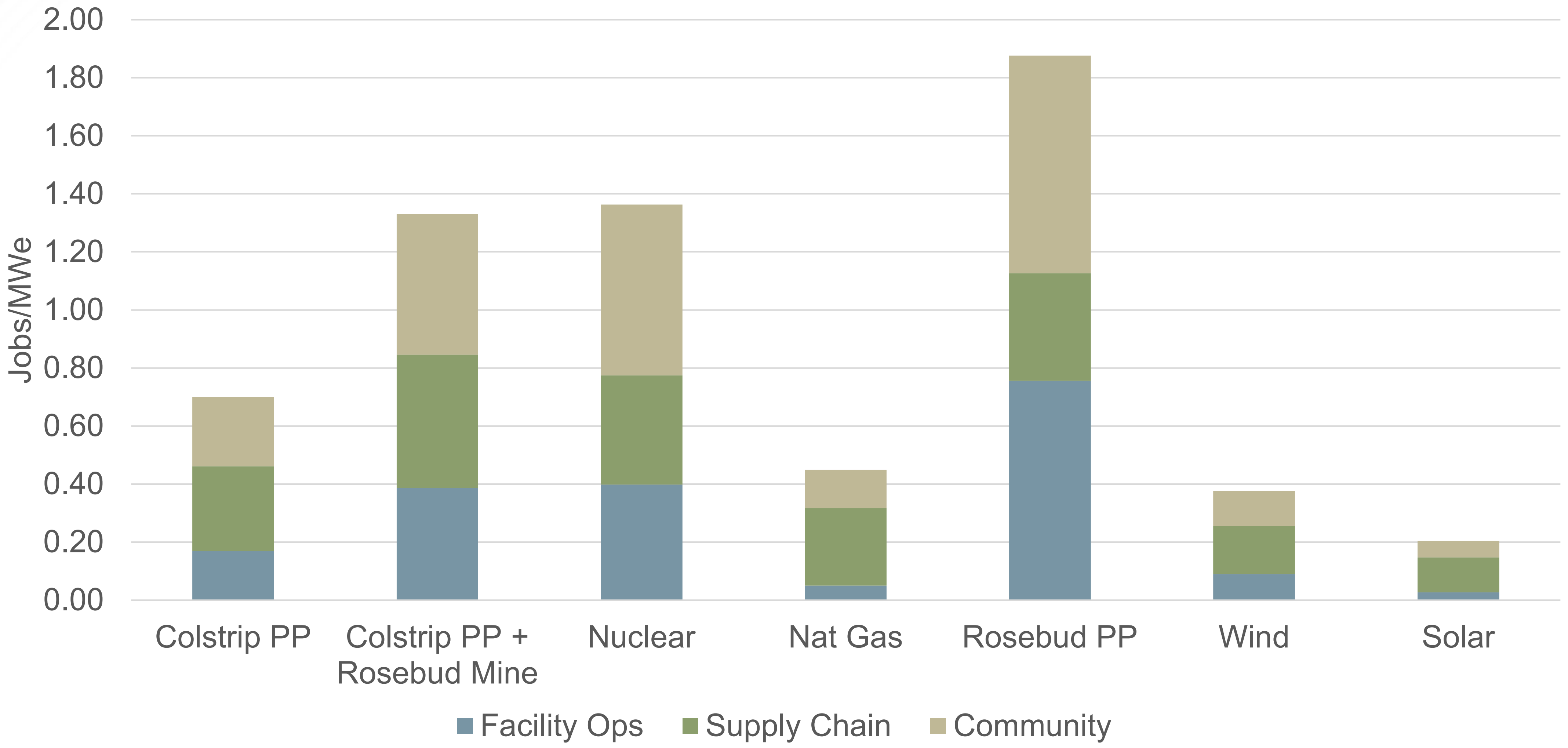
Scope: Evaluate potential regional, economic impacts associated with technologies of interest. Compare results to existing economic impact of coal mining and coal power plant operations in Colstrip.

Identify facility, supply chain, and community impacts

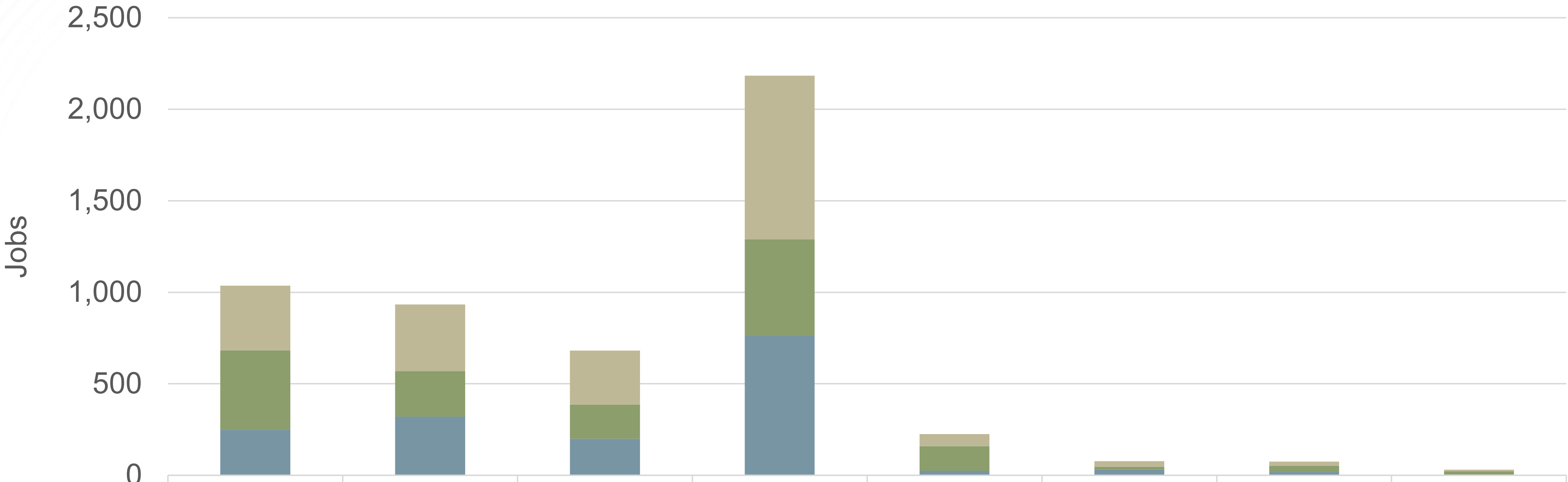
- Total number of jobs and labor income
- Total output (dollar value of industry production)
- Value added (dollar value of production less the cost of imports and intermediate goods)

For nuclear, estimate number of jobs required to support construction.

Employment Impact per MWe Installed Capacity



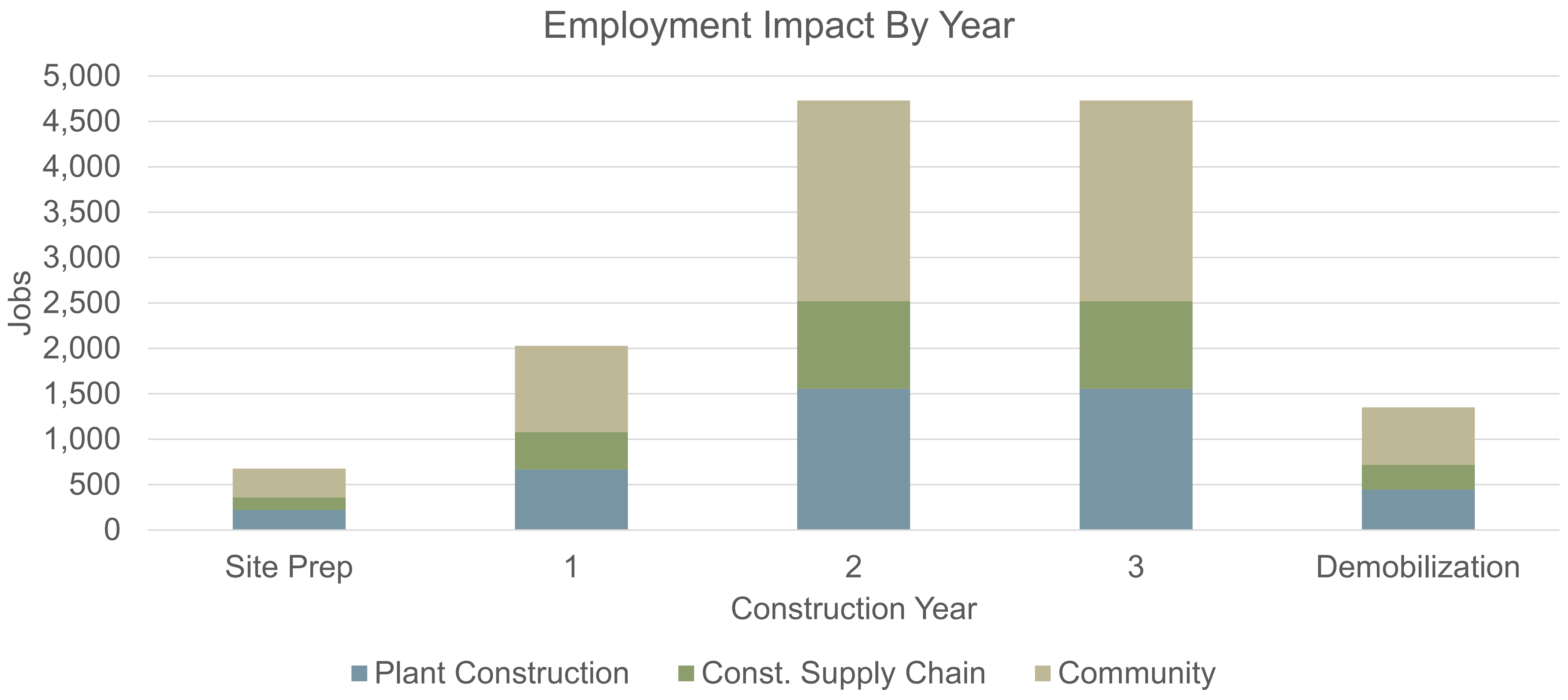
Employment Impact Comparison



	Colstrip Power Plant (1480 MWe)	Rosebud Mine	Nuclear (500 MWe)	Nuclear (1400 MWe)	Natural Gas (500 MWe)	Rosebud Power Plant (41 MWe)	Wind (200 MWe)	Solar (150 MWe)
Community	353	364	294	894	66	31	24	8
Supply Chain	433	248	188	527	134	15	33	18
Facility Ops	250	321	199	762	25	31	18	4

Facility Ops   Supply Chain   Community

Nuclear Construction Employment Impact by Year
500 MWe Installed Capacity



Relevant News in Surrounding States and Intermountain West

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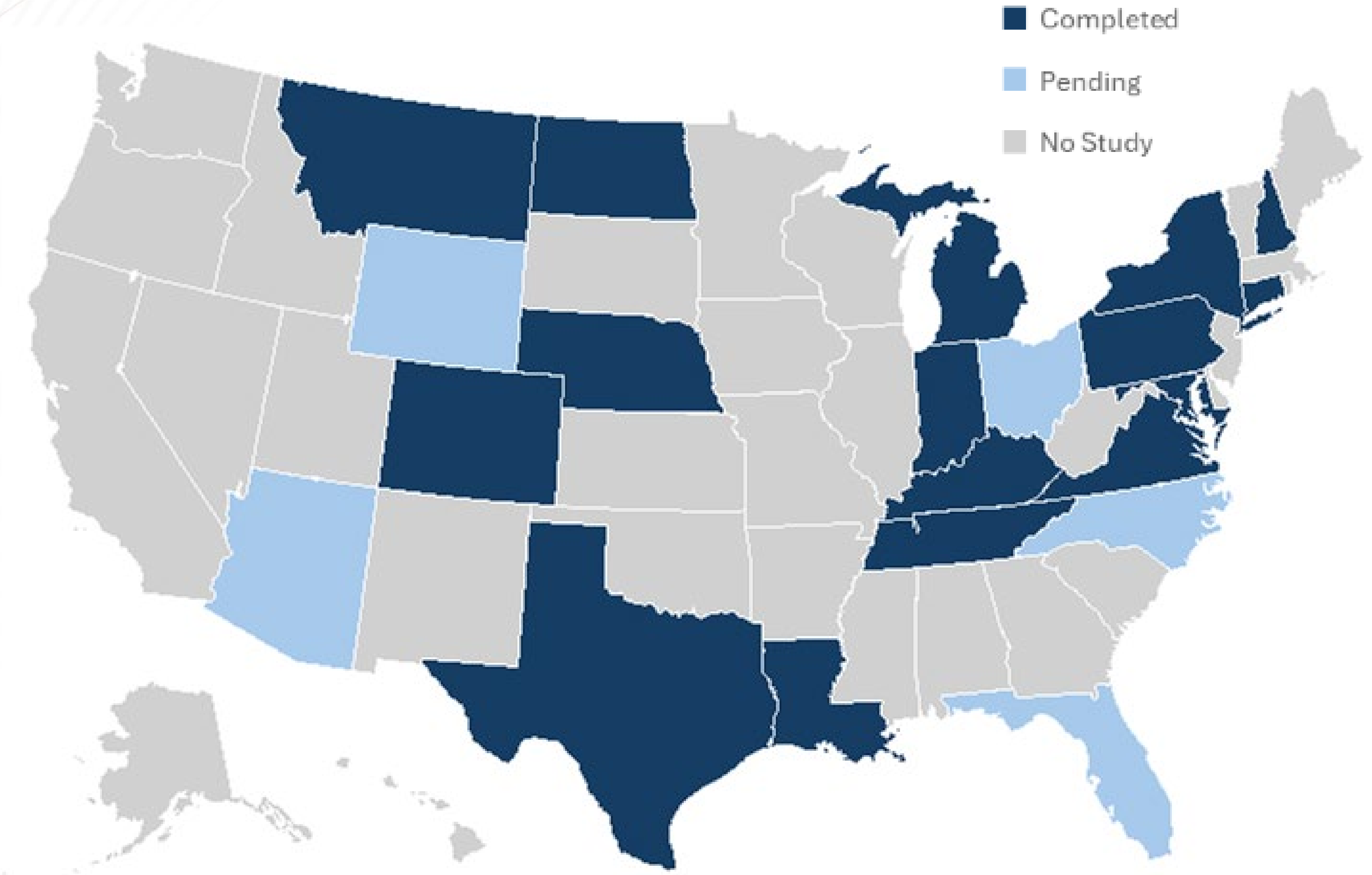
State-led nuclear feasibility studies and working groups



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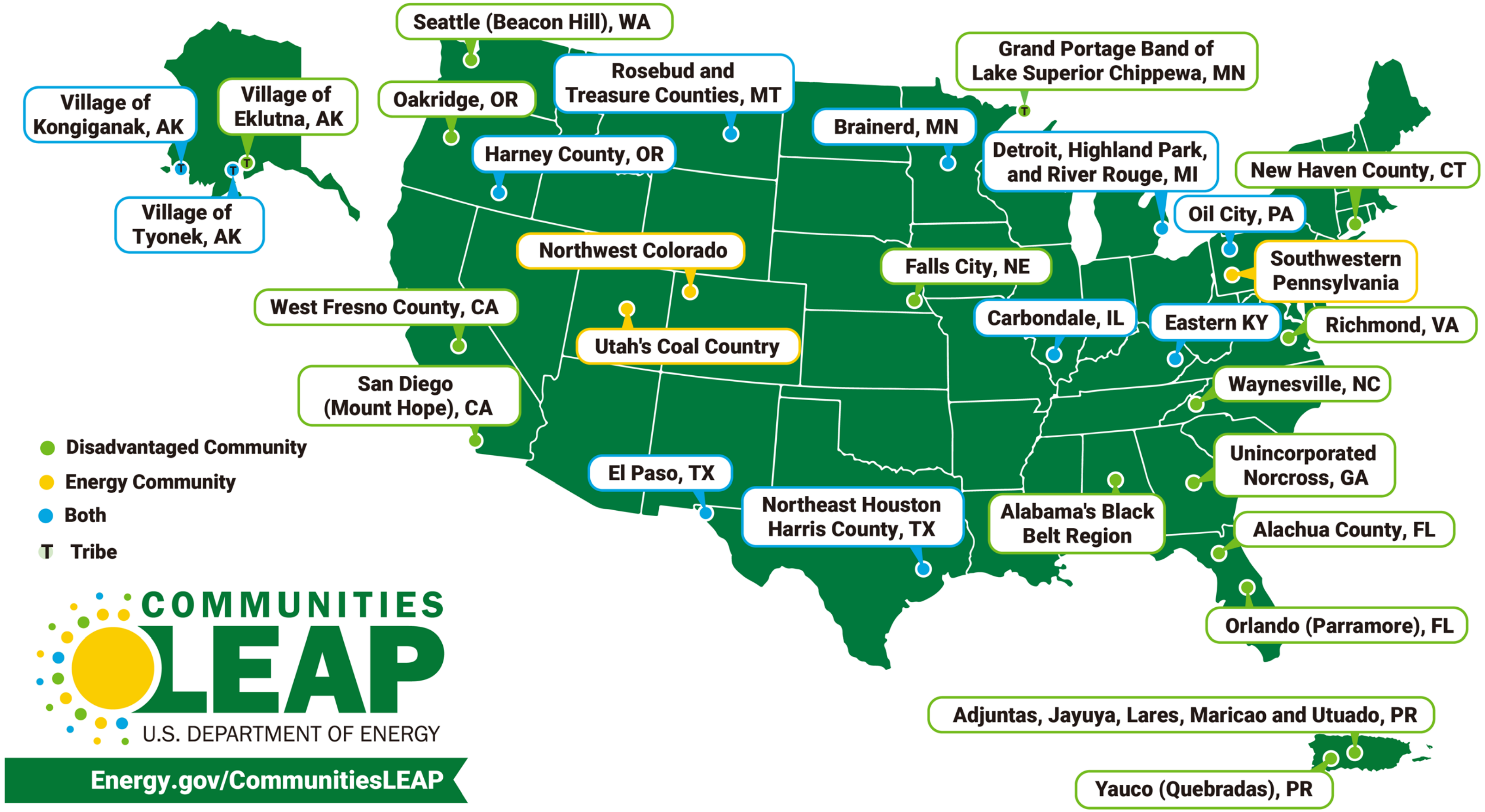
state-led nuclear feasibility studies covering a range of topics including policy, technical, and economic analyses

- ***18*** complete
- ***3*** pending completion by summer 2025
- ***4*** committed studies without set due date
- Active working groups in KY, OH, and TN

DOE Communities Local Energy Action Program (C-LEAP)

- C-LEAP drives community-wide economic benefits through DOE
- C-LEAP Cohort 2 communities exploring nuclear:
  - Eastern Kentucky
  - Northwest Colorado
  - Rosebud and Treasure Counties, Montana
  - Southwestern Pennsylvania
  - Utah’s Coal Country



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National Association of State Energy Officials (NASEO) Advanced Nuclear First Mover Initiative

- Leadership group of states committed to accelerating advanced nuclear projects and bringing more power to the electric grid for reliability, sustainability, and economic growth
  - Co-Chairs: New York, Indiana, Kentucky, Tennessee, and Wyoming
  - Participating States: Louisiana, Maryland, Pennsylvania, Utah, Virgina and West Virgina

NASEO
National Association of State Energy Officials

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Arizona Electric Utilities Team Up to Explore Adding Nuclear Generation

- Arizona Public Service (APS), Salt River Project (SRP) and Tucson Electric Power (TEP) are working together to explore adding nuclear generation in Arizona
  - Recently applied for DOE grant to begin preliminary assessments
- Salt River Project previously partnered with GAIN to assess feasibility of deploying nuclear at Coronado Generating Station in Saint Johns, Arizona

TEP

SRP®

aps®

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State News, Cont'd.

- Washington: Amazon and Energy Northwest in collaboration to develop advanced nuclear
- California and Oregon: Considering lifting restrictions on construction of new nuclear power plants
- Colorado: Recently approved bill to classify nuclear power as 'clean' energy
- Utah: Operation Gigawatt focused on making Utah a nuclear innovation hub via public/private partnerships

Contact Information

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Back-Up

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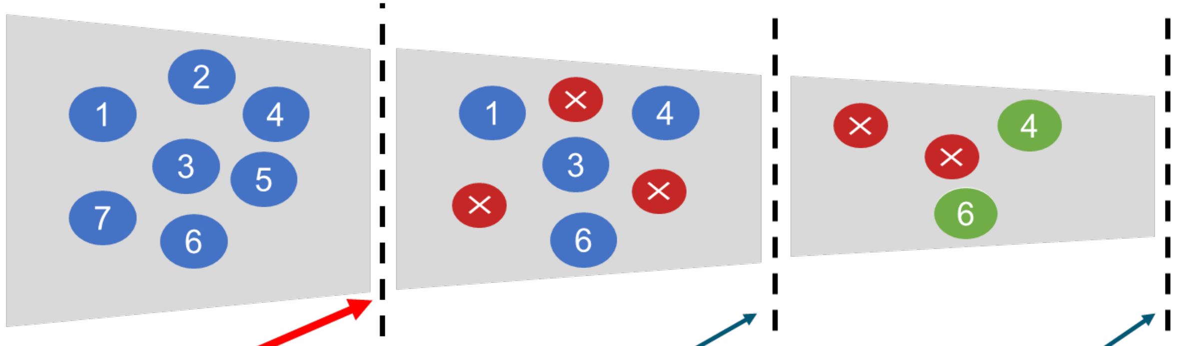
Background: Overview of the Nuclear Siting Process

- Formal siting process for a nuclear reactor is a multi-year process requiring a great level of time, effort, and detail
- Siting criteria identified in industry guidance can be grouped into three distinct stages
- NWE is currently in the Exclusionary/Avoidance Factor Phase



Exclusionary/Avoidance Factor Screen:
- Identify locations with factors that could preclude nuclear or increase cost/risk.

Current Phase

Decision Planning Phase:
- Perform detailed investigations to quantify siting risks that could delay licensing and/or construction.

Future Phase

Licensing Phase:
- An applicant has selected a site and a deployment schedule, and is applying for either an early site permit or a construction permit from the NRC.

Future Phase

GAIN's siting assessment identifies sites that pass the Exclusionary/Avoidance Factor Screen and siting characteristics that should be further evaluated in Decision Planning (should NWE decide to pursue next steps).

Background: Level of Effort Associated with Siting

	Exclusionary/Avoidance Factors	Decision Planning	Licensing
Timeline	Weeks to Months	Months to Years	Years
Level of Effort ($)	Thousands ($)	Millions ($)	Tens of Millions ($)
Primary Objective	Identify locations of interest and screen for factors that could preclude nuclear or increase cost/risk	Down select site(s) based on rough order of magnitude site development costs and alignment with business objectives	Collect site-specific data and complete analysis to support license application
Activities	Review publicly available data and preform desktop studies	Publicly engage stakeholders, conduct detailed investigations to quantify siting risks, perform site walkdowns, etc.	Engage with the Nuclear Regulatory Commission (NRC), prepare license application, collect site-specific data, complete engineering studies, etc.
Examples	Review public geologic data	Identify specific site layout given seismic risks	Collect site core bore samples for laboratory analysis

SIMPLIFIED ⟵⟶ COMPLEX

Note – Table is based on current NRC regulations and licensing framework; however, recent federal legislation requires the NRC to reevaluate level of effort and detail required.

The level of detail, investment (time and resources), and complexity increases significantly as you progress through the nuclear siting process.

GAIN's Approach: Two-Step Siting Assessment

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MPR

1 Step 1: Exclusionary/Avoidance Factor Screen (Based on EPRI's Siting Guide)

- Objectively screen locations of interest (LOIs)
  - Factors that could preclude nuclear (i.e., exclusionary factors)
  - Factors that could increase cost/risk (i.e., avoidance factors)
- Criteria include provided on following slide

2 Step 2: NRC's Advanced Nuclear Reactor Generic Environmental Impact Statement Screen (Based on the NRC's ANR GEIS)

- Objectively screen locations of interest (LOIs) without exclusionary or avoidance factors
  - Environmental criteria expected to minimize licensing risk
- Identified siting characteristics that should be further evaluated in Decision Planning

GAIN followed a two-step approach, leveraging best-in-class industry siting guidance, to 1) identify LOIs with exclusionary and avoidance factors, and 2) inform Decision Planning.

GAIN's Approach: Exclusionary and Avoidance Factors

GAIN evaluated the following exclusionary/avoidance factors as part of site screening (per guidance in EPRI's Siting Guide):

- Geology Seismology
- Cooling Water Supply
- Ambient Air Requirements
- Flooding
- Nearby Hazardous Land Use
- Extreme Weather Conditions
- Population
- Emergency Planning
- Atmospheric Dispersion
- Radionuclide Pathways
- Transportation Safety
- Effects on Surrounding Ecology
- Socio-economic Considerations
- Engineering and Cost-related Considerations

By evaluating exclusionary/avoidance factors early in the siting process, stakeholders can have more confidence investing resources in a particular site.

Revenue Estimating Methodology

- Economic model requires estimating revenue from the plant without accounting for additional value from transmission and delivery services by the utility company.
- Coal Price: $39.32/st (EIA)
- Wholesale Electricity Price: $48.65/MWh (EIA)
- Electricity production based on actual data or based on industry averages (capacity factory X installed capacity)
- Power Plant Revenue
  - $Wholesale\ Electricity\ Price\ per\ MWh \times Annual\ Electricity\ Production\ (MWh) = Plant\ Revenue$
- Coal Mine Revenue
  - $Coal\ Fuel\ Price \times Mine\ Production\ (short\ tons) = Mine\ Revenue$
  - Coal fuel price specific to electric power sector

Assumptions Behind the Model

- Facility sizes for proposed energy options are based on market trends
- Existing facility data was used for Rosebud Mine, Rosebud Power Plant, and Colstrip Generating Plant
- Data Sources
  - U.S. Energy Information Administration (EIA)
  - National Renewable Energy Laboratory – Annual Technology Baseline
  - IMPLAN (economic impact modeling application)
  - NorthWestern Energy
  - SEMDC
  - Reactor developers: TerraPower, X-energy, NuScale
- Batteries not included…
  - US average capacity factor (4-hour): 16%
  - Would require site specific study to estimate additional revenue from battery storage
  - Minimal economic impact once installed besides added revenue
- Generating facility revenue is based on wholesale price of electricity and annual MWh

Model Inputs

Annual Operations Model Inputs							
Facility Type	Installed Capacity (MWe) or Mine Production (st)	Capacity Factor Estimates	Annual MWh	Avg. Annual Employment	Total Ops. Labor Income w/Benefits and Taxes ($Millions)	Average Annual Pay w/Benefits & Taxes	Electricity or Coal Sales ($Millions)
Colstrip Power Plant	1,480	64%	8,362,209	250	$49.7	$198,842	$381.7
Rosebud Coal Mine	7,000,000	NA	NA	321	$53.0	$165,026	$275.2
Nuclear	500	93%	4,073,400	199	$45.5	$228,665	$186.0
Nat Gas	500	59%	2,584,200	25	$5.0	$198,842	$118.0
Rosebud Power Plant	41	82%	293,434	31	$6.2	$198,842	$13.4
Wind	200	34%	595,680	18	$3.2	$176,955	$27.2
Solar	150	23%	306,162	4	$0.6	$166,175	$14.0

Nuclear Construction Assumptions

- 500 MWe Installed Capacity
- 3 years + Site prep and demobilization
- Total Cost $4.8 billion (NREL-ATB)
  - $1.7 billion local
- Peak construction employment: ~1,600 workers
  - Based on TerraPower estimates

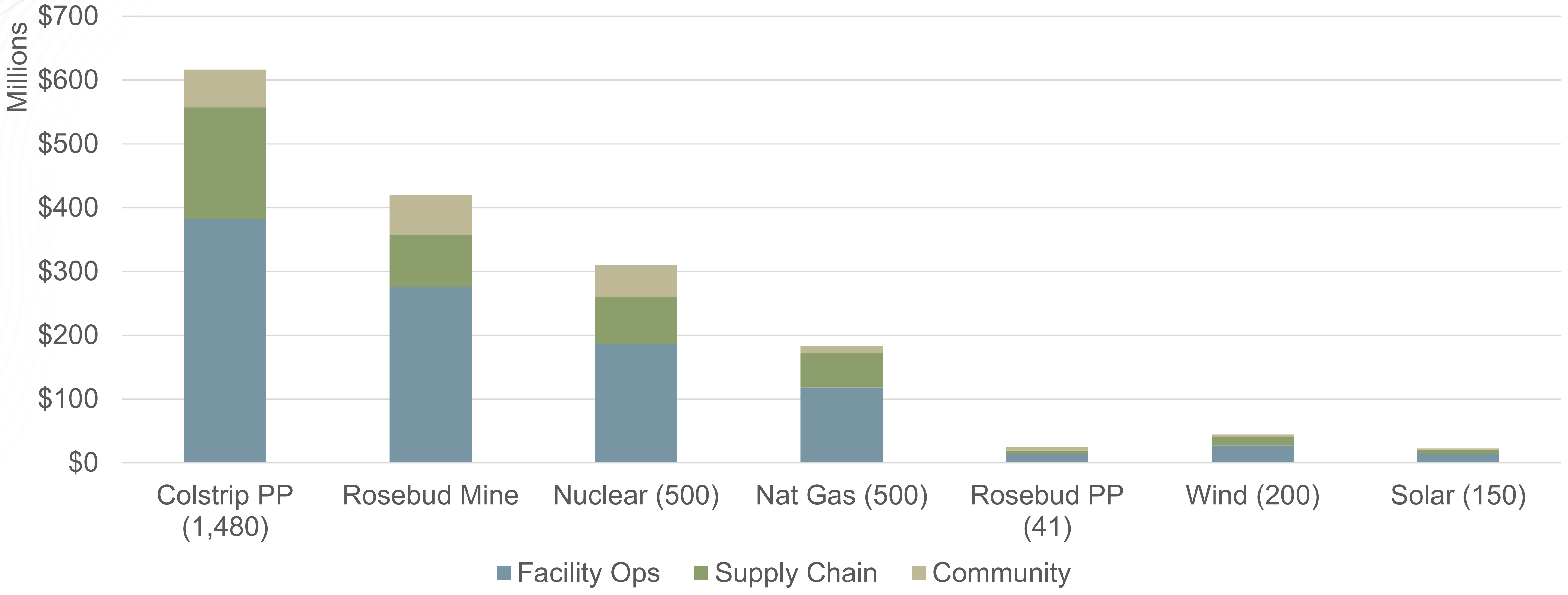
Nuclear Construction Cost Assumptions ($Billions)		
Local Labor	Total Local Spend	Total Cost
$1.148	$1.731	$4.825

Construction Activity Labor Distribution	
Activity	Distribution
Site Prep	5%
Year - 1	15%
Year - 2	35%
Year - 3	35%
Demobilization	10%

Purpose of Economic Impact Studies

- Community Planning
  - Help communities understand how energy transitions impact local economies
  - Insight about potential energy transition related population changes
  - Targeted economic development
- Local Business
  - Understand how supply chains could be impacted
  - Compare household spending effects on local businesses
- Workforce
  - Estimate changes in employment by industry
  - Identify workforce transition opportunities
- Education
  - Forecast education and training needs

Output Impact: Total Dollar Value of Production



Additional Economic Impacts

- Tax impact
  - Will be included in final report
- Occupation specific workforce projections
  - Link to Salt River Project report example
- Occupation specific education requirements by generating technology
- Labor Income Impacts
- Value-Added Impacts (contributions to local gross domestic product)