NP

VOLUME 4

SUPPLY-SIDE RESOURCE ANALYSIS

THE EMPIRE DISTRICT ELECTRIC COMPANY D/B/A LIBERTY ("LIBERTY-EMPIRE")

20 CSR 4240-22.040

FILE NO. EO-2021-0331

April 2022

20 CSR 4240-2.135(2)(A)5-7

****Denotes Confidential****

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

TABLE OF RULE REQUIREMENTS

20 CSR 4240-22.040 SUPPLY-SIDE RESOURCE ANALYSIS

SUPPLY-SIDE RESOURCE ANALYSIS

Commission Rule 20 CSR 4240-22.040, Supply-Side Resource Analysis, provides in part as follows:

PURPOSE: This rule establishes minimum standards for the scope and level of detail required in supply-side resource analysis.

SECTION 1 EXISTING SUPPLY-SIDE RESOURCES

(1) The utility shall evaluate all existing supply-side resources and identify a variety of potential supply-side resource options which the utility can reasonably expect to use, develop, implement, or acquire, and, for purposes of integrated resource planning, all such supply-side resources shall be considered as potential supply-side resource options. These potential supply-side resource options include full or partial ownership of new plants using existing generation technologies; full or partial ownership of new plants using new generation technologies, including technologies expected to become commercially available within the twenty (20)-year planning horizon; renewable energy resources on the utility-side of the meter, including a wide variety of renewable generation technologies; technologies for distributed generation; life extension and refurbishment at existing generating plants; enhancement of the emission controls at existing or new generating plants; purchased power from bi-lateral transactions and from organized capacity and energy markets; generating plant efficiency improvements which reduce the utility's own use of energy; and upgrading of the transmission and distribution systems to reduce power and energy losses. The utility shall collect generic cost and performance information sufficient to fairly analyze and compare each of these potential supply-side resource options, including at least those attributes needed to assess capital cost, fixed and variable operation and maintenance costs, probable environmental costs, and operating characteristics.

This section describes the existing supply-side generation resources included in the Empire District Electric Company d/b/a Liberty ("Liberty-Empire" or "the Company") system to meet Liberty-Empire's current customer energy and capacity needs. Section 1.1 provides a high-level overview of Liberty-Empire's existing generation resource fleet. Section 1.2 describes the history, operating characteristics, and emissions controls (if relevant) of each of the existing resources in more detail. Sections 1.3 and 1.4 provide an overview of planned or completed operating improvements and upgrades to existing plants. Finally, Section 1.5 provides an update on the status of decommissioning the Asbury coal plant.

Pursuant to 20 CSR 4240-22.040(1), Liberty-Empire also identified a variety of potential supply-side resource options that could reasonably be used to meet future customer energy and capacity obligations. Following the discussion of Liberty-Empire's existing generation resource fleet in Section 1, the identification and analysis of these potential supply-side resource options is discussed in more detail in Section 2.

1.1 Overview of Existing and Committed Supply-Side Resources

Liberty-Empire's fleet of existing and committed supply-side resources includes both fully or jointly owned resources and resources for which Liberty-Empire has power purchase agreements ("PPA"). The existing owned resource fleet consists of a variety of fuel and ownership types, including partial ownership shares in two coal-fired plants, several wholly owned natural gas-fired combustion turbines ("CT"), a wholly owned natural gas-fired combined cycle ("CC") unit, a partial ownership share in a natural gas-fired combined cycle unit, a hydroelectric facility, and three wind facilities. Additionally, Liberty-Empire meets its customer needs with long-term PPAs for coal and wind units. Table 4-1 provides a summary of the existing generating facilities owned or contracted by Liberty-Empire. The unit ratings represent summer operating capacity ratings at the time of the 2022 IRP analysis and reflect Liberty-Empire's ownership share of jointly owned units. Units are rerated from time to time as routine capability tests are performed.

Table 4-1 – Liberty-Empire Existing Supply-Side Resources – Owned and Contracted

Owned Resources	Fuel Type	State	% Owned	Summer Operating Capacity (MW)	Winter Operating Capacity (MW)
Iatan 1	Coal	MO	12%	84	84
Iatan 2	Coal	MO	12%	108	108
Plum Point (Owned)	Coal	AR	7.52%	50	50
Riverton 10 CT	Natural Gas/Oil	KS	100%	13	15
Riverton 11 CT	Natural Gas/Oil	KS	100%	15	15
Riverton 12 CC	Natural Gas	KS	100%	254	283
Empire Energy Center 1 CT	Natural Gas/ Oil	MO	100%	81	95
Empire Energy Center 2 CT	Natural Gas/ Oil	MO	100%	80	80
Empire Energy Center 3 CT	Natural Gas/ Oil	MO	100%	40	55

Empire Energy Center 4 CT	Natural Gas/ Oil	MO	100%	43	58
State Line CT	Natural Gas/ Oil	MO	100%	93	113
State Line CC	Natural Gas	MO	60%	300	329
Ozark Beach	Hydro	MO	100%	16	16
North Fork Ridge	Wind	MO	100%	149	149
Kings Point	Wind	MO	100%	149	149
Neosho Ridge	Wind	KS	100%	301	301
Total Owned Capacity:				**1,776**	**1,900**
Long Term PPAs	**Fuel Type**	**State**		**Summer Operating Capacity (MW)**	**Winter Operating Capacity (MW)**
Plum Point	Coal	AR		50	50
Elk River Wind Farm	Wind	KS		150	150
Meridian Way Wind Farm	Wind	KS		105	105
Total Contracted Capacity:				**305**	**305**
Capacity Sales	**Fuel Type**	**State**		**Summer Operating Capacity (MW)**	**Winter Operating Capacity (MW)**
MJMEUC Capacity Sale	Capacity	n/a		-78	-78
Total Capacity Sales:				**78**	**78**

As of the beginning of the 2022 IRP analysis period, 17% of Liberty-Empire's total existing owned and contracted summer operating capacity is from coal-fired units, 32% is from natural gas-fired units, and 51% is from hydro and wind units.

A summary of Liberty-Empire's historical generation by fuel type for 2021 is shown in Figure 4-1 and summarized in Table 4-2. In 2021, 31 percent of Liberty-Empire's generation was supplied by coal, 58 percent by natural gas, and 11 percent by carbon-free sources, including wind and hydro.[1]

[1] Note that as of March 1, 2014, the Southwest Power Pool ("SPP") Integrated Marketplace allows Liberty-Empire to buy generation from and sell generation to participants throughout the SPP region on an hourly basis.

NP

Figure 4-1 - Liberty-Empire Generation by Fuel Type for 2021

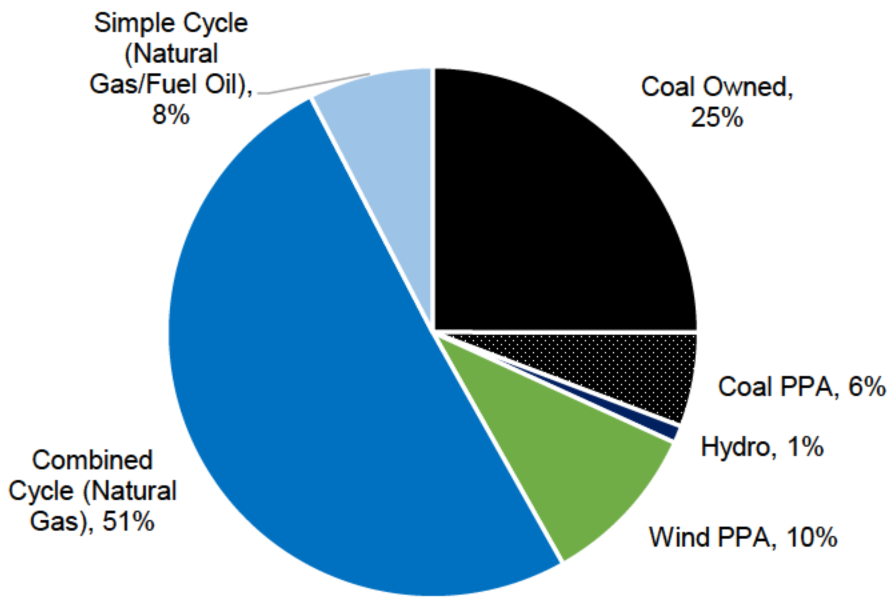


Table 4-2 – Liberty-Empire Generation by Fuel Type for 2021

Type	Generation in 2021 (MWh)	Percent of Liberty-Empire's total generation 2021
Coal Owned	1,196,501	25%
Coal PPA	274,986	6%
Total Coal	1,475,942	31%
Hydro	50,473	1%
Wind PPA	479,459	10%
Total Carbon-Free	529,932	11%
Combined Cycle (Natural Gas)	2,417,626	51%
Simple Cycle (Natural Gas/Fuel Oil)	363,966	8%
Total Natural Gas	2,781,592	58%
Total System MWh (Net System Output)	**4,783,011**	**100%**

1.1.1 Baseline Retirement and PPA Expiration Dates

Table 4-3 summarizes the "baseline" retirement and PPA expiration dates for the existing supply-side resources in Liberty-Empire's portfolio that were included in the 2022 IRP analysis. For resources that are wholly or majority-owned and operated by Liberty-Empire, the retirement date represents the resource's age-based end of life. For resources for which Liberty-Empire is a minority owner, the retirement date represents the planned retirement date indicated by the joint and majority owners. PPA expiration dates represent the assumed date of contract expiration with no assumed extensions for IRP purposes.

Table 4-3 – Base Retirement and PPA Expiration Dates

Owned Unit Name	Commercial Online Year	Age of Facility As of 2022 (Years)	Baseline IRP Retirement Year
Iatan 1	1980	42	2039
Iatan 2	2010	12	n/a
Plum Point (Owned)	2010	12	n/a
Riverton 10 CT	1988[1]	54[1]	2025
Riverton 11 CT	1988[1]	54[1]	2025
Riverton 12 CC	2007 & 2016[2]	15 & 6	n/a
Empire Energy Center 1 CT	1978	44	2026 or 2035[4]
Empire Energy Center 2 CT	1981	41	2026 or 2035[4]
Empire Energy Center 3 CT	2003	19	n/a
Empire Energy Center 4 CT	2003	19	n/a
State Line CT	1995	27	n/a
State Line CC	1997 & 2001[3]	25 & 21	n/a
Ozark Beach	1931	91	n/a
North Fork Ridge	2020	2	n/a
Kings Point	2021	1	n/a
Neosho Ridge	2021	1	n/a
Long Term Power Purchases and Sales	**PPA Start Year**	**PPA Term (Years)**	**Expected PPA Expiration Year**
Plum Point	2010	30	2040
Elk River Wind Farm	2005	20	2025
Meridian Way Wind Farm	2008	20	2028
MJMEUC Capacity Sale	2020	5	2025

Notes:

1. Riverton 10 and 11 were installed at Liberty-Empire in 1988, but the equipment was manufactured in 1967.

2.	Combustion turbine Riverton 12 was installed in 2007. The steam cycle addition (combined cycle conversion) was completed in 2016.
3.	One of the gas turbines at State Line CC was installed in 1997. The other gas turbine and the steam turbine were installed in 2001.
4.	Based on the age of the units, Liberty-Empire plans to retire Energy Center Units 1 and 2 by 2035. The ultimate decision for the planned year of retirement was supported through economic analysis in the 2022 IRP (see Volume 6 for details).

1.1.2 Long-Term Net Zero Target Considerations

In 2021, Algonquin Power & Utilities Corp. established a goal of net-zero by 2050 for scope 1 and scope 2 emissions across its business operations. [2] As shown in Figure 4-1, a significant portion of Liberty-Empire's generation comes from its two existing natural gas CC units, Riverton 12 and the State Line CC. In addition to "baseline" retirement assumptions which assume that both CCs operate beyond 2050, Liberty-Empire also evaluated earlier retirement years for these units in this 2022 IRP to assess the economic feasibility and cost impact of achieving long-term net zero carbon emissions by 2035 or by 2050.[3] Environmental sustainability (carbon reduction) is a key consideration in the Company's scorecard approach described in other IRP volumes. Although 2050 is beyond the planning horizon of this twenty-year IRP, a pathway to the corporate net-zero target along with other factors are discussed in IRP Volumes 6 and 7. For example, additional discussion on the development of Liberty-Empire's net zero alternative plans and the impact of the earlier CC retirements or retrofits can be found in Volume 6.

[2] Scope 1 emissions refer to direct greenhouse gas emissions from sources that are controlled or owned by Liberty-Empire. Scope 2 emissions refer to indirect greenhouse gas emissions associated with the purchase of electricity. Scope 3 emissions are the result of activities from assets not owned or controlled by the reporting organization. For Liberty-Empire, all emissions except those associated with the owned portion of Plum Point and Iatan 1 and 2 are scope 1 and 2 emissions and are counted against Liberty-Empire's net zero goals. Scope 3 emissions are subject to environmental costs but do not count against Liberty-Empire's emissions accounting.

[3] To achieve net zero carbon emissions by *2050*, Liberty-Empire would likely need to retire Riverton 12 in 2045 and State Line CC in 2050 and replace them with carbon-free resources. To achieve net zero carbon emissions by *2035*, Liberty-Empire would likely plan to either retire both Riverton 12 and State Line CC in 2035 or retrofit these CCs to be able to run entirely on a clean fuel like green hydrogen. While it is currently uncertain whether the existing CCs could feasibly operate on 100% hydrogen, Liberty-Empire assumed the technical capability would arise in the long term solely for IRP analysis and testing purposes. The costs associated with performing this hydrogen retrofit on the existing CCs in 2035 are documented in Sections 2 and 4.

1.2 Description of Power Plants Owned or Contracted by Liberty-Empire

This section describes the history and key operating characteristics of each of the existing resources in Liberty-Empire's generation portfolio in more detail.

1.2.1 Iatan Generation Station

Liberty-Empire owns a 12 percent undivided minority interest in the approximately 700 MW, coal-fired Iatan Generation Station located near Weston, Missouri as well as a 3 percent interest in the site and a 12 percent interest in certain common facilities. Liberty-Empire is entitled to 12 percent of the unit's available capacity and is obligated to pay for that percentage of the operating costs of the unit. Iatan Generation Station consists of two units, Iatan Unit 1 ("Iatan 1") and Iatan Unit 2 ("Iatan 2"). For the purposes of this IRP, Liberty-Empire's ownership share of Iatan 1's capacity is assumed to be 84 MW.

Iatan 1 is equipped with a Selective Catalytic Reduction ("SCR") system for the removal of NO_X, a wet scrubber for the removal of SO_2, a fabric filter baghouse for the removal of particulate matter ("PM"), and a powder activated carbon system for the removal of mercury. These additions, undertaken to comply with Environmental Protection Agency ("EPA") regulations and to meet the requirements for an air permit for Iatan 1, were completed in 2009. Evergy Metro, the majority owner of the plant, has indicated that the unit is expected to retire in 2039.

Liberty-Empire also owns a 12 percent undivided interest in the Iatan 2 unit, which for the purposes of this IRP is assumed to be 108 MW. The air quality control systems ("AQCS") (SCR, scrubber, fabric filter) constructed with the relatively new Iatan 2 unit comply with recent and anticipated air quality regulations.

1.2.2 Plum Point (Owned and PPA)

The Plum Point Energy Station ("Plum Point") is a nominal 670 MW, sub-critical, coal-fired generating facility near Osceola, Arkansas. Liberty-Empire owns 7.52 percent (approximately 50 MW) of the project. In addition, Liberty-Empire has a 30-year PPA for an additional 50 MW of capacity that began on September 1, 2010 and expires on August 31, 2040. Plum Point is equipped with an SCR for NO_X removal, a dry scrubber for SO_2 control, combustion controls for volatile organic compounds ("VOC") mitigation, and a fabric filter baghouse for the removal of PM.

[redacted]

1.2.3 Riverton 10, 11, and CC

Liberty-Empire's Riverton Generating Plant is located in Riverton, Kansas and consists of two natural gas-fired CT units ("Riverton 10 and 11") and a natural gas-fired CC unit ("Riverton 12" or "Riverton CC").

Riverton 10 and 11 are powered by natural gas as a primary fuel but can use fuel oil as a backup fuel. **[redacted]

[redacted]**

However, Riverton 10 and 11 rely on equipment that was manufactured in 1967, which is much earlier than the date they were installed at Liberty-Empire (1988). Given the age of the equipment, Liberty-Empire expects to retire both Riverton 10 and 11 in 2025.[5] The units will be directly replaced at the site by a dual-fuel **[redacted]**capable resource in compliance with NERC reliability standards, taking advantage of Riverton 10 and 11's existing interconnection rights at the site.

Riverton 12 is a natural gas-fired Siemens V84.3A2 CT with a Siemens steam turbine/generator with a summer rating of 254 MW. The combustion turbine was initially installed at the Riverton site in 2007. In 2016, the CT was converted into a CC with the addition of the steam turbine, heat recovery steam generator ("HRSG"), cooling tower, and balance of plant equipment.

1.2.4 State Line 1 and CC

Liberty-Empire's State Line Power Plant is located west of Joplin, Missouri and consists of State Line 1 ("State Line 1"), a CT with summer generating capacity of 93 MW, and a CC ("State Line CC" or "SLCC") with a summer generating capacity of approximately 500 MW. All units at the State Line Power Plant burn natural gas as a primary fuel, with State Line Unit 1 able to burn fuel oil as a backup. Burning fuel oil requires water injection for emissions control. State Line 1 and SLCC have dry low NOx burners and an SCR on each HRSG.

State Line CC is a Siemens natural gas-fired CC unit consisting of two combustion turbines (CTs 2-1 and 2-2) with a HRSG on the back of each CT. Steam from the HRSGs is fed into a single steam turbine (ST 2-3). The original CT for SLCC was installed in 1997 as a simple cycle unit. The

---

[4] **[redacted]**

[5] In the 2019 IRP, Liberty-Empire assumed an age-based retirement date of 2033 for both Riverton 10 and 11. However, the 2033 retirement date assumption from the 2019 IRP was based on the date that Riverton 10 and 11 were installed at the Liberty-Empire system (1988). The primary equipment used at Riverton 10 and 11 is actually of 1960s vintage.

combined cycle additions (the additional CT, ST, and HRSGs) were built in 2001 in partnership with Evergy of Topeka, Kansas, with Liberty-Empire owning a 60 percent share of the total SLCC (approximately 300 MW) and serving as the operator. The CC can operate in two modes:

1. 1 x 1 mode (one CT and the steam turbine) with capacity of 150 MW (Liberty-Empire's share)
2. 2 x 1 mode (two CTs and the steam turbine) with total summer capacity of about 300 MW (Liberty-Empire's share)

SLCC completed combustion turbine upgrade projects in 2021. Additional information on the SLCC upgrades can be found in Section 1.4 ("Existing Plant Upgrades").

1.2.5 Energy Center

Liberty-Empire has four CT peaking units at the Empire Energy Center facility in Jasper County, Missouri near the town of Sarcoxie with an aggregate summer operating capacity of approximately 240 MW. Empire Energy Center Units 1 and 2 ("Energy Center 1 and 2" or "EC 1 and 2") are simple cycle frame CTs and were installed in 1978 and 1981, respectively. Empire Energy Center Units 3 and 4 ("Energy Center 3 and 4" or "EC 3 and 4") are aeroderivative CTs installed in 2003. These peaking units operate primarily on natural gas with the capability to burn fuel oil. All units undergo routine maintenance with inspections on a regular cycle and equipment is refurbished as needed. All of the CTs use water injection to control NO_X.

Based on the age of the units, Liberty-Empire plans to retire Energy Center Units 1 and 2 by 2035. The decision for the planned year of retirement was supported through economic analysis in the 2022 IRP (see Volume 6 for details). In addition, the low historical and expected capacity factors from Energy Center 1 and 2 support the possibility to co-locate renewable resources at the site and take advantage of Energy Center 1 and 2's existing interconnection rights at the site.

1.2.6 Ozark Beach

Ozark Beach, Liberty-Empire's hydroelectric generating plant, is located on the White River at Forsyth, Missouri and is comprised of four 4-MW units with a total generating capacity of 16 MW. These units have been updated periodically so that they can continue contributing to Liberty-Empire's renewable portfolio. Liberty-Empire began the renewal process for the FERC license in 2016. The relicensing process takes approximately five years to complete and does not expire for 30 years. The hydroelectric plant backs up the White River and created Lake Taneycomo, located in southwestern Missouri.

1.2.7 Wind Facilities

On June 19, 2019, the Missouri Public Service Commission voted unanimously to grant Liberty-Empire certificates of convenience and necessity ("CCNs") to build and acquire three wind farms: North Fork Ridge, Kings Point, and Neosho Ridge. These projects are expected to provide significant customer savings over the long term. The savings are primarily based on wind production costs and the ability for all projects to take advantage of federal Production Tax Credits. The three wind farms will also provide sustained community benefits to the regional economy and address tightening environmental regulations on existing thermal units, high costs to operate an aging generation fleet, and increasing customer demands for renewable energy.

1.2.7.1 North Fork Ridge and Kings Point

North Fork Ridge Wind Farm and Kings Point Wind Farm are each wind farms of about 150 MW consisting of 69 turbines (for a total of about 300 MW for both). North Fork Ridge Wind Farm is located in Barton and Jasper counties in Missouri and Kings Point Wind Farm is located in Dade, Jasper and Lawrence counties in Missouri.

Liberty-Empire partnered with Tenaska and Steelhead, Vestas' development arm in North America, to develop and construct both projects. In October 2019, Tenaska elected to terminate its participation in the projects, and Liberty, a holding company that is an indirect parent to Liberty-Empire, agreed to purchase Tenaska's interests in the project and continue the development and construction of the projects with Steelhead.

Construction activities for North Fork Ridge Wind Farm and Kings Point Wind Farm began in December 2019 and continued through the first quarter of 2021. Kings Point Wind Farm experienced construction delays due to issues with turbine component deliveries caused by measures taken in response to the COVID-19 public health emergency by governments in countries where components were manufactured.

North Fork Ridge Wind Farm ultimately began commercial operations in December 2020, and Kings Point Wind Farm began commercial operations in April 2021. Both projects are qualified for and receive the full value of the Production Tax Credits available to the project.

1.2.7.2 Neosho Ridge

Neosho Ridge Wind Farm is a 300 MW wind farm located in Neosho County, Kansas consisting of 139 turbines. Liberty-Empire partnered with Apex Clean Energy and Steelhead to develop and construct the Neosho Ridge Wind Farm.

Engineering and construction work at the Neosho Ridge Wind Farm began in fall 2019 and included modifying public roads, building access roads and turbine foundations, installing underground electrical connection lines, foundation work for substations and operations buildings, and building gen-tie lines. Like Kings Point, Neosho Ridge also experienced construction delays due to issues with turbine component deliveries caused by measures taken in response to the COVID-19 public health emergency by governments in countries where components were manufactured. The project began commercial operations in May 2021 and qualifies for the full value of the Production Tax Credits available to the project.

1.2.8 Wind PPAs

1.2.8.1 Elk River Wind PPA

On December 10, 2004, Liberty-Empire entered into a 20-year contract with PPM Energy to purchase all of the energy generated at the Elk River Wind Farm located in Butler County, Kansas. This wind farm began commercial operation on December 15, 2005. The facility consists of 100 1.5-MW turbines for a total generating capacity of 150 MW. Liberty-Empire has contracted to purchase all of the output of the project. This contract will expire in mid-December 2025. Liberty-Empire has the ability to extend the contract term for five years after the end of the 20-year contract period.

1.2.8.2 Meridian Way Wind PPA

In June 2007, Liberty-Empire signed a contract with Horizon Wind Energy to buy wind energy from the Cloud County Wind Farm, LLC, which receives energy from the 105-MW Meridian Way Wind Farm located in Cloud County, Kansas, near Concordia. The contract expires in December of 2028. The facility began commercial operation on December 23, 2008.

1.2.9 MJMEUC Capacity Sale

Liberty-Empire entered into a five-year power purchase agreement with the Missouri Joint Municipal Utility Commission (“MJMEUC”) for a capacity and energy sale beginning June 1, 2020 and ending May 31, 2025. The capacity sale is based on a “slice of Liberty-Empire system” approach, with a total capacity sale of 78 MW during the agreement period. The MJMEUC agreement also enables MJMEUC to receive payment from SPP for energy sold into the market from Liberty-Empire resources that are allocated to MJMEUC by this agreement. MJMEUC compensates Liberty-Empire for the capacity and for their allocated portion of the fuel costs, startup costs, an additional amount per unit of energy and some transmission costs as described by the agreement.

1.3 Generating Plant Efficiency Improvements to Reduce Energy Use

Liberty-Empire continually evaluates generating resource efficiency improvement opportunities through which Liberty-Empire can reduce its overall auxiliary load at existing power plants and reduce its own use of energy. Potential improvement projects for reducing auxiliary loads are dependent on the type of fuel and power plant. A few examples of projects that may reduce the utility’s own use of energy at existing power plants are as follows:

- On-line condenser cleaning systems;
- Duct leakage reduction;
- Insulation improvements.

The coal-fired power plants within Liberty-Empire’s power supply portfolio recently underwent plant upgrades or are relatively newer constructions. Newer coal plants, like Iatan 2 and Plum Point, are typically designed to reduce auxiliary load consumption in order to make the unit significantly more efficient. During recent upgrade projects, such as the environmental upgrades at Iatan 1, utilities typically take the opportunity to implement additional efficiency projects. Due to the age of the newly constructed units, the recent upgrades at Iatan 1, and the uncertain future of coal-fired generation in general, few plant efficiency projects remain at the coal facilities that have not already been implemented.

Liberty-Empire does not necessarily operate all of the units within its power supply portfolio and does not control the improvements implemented at those plants. For the plants that Liberty-Empire does operate, the Company evaluates potential improvement projects as part of its regular operations and maintenance program for the plants. A list of the plant improvement projects that Liberty-Empire has implemented over the years has been regularly provided to the Commission as part of the FAC filings.

Liberty-Empire will continue to explore cost-effective generating plant efficiency improvements which reduce the utility's own use of energy.

1.4 Existing Plant Upgrades

Liberty-Empire continually examines potential upgrades to existing plants. As described previously in this section, recently completed upgrades at Liberty-Empire's existing plants include:

1. The conversion of Riverton 12 (a CT) to a CC unit was completed in 2016. See Section 1.2.3 for more detail.
2. New pollution control systems were installed at the Iatan 1 unit. A scrubber, SCR, fabric filter, and powder activated carbon system were installed at Unit 1 in 2009. See Section 1.2.1 for more detail.
3. Turbines at State Line CC were upgraded in 2021. These projects consisted of both combustion turbines being upgraded to the FD3 level which will add about 70 additional MW (42 MW Liberty-Empire's share) to the existing winter capacity of the unit, and 36 MW (22 MW Liberty-Empire's share) to the summer capacity after completing the necessary SPP studies. In addition, efficiency increases are expected via heat rate

improvements. Liberty-Empire's normal, ongoing maintenance program at each of its plants addresses critical operational and mechanical issues to ensure the longevity of the units. See Section 1.2.4 for more detail.

Ozark Beach Upgrade Option

In addition to completed upgrades, Liberty-Empire included and evaluated a potential upgrade project that would add generation at the existing Ozark Beach hydroelectric facility. To the 16 MW generating capacity currently at the site, the upgrade would add approximately 14 MW of generating capacity at a low estimated capacity factor, adding about 20% more generation per year on average.[6] The upgrade would require approximately **[redacted]** in upfront capital and small increases in annual FOM and VOM. This upgrade was included and modeled in the 2022 IRP as a potential supply-side resource option.

1.5 Asbury Decommissioning Status

The Asbury Power Plant ("Asbury") was an approximately 200 MW mine-mouth coal-fired electric power plant located in Jasper County, Missouri, first operational in 1970. The unit was wholly owned and operated by the Company until being officially de-designated from SPP as of March 1, 2020. The electric generating unit is no longer in service.

The Asbury Power Plant campus includes facilities and buildings that were necessary to support the operations of the original plant. Some of these facilities are now repurposed to support the Asbury Renewable Operations Center ("AROC") used to maintain the new North Fork Ridge Wind Farm, Neosho Ridge Wind Farm, and Kings Point Wind Farm, as well as the Prosperity Solar Facility. The AROC could also potentially be used to support other renewable facilities in the future. The Asbury 161kV substation is also the point of interconnection for the North Fork Ridge Wind Farm, which provides 150 MW of wind energy to the SPP grid.

[6] Actual year to year generation would depend on weather and other conditions.

The Company is continuously looking for opportunities to further repurpose the site for new green technologies and generation and will provide updates as they become available. As SPP market products change, battery technology improves, and reliability requirements increase, the Company will continue exploring the development of a renewable energy campus that repurposes the Company's current assets at the AROC.

SECTION 2 ANALYSIS OF POTENTIAL SUPPLY-SIDE RESOURCE OPTIONS

(2) The utility shall describe and document its analysis of each potential supply-side resource option referred to in section (1). The utility may conduct a preliminary screening analysis to determine a short list of preliminary supply-side candidate resource options, or it may consider all of the potential supply-side resource options to be preliminary supply-side candidate resource options pursuant to subsection (2)(C). All costs shall be expressed in nominal dollars.

2.1 Overview of Supply-Side Resource Option Analysis

Pursuant to 20 CSR 4240-22.040(1) and 20 CSR 4240-22.040(2), Liberty-Empire considered a wide range of potential supply-side resource options for inclusion in its future portfolio resource mix, then narrowed the range down to a subset of feasible and commercially viable options to be evaluated in the fuller integrated portfolio analysis in conjunction with demand-side resources.

Liberty-Empire began with a broad list of all potential resource types that it could reasonably expect to use, develop, implement, or acquire, including plants utilizing existing generation technologies, new generation technologies, emerging technology types expected to become commercially viable within the 20-year IRP horizon, distributed resources, any available existing resource upgrades or life extensions, and purchased power from SPP. This initial list of all potential supply-side resource options is described and documented in Section 2.2.

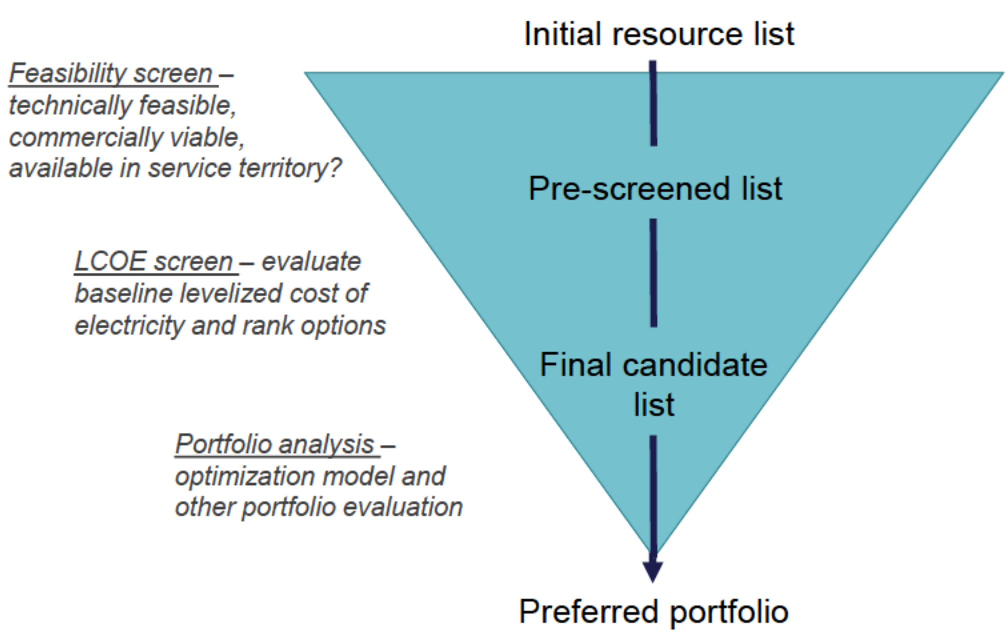
Liberty-Empire then used a screening process to narrow down the broader list of resource options to only those that were likely feasible to develop and operate in the Company's service territory. The process and results of the feasibility screening are described and documented in Section 2.3.

After the identification of the feasible supply-side resource options, planning-level cost and operating assumptions for each of the feasibility-screened resource options were collected and developed by Liberty-Empire's IRP consultant, Charles River Associates ("CRA"), with review and input by experts from a third-party engineering firm, Black and Veatch. Cost and operating estimates for the resource options were developed using a market scan approach for cost and operational parameters. Using the cost and operating parameters from this market scan analysis, Liberty-Empire evaluated the levelized cost of electricity ("LCOE") and levelized cost of capacity of the feasible resource options to determine whether any options were commercially unviable relative to other resources under consideration. The commercial viability screening is described in more detail in Section 2.4. The cost and performance assumptions developed for the resource options are described and documented in Section 4 of this volume.

Based on the results of the two rounds of screening analyses, as well as considerations for probable environmental costs of each potential supply-side resource option, Liberty-Empire ultimately identified a "shortlist" of potential supply-side resource options, representing the preliminary supply-side candidate resource options to be included in the integrated resource planning analysis described in Volume 6. The final list of supply-side candidate resource options is shown in Section 2.6.

An illustration of the supply-side option resource screening process is shown in Figure 4-2.

Figure 4-2 – Supply-Side Resource Screening Approach



2.2 All Potential Supply-Side Resource Options

Pursuant to 20 CSR 4240-22.040(1), Liberty-Empire began with a broad list of all potential resource types that it could reasonably expect to use, develop, implement or acquire, including plants utilizing existing generation technologies, new generation technologies, emerging technology types expected to become commercially viable within the 20-year IRP horizon, distributed resources, any available existing resource upgrades or life extensions, and purchased power from SPP. The potential supply-side resource options selected for further investigation are as follows:

1. Carbon Capture and Storage ("CCS") – supercritical coal CCS, natural gas-fired combined cycle with CCS, retrofit CCS on existing plants
2. Natural gas-fired simple cycle – Aeroderivative CT and F-class frame CT
3. Natural gas-fired combined cycle – 1 x 1 H Class
4. Natural gas-fired reciprocating engines ("RICE")*
5. Traditional nuclear and small modular nuclear reactor
6. Wind – on-shore and off-shore, including re-powering of existing assets
7. Biomass – wood waste and poultry waste
8. Landfill gas
9. Solar photovoltaic ("PV")* – fixed tilt and single axis tracking, with and without paired storage
10. Energy storage – lithium-ion battery*, vanadium redox flow battery, molten salt, Energy Vault concrete block gravity storage, compressed air
11. Combined heat and power ("CHP")*
12. Hydrogen – retrofit on existing gas-fired combined cycle units and new combined cycle combustion turbine

*Denotes a resource option evaluated as both a distributed and utility scale energy resource.

2.3 Feasibility Screening

Based on Liberty-Empire's size and location, the initial feasibility screen eliminated the following supply-side resource options from consideration:

- Off-shore wind, given the lack of the resource type in Liberty-Empire's region;
- Re-powering of existing wind assets, given feedback from owners of the projects currently under contract with Liberty-Empire that they are not exploring re-powering opportunities at this time;
- CHP options, given uncertainty regarding feasible sites within Liberty-Empire's service territory and the lack of potential partners that have shown interest in pursuing CHP relationships with Liberty-Empire;
- Carbon capture, given the engineering complexity of capture and transportation, lack of natural geology for storage, and scarcity of operating examples to draw upon;
- Traditional nuclear, given the large size of the option (~1,000 MW) and the inability to assume with confidence that Liberty-Empire would have access to a partial ownership interest in a new development in any proximity to its service territory;
- Biomass and landfill gas, given limited access to a reliable source of fuel in close proximity to the Liberty-Empire service territory; and
- Molten salt energy storage and compressed air energy storage, given the engineering complexity of development and operation, lack of natural geology for compressed air storage, and scarcity of operating examples of molten salt energy storage to draw upon.

2.4 Cost Ranking Screening

(A) Cost rankings of each potential supply-side resource option shall be based on estimates of the installed capital costs plus fixed and variable operation and maintenance costs levelized over the useful life of the potential supply-side resource option using the utility discount rate.

The second supply-side resource option screening involved calculating the levelized cost of electricity ("LCOE"), defined as the net present value of the unit-cost of electricity over the lifetime of the generating resource, of the various supply-side resource candidates and ranking them to determine whether any options were commercially unviable relative to other resources under consideration. Pursuant to 20 CSR 4240-22.040(2)(A), the LCOE was based on the assumed variable costs of generation plus the installed capital costs and fixed operations and maintenance ("O&M") costs for the potential resource options, levelized and discounted over the lifetime of the asset using the utility's discount rate. The levelized cost of capacity associated with only capital and fixed costs was also applied as a second measure of economic viability.

The remainder of this section summarizes the results of the LCOE and levelized cost of capacity analyses. The cost and operating assumptions used to calculate the LCOE and levelized cost of capacity are summarized here at a high level and are described and documented in more detail in Section 4 of this volume.

2.4.1 Summary of Cost and Operating Parameter Assumptions for LCOE Analysis

After the identification of the feasible supply-side resource options, planning-level cost and operating assumptions for each of the remaining resource options were collected and developed by CRA with review and input by experts from a third-party engineering firm, Black and Veatch. Cost and operating estimates for the resource options were developed using a market scan approach for cost and operational parameters. The market scan approach involved in-depth research into recent costs data points from a variety of sources, including public reports, other utility IRP filings and Requests for Proposals, proprietary subscription-based data sources, and Liberty-Empire's and Black and Veatch's internal view based on actual and recent project estimates. The results of the market research findings were used to develop current cost estimates for the technologies as well as projections for cost changes over time. A summary of the costs and operating parameters for each of the potential feasibility-screened supply-side resource options analyzed in the LCOE screening are presented in Table 4-4.

The cost estimates presented in Table 4-4 reflect all-in costs for each resource option, including costs of engineering, procurement, and construction ("EPC"); land; base interconnects; ownership costs; and contingency costs. Cost estimates reflect the 2022 IRP Base Case assumptions for all resources, though "Low" and "High" Case assumptions were also developed with Black and Veatch input and incorporated in the 2022 IRP risk analysis. The average annual expected capacity factors for non-dispatchable renewable resources are based on expectations for renewable availability in the region. The capacity factors for dispatchable resources are based on initial, screening-level dispatch simulations of the SPP market using 2022 IRP Base Case market and fuel price inputs.

Table 4-4 - Costs and Analysis Descriptors of Potential Supply-Side Resource Options

Dollars in 2020$	CCGT	CT - Aero	CT - Frame	RICE	Dist. Rice
Size (MW)	420	50	240	30	2
2023 Full Load Net Heat Rate (Btu/kWh)	6,422	9,124	9,905	8,298	9,250
2023 Installed Capital Cost ($/kW)	1,081	1,191	735	1,562	1,703
2028 Installed Capital Cost, ($/kW)	1,064	1,157	716	1,516	1,658
2033 Installed Capital Cost, ($/kW)	1,042	1,127	698	1,473	1,617
2023 Fixed O&M ($/kW-year)	14.9	16.5	7.1	25.0	25.0
2023 Firm Gas Delivery ($/kW-year)	22.0	31.2	33.9	28.4	31.6
2023 Ongoing Capex ($/kW-year)	3.3	4.1	1.1	4.1	4.1
2023 Variable O&M ($/MWh)	2.4	7.5	4.6	7.0	7.0
2023 Avg. Expected Capacity Factor (%)	59%	23%	24%	30%	25%

Dollars in 2020$	Solar – Single-axis Track-ing	Solar – Fixed Tilt	Solar + Stor-age (4:1)	Solar + Stor-age (2:1)	Utility-Scale Wind	Dist. Solar PV	Dist. Solar + Stor-age (2:1)
Size (MW)	50	50	50	60	100	5	3
2023 Full Load Net Heat Rate (Btu/kWh)	n/a						
2023 Installed Capital Cost ($/kW)	1,200	1,156	1,227	1,244	1,369	1,680	1,722
2028 Installed Capital Cost, ($/kW)	999	963	1002	1,005	1,214	1,360	1,365
2033 Installed Capital Cost, ($/kW)	842	811	853	861	1,077	1,106	1,144
2023 Fixed O&M ($/kW-year)	12.0	11.5	11.6	11.3	32.2	14.0	12.7
2023 Ongoing Capex ($/kW-year)	0.0	0.0	7.0	11.7	18.0	0.0	15.4
2023 Variable O&M ($/MWh)	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2023 Avg. Expected Capacity Factor (%)[7]	25%	17%	20%	16%	44%	25%	16%

Dollars in 2020$	H2 CC Retrofit[8]	H2 CC[6]	Nuclear SMR
Size (MW)	Same as underlying CC	420	300
2035 Full Load Net Heat Rate (Btu/kWh)	Same as underlying CC	6,422	10,455
2035 Capital Cost ($/kW)	63	1,339	3,500
2035 Fixed O&M ($/kW-yr)	30.8	14.9	96.2
2035 Ongoing Capex ($/kW-yr)	28.3	6.2	5.5
2035 Variable O&M ($/MWh)	1.5	6.9	3.0
2035 Avg. Expected Capacity Factor (%)	62%	66%	95%

[7] Paired solar + storage system capacity factor represents generation calculated as a proportion of total system capacity, including the storage component.

[8] Hydrogen capacity factor is not based on economic dispatch, and instead represents estimate of dispatch level required to provide sufficient clean energy to replace CC output for net-zero portfolios in combination with spare capacity for load following. Assumes 100% green hydrogen fuel.

2.4.2 LCOE Analysis

Using the cost and operating parameters from the market scan analysis, Liberty-Empire evaluated the levelized cost of electricity and levelized cost of capacity of the feasible resource options to determine whether any options were commercially unviable relative to other resources under consideration. When evaluating the LCOE, Liberty-Empire accounted for all installed capital costs, interconnection costs, FOM, firm gas delivery costs, ongoing capex, VOM, fuel costs, and emission costs for all resource options. For each dispatchable resource option, capacity factor estimates were developed through screening-level dispatch analysis of the SPP market. For renewable and paired storage resources, Liberty-Empire accounted for potential tax benefits associated with Liberty-Empire's assumptions for federal production tax credit ("PTC") eligibility, federal investment tax credit ("ITC") eligibility, and accelerated MACRS tax depreciation rules. The PTC provides a credit of $25/MWh (in 2021$, which is indexed to inflation), while the ITC provides a credit as a fraction of the total capital cost of the resource. Historically, wind resources have typically taken advantage of the PTC due to their higher capacity factors, while standalone solar and paired storage resources have used the ITC.

Based on current tax law (as of March 2022), equipment must be safe-harbored by a certain date and the project must enter into service by a certain date later on to qualify for the credits. The safe-harbor requirements entail an investment of at least 5 percent of the total project cost or other demonstration of continuous development. In December 2020, Congress passed an extension of the ITC, which provides 26% tax credit eligibility for systems commencing construction in 2020-2022, 22% for systems commencing construction in 2023, and 10% for systems commencing construction in 2024 or later. Any system placed in service by the end of 2025 can receive the 26% and 22% tax credit levels,[9] while those entering into service after 2025, regardless of when they commenced construction, can receive a maximum tax credit of only 10%.

[9] Note that because 26% and 22% ITC-qualified resources must enter into service by 2025, Liberty-Empire has assumed that all pre-2026 solar projects will be able to take advantage of the 26% ITC.

Congress also passed an extension of the PTC, which provides 60% tax credit eligibility for wind projects that begin construction in 2020 or 2021.

Relative to the tax provisions currently in law, Liberty-Empire's 2022 IRP Base Case tax credit assumptions expect minor extensions to both the investment and production tax credits similar to those seen in recent history. Table 4-5 summarizes the Base Case phase-out schedule assumptions for the PTC and ITC used in the development of the LCOE analysis.[10]

Table 4-5 – PTC and ITC Phase-out Schedule

Year for Safe Harbored Equipment	Production Tax Credit (PTC)		Investment Tax Credit (ITC)	
	Last Year to be Placed in Service for PTC	Wind PTC (%)	Last Year to be Placed in Service for ITC	ITC Rate (%)
2019	2023	60%	2023	30%
2020	2024	60%	2024	26%
2021	2025	60%	2025	26%
2022	2026*	60%*	2026*	26%*
2023	n/a	0%	2027*	26%*
2024+	n/a	0%	2028+	10%

*Denotes tax credit eligibility *extensions* relative to current law as of March 2022.

In addition to federal tax credits, renewable resources are also able to take advantage of accelerated depreciation for tax purposes. Nuclear and fossil fuel-fired resources can generally be depreciated for tax purposes on 20- or 15-year schedules, while renewables and storage resources can take advantage of 7- or 5-year schedules. These tax depreciation schedules are summarized in Table 4-6, along with the book life depreciation schedules for all resource options.

[10] Note that Liberty-Empire also evaluated tax credits under current law and under an assumed longer extension in its Critical Uncertain Factor (CUF) analysis, which is described in Volume 6. The LCOE analysis was performed under the Base Case assumptions for screening purposes.

Table 4-6 – Depreciation and Tax Life Assumptions

Technology	Tax Life	Book Life
Gas CC	20	30
Gas CT	15	30
Solar PV	5	30
Onshore Wind	5	30
Lithium-Ion 4-hr	7	30*
Flow Battery	7	30
Nuclear	15	60
RICE	15	30
Hydrogen CC	20	30
Gravity	7	30
Solar PV + Storage[11]	5	30
Hydrogen Retrofit on CC	15	15

*Note: Lithium-ion battery life is based on the assumption of one complete refurbishment/replacement of cells. The augmentation costs associated with this are included in ongoing capex assumptions.

The LCOE analysis incorporates the value of federal tax credits for renewable/storage technologies through the modeling of a hypothetical tax equity partnership between Liberty-Empire and a tax equity partner. Liberty-Empire modeled the financial contribution that a tax equity partner would provide toward the total cost of a renewable project given the value of the tax credits (PTC for wind, ITC for solar and solar + storage), accelerated MACRS tax depreciation, and an internal rate of return ("IRR") of 7 percent for the tax equity partner. Liberty-Empire modeled the effects of a tax equity partnership for each generic technology as applicable (wind, solar, solar + storage) and for each year over time. The tax equity modeling results in a percentage reduction in capital cost for Liberty-Empire plus an annual cost "adder" representing the additional cash payments Liberty-Empire would make to the tax equity partner over the life of the partnership. Table 4-7 shows capital cost reductions applied for each tax credit eligibility level.

[11] Battery paired with renewable energy is eligible for 5-year MACRS.

Table 4-7 – Tax Equity Partnership Capital Cost Reduction Assumptions

ITC %	Capital Cost Reduction from ITC	PTC %	Capital Cost Reduction from PTC
30%	35%	60%	45%
26%	31%		
10%	13%		

In addition to the capital costs (adjusted for potential tax equity contributions), FOM costs, firm gas delivery, and VOM costs outlined in Table 4-4, the LCOE is significantly influenced by expectations for the cost of fuel and emissions over time. Probable environmental costs are summarized in Section 2.5.4. The projected fuel costs over time are summarized in Table 4-8. Natural gas prices represent 2022 IRP Base Case assumptions and are discussed in further detail in Section 5.1. Hydrogen fuel prices were derived from a combination of public sources including Wood-Mackenzie and Bloomberg New Energy Finance ("BNEF").

Table 4-8 – Delivered Fuel Projections used in LCOE Analysis for Select Years (Nominal $/MMBtu)

****Confidential in its Entirety****

[redacted]

In addition to the LCOE, each resource type was also evaluated on the basis of its levelized cost of capacity. The levelized cost of capacity calculation considers only costs that are fixed in nature and required for the resource to be available to operate during times of peak demand. These costs include capital, FOM, ongoing capex, and firm gas delivery, levelized over the lifetime of the generating resource. The unit capacity is de-rated to account for forced outages and the most recent guidance on proposed SPP accreditation for renewables, representing the amount of the nameplate capacity that is "firm" or available to operate during peak hours.

Figure 4-3 and Figure 4-4 summarize the results of the levelized cost analysis for select years, 2023 and 2035, in dollars per MWh for LCOE (on the y-axis) and in dollars per UCAP kW-year for the levelized cost of capacity (on the x-axis), all in nominal terms. Each graphic represents the projected cost for a resource that would enter into service in the indicated year. A resource in the lower left quadrant of the graphic has both a low levelized cost of electricity and low levelized cost of capacity relative to other resources; meanwhile, a resource in the upper right quadrant has both a high levelized cost of electricity and a high levelized cost of capacity relative to other resources. For graphical purposes, the supply-side resources are categorized into three major groups: natural gas-fired (blue dots), renewable (green dots), and clean baseload resources (red dots). Renewable resources include wind, solar, and hybrid systems paired with storage. Clean baseload resources include resources that offer carbon-free generation with dispatch control or non-intermittent output, namely hydrogen-fired resources and nuclear SMR. The clean baseload resources were considered only for the longer-term net-zero portfolios, which are described in more detail in Volume 6 of the IRP.

Due to their lower expected capacity factors (approximately 20-25% under Liberty-Empire's Base Case market environment), the LCOE values of gas peaking options (simple cycle CT and RICE) tend to be higher than those of a combined cycle since fixed costs are spread across a lower number of megawatt hours. Although RICE options have higher capital costs than other peaking resource types, their lower heat rates and higher capacity factors result in an LCOE in between aeroderivative and frame CT. Frame CT offers the lowest levelized cost of capacity of all gas options, owing primarily to its relatively low capital cost.

When tax incentives are incorporated, wind and solar resources are the lowest LCOE options in the initial years of the planning period. Over time, the expected costs of wind and solar increase due to tax credit phase-outs, but remain substantially lower cost than the other resource options as their capital costs are expected to decline in real dollar terms, reflecting expectations for technological advancement and efficiency improvements relative to other technologies.

Solar cost projections are similar to wind costs over time and have a high potential to decline in real dollar terms in a high technological advancement scenario. Furthermore, solar resources may offer more capacity value to Liberty-Empire than wind resources in the summer months given their greater availability during summer days when the SPP system realizes its system peak.

Within the solar resource category, the small capital cost premium associated with single-axis tracking PV relative to fixed tilt PV is more than offset by a significantly improved expected capacity factor, which lowers its cost on an LCOE basis. Finally, while the paired solar + storage resources have a higher LCOE than standalone solar, this configuration also provides more capacity value per unit of capital cost, as reflected in its lower levelized cost of capacity.

In 2035 and beyond, the commercial availability of hydrogen-fired gas CCs and nuclear SMR provide an opportunity to supply clean energy with stable output. The low fuel cost and high capacity factor of SMR allow for a lower LCOE than hydrogen options. The lower capital cost of hydrogen relative to SMR makes it a comparatively more economic source of capacity, but a higher cost source of energy due to the high cost of hydrogen fuel.

Figure 4-3 – LCOE and Levelized Cost of Capacity Projections (2023)

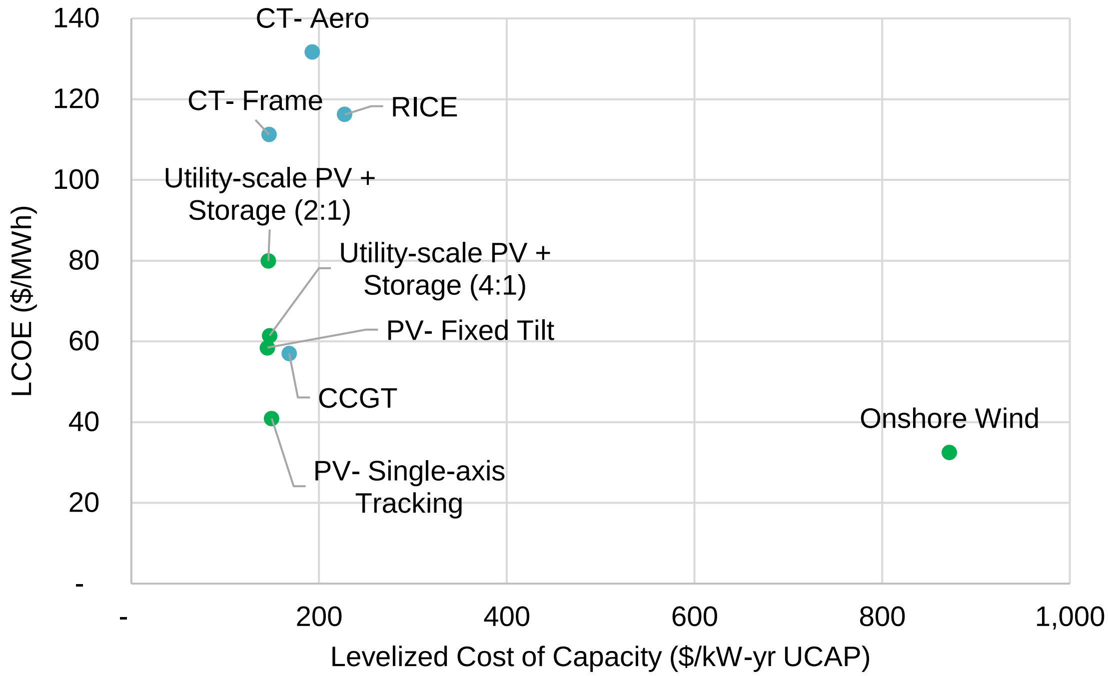
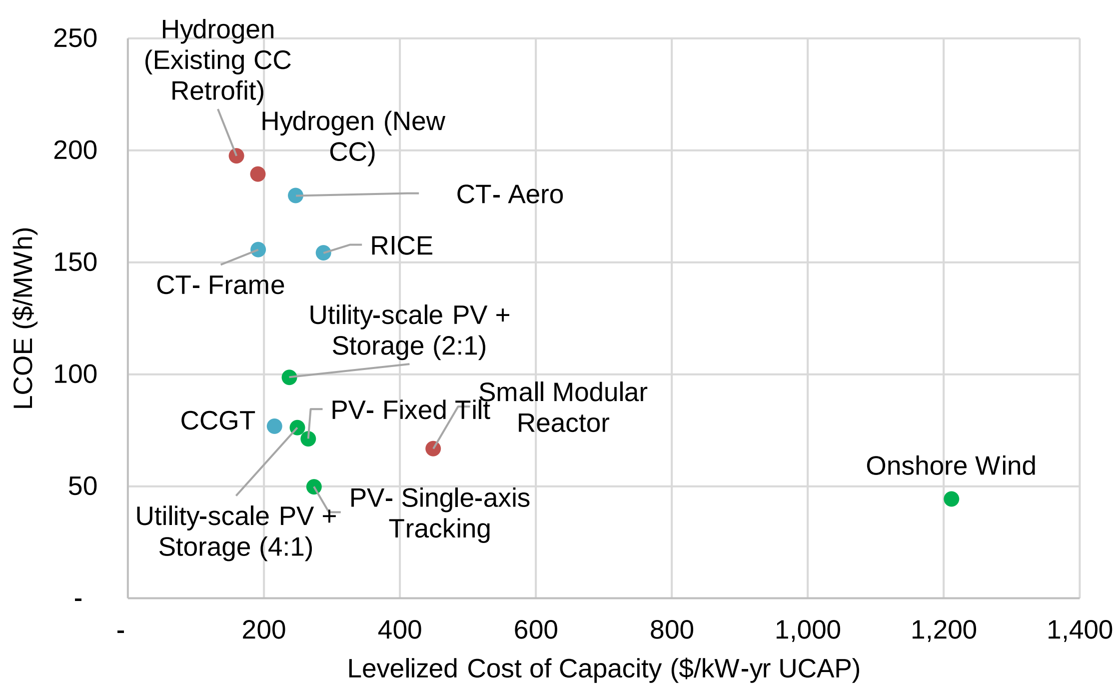


Figure 4-4 - LCOE and Levelized Cost of Capacity Projections (2035)



Overall, the supply-side candidate resource options show a wide range of costs. Other than fixed-tilt solar PV, Liberty-Empire determined that all generation technology types should advance to the next phase of analysis due to a wide range economic and performance benefits for the Liberty-Empire system. These benefits can be summarized as follows:

- **Energy** – Wind, solar, paired solar + storage, and CCGT offer low cost of levelized energy;
- **Capacity** – Natural gas options including CCGT, simple cycle CT, and RICE have the lowest levelized cost of capacity;
- **Clean baseload** – For net-zero evaluation, hydrogen and nuclear SMR offer various levels of energy and capacity value;
- **Locational** – Distributed options including solar, RICE, and storage are at a cost premium to their utility scale counterparts; however, they may provide benefits associated with avoided distribution system-level expenditures.

2.4.3 Storage Resource Screening

In addition to generation resources, Liberty-Empire believes that with observed rapid cost reductions and a growing availability of commercially viable options, storage is an important asset class to be considered as part of the 2022 IRP. Unlike typical generating resources, storage resources do not provide net energy to the grid, but instead shift energy during the day or even across a week to peak or high-priced hours. Because storage resources do not produce net generation, they cannot be appropriately evaluated in the traditional LCOE framework. Thus, Liberty-Empire assessed and screened storage options on the basis of total cost, including capital, FOM, and ongoing capex, levelized over the lifetime of the resource.

Liberty-Empire has not definitively eliminated any traditional or advanced storage technologies from future consideration since storage technologies are rapidly evolving and use cases are developing. However, for planning purposes in the 2022 IRP, Liberty-Empire focused its analysis of storage options on three distinct storage technologies: 4-hour lithium-ion battery storage, 8-hour vanadium flow battery storage, and Energy Vault concrete block gravity storage.

To quantitatively assess the comparative costs and benefits of these three storage resource types, Liberty-Empire developed assumptions around key operating parameters, including charge duration in hours, round trip efficiency, charging and discharging time, and depth of discharge. These planning-level estimates were reviewed by Black and Veatch and are summarized in Table 4-9.

Table 4-9 – Preliminary Storage Parameters

Parameter	Lithium-Ion	Flow	Gravity
Size (MW)	50	50	50
Assumed First Year of Availability	2025	2035	2035
2023 Installed capital cost (2020$/kW-yr)	1,333	N/A	N/A
2028 Installed capital cost (2020$/kW-yr)	1,016	N/A	N/A
2033 Installed capital cost (2020$/kW-yr)	899	N/A	N/A
2038 Installed capital cost (2020$/kW-yr)	840	1,966	1,514
FOM (2020$/kW-yr)	10.0	5.5	20.0
Ongoing capex (2020$/kW-yr)	35.0	0.0	0.0
Round trip efficiency (%)	87%	70%	82%
Storage duration (Hours)	4	8	8
Charge time (Hours)	4	8	8
Discharge time (Hours)	4	8	8
Depth of discharge (%)	80%	90%	100%

Based on these operating parameters, Liberty-Empire performed an analysis of the levelized costs of the three potential storage resources over a long-term planning period. The levelized cost of each technology on an ICAP basis is summarized in Figure 4-5. Flow battery and gravity storage are shown beginning in 2035, reflecting their later assumed commercial availability given the limited current supply chain and few operating examples at scale. The estimated ELCC capacity credit that each technology is expected to qualify for under 2022 IRP Base Case market assumptions is shown in Table 4-10**Error! Reference source not found.**, while the resulting levelized cost of capacity on a UCAP basis is shown in Figure 4-6.

Figure 4-5 – Levelized Cost of Storage Options (ICAP)

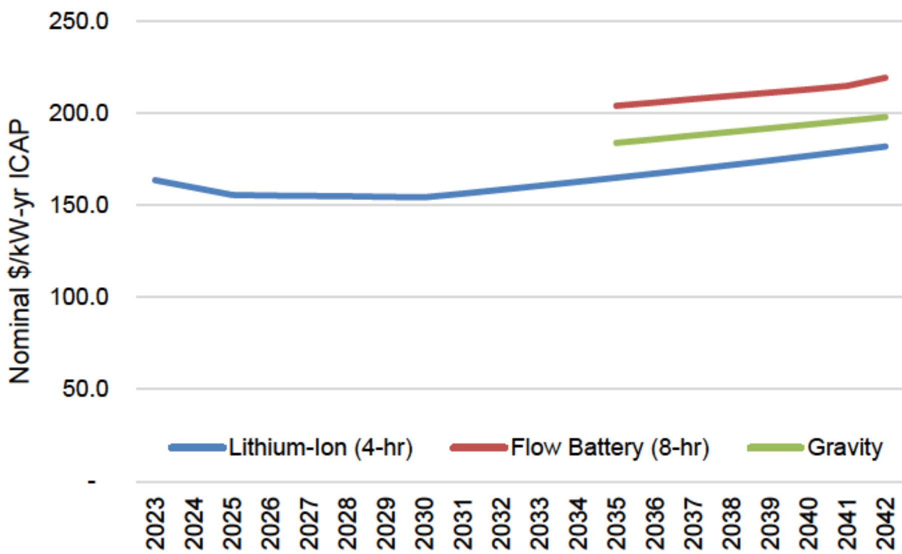
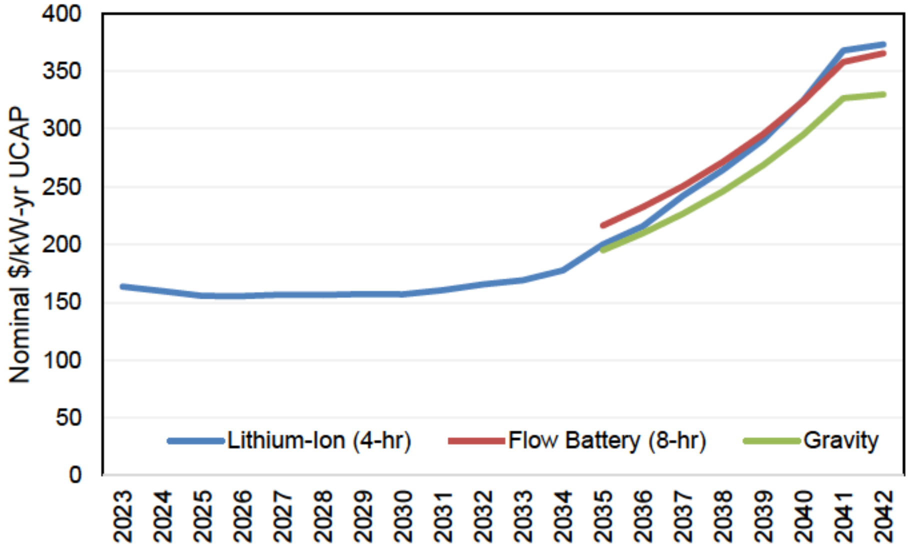


Table 4-10 – Storage Option ELCC (Capacity Credit)

	Lithium-Ion (4-hr)	Flow Battery (8-hr)	Gravity (8-hr)
2023	100%	100%	100%
2024	100%	100%	100%
2025	100%	100%	100%
2026	100%	100%	100%
2027	99%	100%	100%
2028	99%	100%	100%
2029	98%	100%	100%
2030	98%	100%	100%
2031	98%	100%	100%
2032	96%	100%	100%
2033	95%	100%	100%
2034	92%	100%	100%
2035	83%	94%	94%
2036	78%	89%	89%
2037	70%	83%	83%
2038	65%	77%	77%
2039	60%	71%	71%
2040	54%	66%	66%
2041	49%	60%	60%
2042	49%	60%	60%

Figure 4-6 – Levelized Cost of Storage Options (UCAP)



Based on this screening analysis, Liberty-Empire found that lithium-ion batteries are cost-competitive with standard generation resources on a capacity basis, although the value of the capacity is likely to erode over time as more storage is added to the system. Relative to other storage resources, the high level of flexibility and efficiency associated with lithium-ion batteries also provide significant value opportunities across multiple SPP markets, with additional long-term energy arbitrage opportunities and ancillary service value potential associated with expected growth of intermittent resource capacity in the market.[12]

The screening analysis also demonstrated that flow batteries and gravity storage are expected to be competitive with lithium-ion in the longer term, due in large part to the longer duration configuration of these technologies, which allows them to provide more capacity value for deployment during times of peak demand. Liberty-Empire will consider the development of flow batteries for 2035 and beyond, and gravity storage only for net-zero portfolios in the same time

[12] While ancillary service value is not included in the LCOE analysis, Liberty-Empire did include estimates in the integrated resource planning stage and in the critical uncertain factor analysis. See section 5.5 of this volume for details.

frame. Liberty-Empire will continue to evaluate emerging storage technologies as markets evolve and as potential use cases are further identified.

In addition to peak load-shifting value, energy arbitrage value, and capacity value, storage resources also have the potential to provide a host of ancillary services such as frequency regulation and spinning reserves. Thus, Liberty-Empire also assessed and incorporated the ancillary service value of storage resources (as well as thermal resources) in the integrated resource analysis, based on potential SPP market revenues in the spinning reserve, regulation up, and regulation down markets.

2.4.4 Distributed Resource Screening

Distributed solar and battery storage resources have been found to have a capital cost premium of up to 40 percent to their utility-scale counterparts, while distributed RICE is more comparable to the utility-scale alternative. However, Liberty-Empire determined that it is not appropriate to eliminate any feasible distributed resource options through an LCOE approach since they may provide benefits to the system associated with avoided distribution-level expenditures on Liberty-Empire's system, as further described in Section 2.4.4.1. Therefore, the distributed resource options for solar, battery storage, and reciprocating engines have been preserved as candidate resource options.

2.4.4.1 Avoided Distribution Upgrade Costs

Positioning a distributed energy resource in an area with historically high congestion or delivery costs could yield benefits to Liberty-Empire's system and customers by way of injection at the load site as opposed to the transmission of energy across various delivery systems. While determining the exact value of such benefits is complex, it can be estimated by quantifying the ability of distributed energy resources to defer certain distribution system upgrade costs.

NP

To assess the value of distributed energy resources, such as distributed solar and distributed storage (paired or unpaired), Liberty-Empire identified a set of planned and/or representative distribution upgrade projects that could be deferred if transformer current was reduced. Assuming that distributed solar and storage resources can be placed at specific sites on the distribution grid to avoid system upgrades, Liberty-Empire incorporated the value of these representative upgrade projects as offsets to the capital and fixed costs of distributed solar and storage resources. Based on the identified representative distribution upgrade projects, Liberty-Empire could avoid approximately **[redacted]** in project capital costs and [redacted]** per year in fixed O&M costs by installing at least **[redacted]** of firm distributed capacity at one representative site, and avoid approximately **[redacted]** in project capital costs and **[redacted]** per year in fixed O&M costs by installing at least **[redacted]** of firm distributed capacity at another representative site.

Future intersections of resource cost paired with increases in infrastructure/labor costs may provide additional benefits that are not currently quantifiable. Additionally, a multiplying effect may arise if DER aggregation facilitated by FERC Order 2222 materializes to a level which could become impactful to load centers.

2.5 Probable Environmental Costs of Potential Supply-Side Resource Options

> *(B) The probable environmental costs of each potential supply-side resource option shall be quantified by estimating the cost to the utility to comply with additional environmental legal mandates that may be imposed at some point within the planning horizon. The utility shall identify a list of environmental pollutants for which, in the judgment of the utility decision-makers, legal mandates may be imposed during the planning horizon which would result in compliance costs that could significantly impact utility rates. The utility shall specify a subjective probability that represents utility decision-maker's judgment of the likelihood that legal mandates requiring additional levels of mitigation will be imposed at some point within the planning horizon. The*

utility, based on these probabilities, shall calculate an expected mitigation cost for each identified pollutant.

Liberty-Empire is subject to various federal, state, and local laws and regulations with respect to air and water quality and with respect to hazardous and toxic materials and hazardous and other wastes including their identification, transportation, disposal, record-keeping, and reporting as well as remediation of contaminated sites and other environmental matters. Liberty-Empire operates its generating facilities in compliance with environmental laws and regulations. Environmental laws or regulations that may be imposed at some point within the planning period may impact air emissions, water discharges, or waste material disposal. The rest of this section provides a brief discussion of each of these pollutants that could result in compliance costs that may impact utility rates. Liberty-Empire is not in a position to accurately estimate compliance costs for any new requirements.

2.5.1 Air Emission Impacts

2.5.1.1 National Ambient Air Quality Standards

The Clean Air Act ("CAA") requires the EPA to set National Ambient Air Quality Standards ("NAAQS") for four air pollutants associated with fossil-fuel generation, including particulate matter, ground-level ozone, sulfur dioxide (SO_2), and nitrogen dioxides (NO_X). These air pollutants are regulated by setting human health-based or environmental-based criteria for permissible levels.

2.5.1.2 Particulate Matter

In 2013, the EPA strengthened the PM standard. The Jasper County area is currently in attainment of the 2013 PM NAAQS. No additional emission control equipment is currently needed to comply with this standard. It is not known whether the Jasper County area will remain in attainment of a future revision of the standard. Future non-attainment of revised standards could require additional reduction technologies, emission limits, or both on fossil-fueled units.

2.5.1.3 Ozone

In 2015, the EPA strengthened the NAAQS for ground-level ozone. The Jasper County area is currently in attainment of the 2015 Ozone NAAQS. No additional emission control equipment is currently needed to comply with this standard. Future non-attainment of revised standards could result in regulations requiring additional NO_X reduction technologies, emission limits, or both on fossil-fueled units.

2.5.1.4 Sulfur Dioxide

In 2010, the EPA strengthened the NAAQS for SO_2. The Jasper County area is currently in attainment of the 2010 SO_2 NAAQS. No additional emission control equipment is currently needed to comply with this standard. Future non-attainment of revised standards could result in regulations requiring additional SO_2 reduction technologies, emission limits or both on fossil-fueled units.

2.5.1.5 Nitrogen Dioxides

In 2010, the EPA strengthened the NAAQS for NO_X. The Jasper County area is currently in attainment of the 2010 NO_X NAAQS. No additional emission control equipment is currently needed to comply with this standard. Future non-attainment of revised standards could result in regulations requiring additional NO_X reduction technologies, emission limits or both on fossil-fueled units.

2.5.1.6 Cross-State Air Pollution Rule

In 2011, the EPA finalized the Cross-State Air Pollution Rule (“CSAPR”), requiring eastern and central states to significantly reduce power plant emissions that cross state lines and contribute to ground-level ozone and fine particle pollution in other states. The CSAPR Update Rule took effect in 2017 with more stringent ozone-season NO_X emission budgets for electric generating units (“EGUs”) in many states to address significant contribution and maintenance issues with respect to the ozone NAAQS established in 2008. In 2021, the EPA issued new amended budgets for 12 states, although Missouri and Kansas were not impacted. No additional emission control equipment is currently needed to comply with this rule. The Company complies through a combination of trading allowances within or outside its system in addition to changes in operations as necessary. Future strengthened ozone, NO_X, or SO_2 standards could result in additional cross-state rule updates requiring additional trading of allowances, emission reduction technologies or reduced generation on fossil-fueled units.

2.5.1.7 Regional Haze

In June 2005, the EPA finalized amendments to the July 1999 Regional Haze Rule. These amendments apply to the provisions of the Regional Haze Rule that require emission controls known as best available retrofit technology (“BART”) for industrial facilities emitting air pollutants that reduce visibility by causing or contributing to regional haze.

The pollutants that reduce visibility include $PM_{2.5}$ and compounds which contribute to $PM_{2.5}$ formation, such as NO_X, SO_2, and under certain conditions, volatile organic compounds and ammonia. Under the 1999 Regional Haze Rule, states are required to set periodic goals for improving visibility in natural areas. As states work to reach these goals, they must develop regional haze implementation plans that contain enforceable measures and strategies for reducing visibility-impairing pollution.

The Regional Haze Rule directs state air quality agencies to identify whether visibility-reducing emissions from sources subject to BART are below limits set by the state or whether retrofit measures are needed to reduce emissions. It also directs these agencies to file Regional Haze plans with the EPA for approval.

Future visibility progress goals could result in additional SO_2, NO_X, and PM controls or reduction technologies on fossil-fired units.

2.5.1.8 Affordable Clean Energy Rule

In December 2017, the EPA issued an advance notice of proposed rulemaking ("ANPRM") in which the agency proposed emission guidelines to limit greenhouse gas ("GHG") emissions from existing EGUs and solicited information on the proper respective roles of the state and federal governments in that process, as well as information on systems of emission reduction that are applicable at or to an existing EGU, information on compliance measures, and information on state planning requirements under the CAA. This ANPRM did not propose any regulatory requirements.

As a result of this ANPRM, on August 21, 2018, the EPA proposed the Affordable Clean Energy ("ACE") rule which would establish emission guidelines for states to develop plans to address GHG emissions from existing coal-fired power plants. The ACE rule replaces the 2015 Clean Power Plan, which the EPA has proposed to repeal because it exceeded EPA's authority. The Clean Power Plan was stayed by the U.S. Supreme Court and has never gone into effect.

In June 2019, the EPA issued the final Affordable Clean Energy ("ACE") rule and repealed the Clean Power Plan. The ACE rule established emission guidelines for states to develop plans to address GHG emissions from existing coal-fired power plants. The ACE rule has several components: a determination of the best system of emission reduction for greenhouse gas emissions from coal-fired power plants, a list of "candidate technologies" states can use when developing their plans, a new preliminary applicability test for determining whether a physical or operational change made to a power plant may be a “major modification” triggering New Source Review, and new implementing regulations for emission guidelines under Clean Air Act section 111(d). During 2020, Missouri utilities conducted regular meetings with the Missouri Department of Natural Resources to determine the standard of compliance for this rule. Plum Point Energy Associates has also been working through the standard of compliance with the Arkansas Division of Environmental Quality. However, on January 19, 2021, the United States Court of Appeals for the District of Columbia Circuit struck down the ACE Rule, and the new Biden Administration is now expected to propose a replacement that will be materially different. Liberty-Empire will continue tracking EPA action related to GHG emissions going forward.

2.5.1.9 Mercury and Air Toxics Standards (MATS)

In 2011, the EPA finalized a rule to reduce emissions of toxic air pollutants from power plants. These MATS for power plants reduced emissions from new and existing coal and oil-fired electric EGUs. Control equipment was installed at Liberty-Empire facilities to comply with this rule. No additional emission control equipment is currently needed to comply with this standard. It is not known whether the rule will be strengthened in the future. Future strengthening of the rule could require additional reduction technologies, emission limits, or both on coal and oil-fired units.

2.5.2 Water Related Impacts

Liberty-Empire operates under the Kansas and Missouri Water Pollution Plans that were implemented in response to the Federal Clean Water Act (“CWA”). Liberty-Empire operates its generation facilities in compliance with applicable regulations, and all facilities have received necessary discharge permits.

2.5.2.1 Clean Water Act Section 316(b)

On September 17, 2018, the Kansas Department of Health and Environment ("KDHE") issued a Certificate of Determination stating that the Riverton Generating Station cooling water intake structure ("CWIS") is in compliance with Section 316(b) of the CWA. The location, design, construction and capacity of the CWIS reflects the best technology available ("BTA") for minimizing adverse environmental impacts. Additionally, Iatan 2 and Plum Point Unit 1 also meet the BTA standard. Future modifications at the Iatan 1 facility could range from flow velocity reductions, traveling screen modifications, or the installation of a closed cycle cooling tower retrofit.

2.5.2.2 Surface Impoundments

Liberty-Empire owns and maintains a coal ash impoundment at the Asbury Power Plant. Additionally, Liberty-Empire owns a 12 percent interest in a coal ash impoundment at the Iatan Generating Station and a 7.52 percent interest in a coal ash impoundment at Plum Point. Future closure of all surface impoundments is anticipated.

Effluent Limitation Guidelines ("ELGs") for Steam Electrical Power Generating Point Sources are currently incorporated into all facilities' wastewater discharge permits. The EPA rule defines bottom ash transport water, fly ash transport water, and scrubber wastes as wastewaters which cannot be discharged after December 21, 2023.

2.5.3 Coal Combustion Residuals

In compliance with the EPA-published final rule to regulate the disposal of coal combustion residuals ("CCRs") as a non-hazardous solid waste under subtitle D of the Resource Conservation and Recovery Act, Liberty-Empire has published a Closure Plan for the Asbury Plant CCR Impoundment. Final closure of the existing ash impoundment will begin in 2020 and will be complete within the coming years. Expected costs for closure are in the $15-20 million range.

Liberty-Empire has posted a $20.8 million asset retirement obligation ("ARO") for the Asbury pond closure costs. Liberty-Empire expects resulting costs to be recoverable in rates. Final closure of the other existing ash impoundment, for which an asset retirement obligation of $4.4 million has been recorded for Liberty-Empire's interest in the coal ash impoundment at the Iatan Generating Station, has been accounted for in Liberty-Empire's ARO. In December 2016, The Missouri Department of Natural Resources ("MDNR") granted Liberty-Empire a Utility Waste Disposal Area Construction Permit that can be used for CCR waste disposal. Construction of the landfill is not expected in the immediate future, as Liberty-Empire anticipates that the existing Asbury impoundment will be closed by leaving all accumulated CCR in place.

In 2014, the former Riverton Plant impoundment was closed as a CCR landfill in accordance with Kansas Department of Health and Environment regulations.

2.5.4 Assigning Environmental Probabilities

Pursuant to 20 CSR 4240-22.040(2)(B), Liberty-Empire evaluated the probable environmental costs of new supply side resource options associated with potential CO2 emissions. Although several legislative and executive actions related to carbon emissions have been attempted over the last decade, there is currently no price on carbon and no binding emission limits at the federal level. At the time of the development of Liberty-Empire's 2022 IRP assumptions, the Biden Administration had begun to take executive actions related to carbon emission reductions and had introduced several climate-related legislative proposals as part of its overall infrastructure package. However, no policies directly regulating carbon emissions were signed into law as of March 2022.

Given a number of previous federal proposals to regulate carbon emissions, Liberty-Empire's Base Case incorporates a modest price on carbon emissions of $9-10/short ton starting in 2026, which can be seen as a proxy for several different potential pathways for legislative action or executive regulation (not explicitly a carbon tax). CRA's analysis suggests that pricing between $9-15/ton (in real 2020$) between 2026 and 2040 would achieve 70-80% carbon-free generation from the U.S. power sector over the long term, depending on other market factors and dynamics. Such a carbon price would likely result in significant additional coal-to-gas switching nationwide and pressure approximately 80% of the existing coal fleet across the country to retire by 2040. The price would also improve the economics of renewable and other clean energy generation.

Assuming 2022 IRP Base Case CO2 price assumptions, Table 4-11 presents the levelized environmental cost expectations for the Base Case over the twenty-year planning period due to CO2 emissions. Although NOx and SO2 emission costs were also modeled in the 2022 IRP analysis, given the minor cost impact of these resources, they are excluded from this table.

Table 4-11 – Probable Environmental Costs

Technology	Levelized Probable Environmental Costs – Emissions-based ($/MWh)
CCGT	4.37
RICE	5.64
CT – Aero	6.20
CT – Frame	6.74
Hydrogen CC	0
Nuclear SMR	0
Hydrogen Retrofit	0
PV - Single-Axis tracking	0
Solar + Storage (4:1)	0
Solar + Storage (2:1)	0
Wind	0
Dist. Solar PV	0
Dist. Solar + Storage (2:1)	0
Dist. RICE	6.29

2.6 Selection of Preliminary Supply-Side Candidate Resource Options

(C) The utility shall indicate which potential supply-side resource options it considers to be preliminary supply-side candidate resource options. Any utility using the preliminary screening analysis to identify preliminary supply-side candidate resource options shall rank all preliminary supply-side candidate resource options based on estimates of the utility costs and also on utility costs plus probable environmental costs.

Based on the feasibility and cost ranking screening analyses described previously in this section, Liberty-Empire identified a final list of technologies representing the preliminary supply-side future candidate resource options to be included in the 2022 integrated planning analysis. The final list of candidate supply-side resource options is as follows:

- Natural gas-fired simple cycle Aeroderivative CT and frame CT;
- Natural gas-fired CC – 1 x 1 H Class;
- Natural gas-fired RICE*;
- Onshore wind;

- Solar photovoltaic (PV)* – single axis tracking, with and without paired storage;
- Energy storage – lithium ion battery*, vanadium redox flow battery, concrete block gravity storage;
- Nuclear small modular reactor;
- Hydrogen – retrofit on exiting CC plants, new 1 x 1 CC.

*Denotes a resource option evaluated as both a distributed and utility scale energy resource.

2.6.1 Potential Supply-Side Resource Option Table

1. Provide a summary table showing each potential supply-side resource option and the utility cost and the probable environmental cost for each potential supply-side resource option and an assessment of whether each potential supply-side resource option qualifies as a utility renewable energy resource; and

Pursuant to 20 CSR 4240-22-040(2)(C) and 20 CSR 4240-22-040(2)(C)(1), Table 4-12 summarizes the expected utility levelized cost of electricity for each potential supply side resource option at select periods in time. Table 4-11 presents the levelized environmental cost expectations. As discussed in Section 2.4.3, storage resources were excluded from these tables due to their inability to be appropriately evaluated on a traditional LCOE basis.

Table 4-12 – LCOE by Supply Side Resource at Select Periods in Time

Technology		Levelized Cost of Electricity (Nominal $/MWh)		
		2025	2030	2035
Natural Gas	Reciprocating Engine – Utility-Scale	122.8	138.3	154.2
	CCGT	60.5	68.6	76.7
	CT - Aero	140.0	159.8	179.7
	CT - Frame	119.0	137.6	155.6
Renewable	Wind	33.8	41.3	44.4
	Solar PV - Single Axis Tracking	44.6	46.3	49.8
	Solar PV – Fixed tilt	63.7	66.1	71.3
	Utility Scale PV + Storage (4:1)	65.6	70.2	76.2
	Utility PV + Storage (2:1)	84.2	91.1	98.7
Clean Baseload	Small Modular Nuclear	N/A	N/A	66.7
	Hydrogen CC	N/A	N/A	189.4
	Hydrogen Retrofit CC	N/A	N/A	197.53

2.6.2 Elimination of Potential Supply-Side Resource Options

2. Explain which potential supply-side resource options are eliminated from further consideration and the reasons for their elimination.

As discussed in Sections 2.3 and 2.4, Liberty-Empire performed two rounds of screening analyses to narrow down its initial list of all potential supply-side resource options to a final list of preliminary options to be included in the fuller integrated portfolio analysis.

Based on the feasibility screen, Liberty-Empire eliminated the following supply-side resource options from consideration:

- Off-shore wind, given the lack of the resource type in Liberty-Empire's region;
- Re-powering of existing wind assets, given feedback from owners of the projects currently under contract with Liberty-Empire that they are not exploring re-powering opportunities at this time;
- CHP options, given uncertainty regarding feasible sites within Liberty-Empire's service territory and the lack of potential partners that have shown interest in pursuing CHP relationships with Liberty-Empire;

- Carbon capture, given the engineering complexity of capture and transportation, lack of natural geology for storage, and scarcity of operating examples to draw upon;
- Traditional nuclear, given the large size of the option (~1,000 MW) and the inability to assume with confidence that Liberty-Empire would have access to a partial ownership interest in a new development in any proximity to its service territory;
- Biomass and landfill gas, given limited access to a reliable source of fuel in close proximity to the Liberty-Empire service territory; and
- Molten salt energy storage and compressed air energy storage, given the engineering complexity of development and operation, lack of natural geology for compressed air storage, and scarcity of operating examples of molten salt energy storage to draw upon.

Based on the cost screen, Liberty-Empire only eliminated one option: fixed tilt solar PV. The small capital cost premium associated with single axis tracking was more than offset by the improvement in expected capacity factor relative to fixed tilt solar, resulting in Liberty-Empire determining that fixed tilt solar PV should be eliminated from further consideration. Despite a wide range of costs for the remaining resource types, all options proceeded to the final candidate list due to a wide range of economic and performance benefits for the Liberty-Empire system, including energy, capacity, clean baseload, and locational. Hydrogen and SMR options were considered less mature technologies, and thus were assumed to be first commercially available in 2035 and beyond as a means to provide a combination of relatively large amounts of clean energy and stable output and were considered for inclusion only in the "net zero" target portfolios. Further discussion of the net zero alternative plan development can be found in Volume 6.

Detailed descriptions and documentation of the cost and operating parameters assumed for each of the final candidate supply-side resource options can be found in Section 4.1.

SECTION 3 INTERCONNECTION AND TRANSMISSION REQUIREMENTS OF PRELIMINARY CANDIDATE OPTIONS

(3) The utility shall describe and document its analysis of the interconnection and any other transmission requirements associated with the preliminary supply-side candidate resource options identified in subsection (2)(C).

3.1 Interconnection and Transmission Constraints Analysis

(A) The analysis shall include the identification of transmission constraints, as estimated pursuant to 4 CSR 240-22.045(3), whether within the Regional Transmission Organization's (RTO's) footprint, on an interconnected RTO, or a transmission system that is not part of an RTO. The purpose of this analysis shall be to ensure that the transmission network is capable of reliably supporting the preliminary supply-side candidate resource options under consideration, that the costs of the transmission system investments associated with preliminary supply-side candidate resource options, as estimated pursuant to 4 CSR 240-22.045(3), are properly considered and to provide an adequate foundation of basic information for decisions to include, but not be limited to, the following:

1. Joint ownership or participation in generation construction projects;

2. Construction of wholly-owned generation facilities;

3. Participation in major refurbishment, life extension, upgrading, or retrofitting of existing generation facilities;

4. Improvements on its transmission and distribution system to increase efficiency and reduce power losses;

5. Acquisition of existing generating facilities; and

6. Opportunities for new long-term power purchases and sales, and short-term power purchases that may be required for bridging the gap between other supply options, both firm and nonfirm, that are likely to be available over all or part of the planning horizon.

Liberty-Empire is a member of SPP and is thus reliant on SPP's determination of transmission capacity expansion requirements. As a member of SPP, Liberty-Empire is assigned a cost-sharing allocation of all lines that are built in the SPP footprint. SPP conducts three studies directly associated with transmission planning: large generation interconnect studies, aggregate transmission service studies, and the SPP integrated transmission plan ("ITP"). The large generation interconnection study determines if any modifications are needed to connect a new generator into the transmission system. The aggregate transmission service studies determine system upgrades required to grant transmission service from a generation source to a load source. The ITP is a three-year study process which assesses SPP's regional transmission needs in the long- and near-term with the intention of creating a cost-effective, flexible, and robust transmission network that will improve access to the region's diverse generating resources. Liberty-Empire actively participates in SPP transmission planning processes through committee membership, meeting and working group attendance, participation as a customer and a transmission owner in the development and implementation of all of SPP's transmission studies, and other avenues.

Liberty-Empire modeled a generic transmission cost adder for each alternative resource examined in this IRP. For the purposes of Liberty-Empire's 2022 IRP, Liberty-Empire assigned transmission costs on a dollar per kilowatt basis for each candidate resource examined in this IRP. This cost was $225/kW in 2022 dollars and was assumed to remain flat on a real basis through the long-term horizon. The generator interconnection cost estimate is described in more detail in Section 4.3.

3.2 New Supply-Side Resources Output Limitations

(B) This analysis shall include the identification of any output limitations imposed on existing or new supply-side resources due to transmission and/or distribution system capacity constraints, in order to ensure that supply-side candidate resource options are evaluated in accordance with any such constraints.

Liberty-Empire cannot provide a generic list of transmission upgrades needed to physically interconnect any given generation source within the SPP footprint. Each request for Generator Interconnection ("GI") is required to submit to the SPP Generation Interconnection process as defined in the SPP transmission tariff. This process examines the specific location proposed for generator interconnection, its unique technical characteristics, and determines the necessary transmission upgrades necessary for that unique interconnection, as required by SPP.

SECTION 4 SUPPLY-SIDE CANDIDATE RESOURCE OPTIONS

4.1 Supply-Side Candidate Resource Options for Integration

(4) All preliminary supply-side candidate resource options which are not eliminated shall be identified as supply-side candidate resource options. The supply-side candidate resource options that the utility passes on for further evaluation in the integration process shall represent a wide variety of supply-side resource options with diverse fuel and generation technologies, including a wide range of renewable technologies and technologies suitable for distributed generation.

(A) The utility shall describe and document its process for identifying and analyzing potential supply-side resource options and preliminary supply-side candidate resource options and for choosing its supply-side candidate resource options to advance to the integration analysis.

Liberty-Empire's process for identifying and analyzing potential supply-side resource options and preliminary supply-side candidate resource options and for choosing its supply-side candidate resource options to advance to the integration analysis is described and documented in Sections 2.2 through 2.6.

As discussed in Section 2.6, the following supply-side candidate options were identified for including in the integration process:

- Natural gas-fired simple cycle Aeroderivative CT and frame CT;
- Natural gas-fired CC – 1 x 1 H Class;
- Natural gas-fired RICE*;
- Onshore wind;
- Solar photovoltaic (PV)* – single axis tracking, with and without paired storage;
- Energy storage – lithium ion battery*, vanadium redox flow battery, concrete block gravity storage;
- Nuclear small modular reactor;
- Hydrogen – retrofit on exiting CC plants, new 1 x 1 CC

*Denotes a resource option evaluated as both a distributed and utility scale energy resource.

The remainder of this section describes and documents the cost and performance assumptions developed for the resource options as used in the LCOE analysis described in Section 2.4 and the integrated planning analysis described in Volume 6. Planning-level cost and operating assumptions for all feasible resource options were collected and developed by Liberty-Empire's IRP consultant, CRA, with review and input by experts from a third-party engineering firm, Black and Veatch. Cost and operating estimates for the resource options were developed using a market scan approach for cost and operational parameters. The market scan approach involved in-depth research into recent costs data points from a variety of sources, including public reports, other utility IRP filings and Requests for Proposals, proprietary subscription-based data sources, and Liberty-Empire's and Black and Veatch's internal view based on actual and recent project estimates. The results of the market research findings were used to develop current cost estimates for the technologies as well as projections for cost changes over time.

4.1.1 Simple Cycle Technologies

A simple cycle gas CT plant utilizes natural gas to produce power in a gas turbine generator. Gas turbine manufacturers continue to develop high-temperature materials and cooling techniques to allow higher firing temperatures of the turbines, resulting in increased efficiency. Typically, CTs are used for peaking power due to their fast load ramp rates and relatively low capital costs. Typical simple cycle plants operate with natural gas as the operating fuel. Often, the ability to operate on fuel oil is also required in case the demand for power exists when the natural gas supply does not.

Frame turbines are industrial turbines designed specifically for land-based power generation or mechanical drive applications that are typically used in intermediate to peaking applications. In simple cycle configurations, these machines typically have higher heat rates when compared to aeroderivative engines; however, their capital cost per unit of capacity is also typically lower. Aeroderivative turbines are considered a mature technology and have been used in power generation applications for decades. These machines are commercially available from several vendors, including General Electric ("GE"), Siemens, and Mitsubishi Power. The combustion turbine assumptions are summarized in Table 4-13.

Table 4-13 – Combustion Turbine Performance Parameters

Parameter	Aeroderivative CT	Frame CT
Earliest Feasible Year of Installation	2025	2025
Lead Time in Years (includes development and construction)	2.0	2.0
Equivalent Forced Outage Rate	5%	5%
Scheduled Outage Days per Year	18	18
ISO Net Output, Full Load MW	50	240
Full Load Net Heat Rate, Btu/kWh	9,124	9,905
Minimum Load Net Heat Rate, Btu/kWh	12,000	10,896
Capital cost, 2023 (2020$/kW)	1,191	735
Capital cost, 2028 (2020$/kW)	1,157	716
Capital cost, 2033 (2020$/kW)	1,127	698
Fixed O&M (2020$/kW-year)	16.5	7.1
Variable O&M (2020$/MWh)	7.5	4.6
Ongoing capex (2020$/kW-year)	4.1	1.1
CO_2 Emissions (lbs/MMBtu, HHV)	119	119

4.1.2 Combined Cycle Technologies

The basic principle of the Combined Cycle Gas Turbine ("CCGT") plant is to utilize natural gas to produce power in a gas turbine which can be converted to electric power by a coupled generator, and to also use the hot exhaust gases from the gas turbine to produce steam in a HRSG. This steam is then used to drive a steam turbine and generator to produce electric power. Additionally, natural gas can be fired in the HRSG to produce additional steam and associated output for peaking load, a process commonly referred to as duct firing.

The use of both gas and steam turbine cycles (Brayton and Rankine) in a single plant to produce electricity results in high conversion efficiencies. Combined cycle facilities have heat rates that have in recent history been in the 6,500 Btu/kWh range. In the 2022 IRP, a greenfield 1 x 1 H-class CC option was included in the candidate resource option list. Operating parameters for such a resource are summarized in Table 4-14.

Table 4-14 – Combined Cycle Performance Parameters

Parameter	Combined Cycle Gas Turbine
Earliest Feasible Year of Installation	2025
Lead Time in Years (includes development and construction)	3.0
Equivalent Forced Outage Rate	5%
Scheduled Outage Days per Year	18
ISO Net Output, Full Load MW	420
Full Load Net Heat Rate, Btu/kWh	6,422
Minimum Load Net Heat Rate, Btu/kWh	7,064
Capital cost, 2023 (2020$/kW)	1,081
Capital cost, 2028 (2020$/kW)	1,064
Capital cost, 2033 (2020$/kW)	1,042
Fixed O&M (2020$/kW-year)	14.9
Variable O&M (2020$/MWh)	2.4
Ongoing capex (2020$/kW-year)	3.3
CO_2 Emissions (lbs/MMBtu, HHV)	119

4.1.3 Reciprocating Engine Technologies

The reciprocating, or piston, engine, often referred to as a RICE, operates on the four-stroke Otto cycle for the conversion of pressure into rotational energy. Many different vendors offer reciprocating engines, and they are becoming more popular due to their quick start times and operational flexibility. There are slight differences between manufacturers in engine sizes and other characteristics, but all largely share the common characteristics of quick ramp rates and quick start up.

The Wartsila 10V50DF (natural gas-fired, dual fuel) reciprocating engine, or similar, was evaluated in this assessment as a potential candidate in blocks of three engines. In addition to these utility scale estimates, a distributed resource option as a single 2 MW engine was also included. The parameters for both reciprocating engine options are summarized in Table 4-15.

Table 4-15 – Reciprocating Engine Performance Parameters

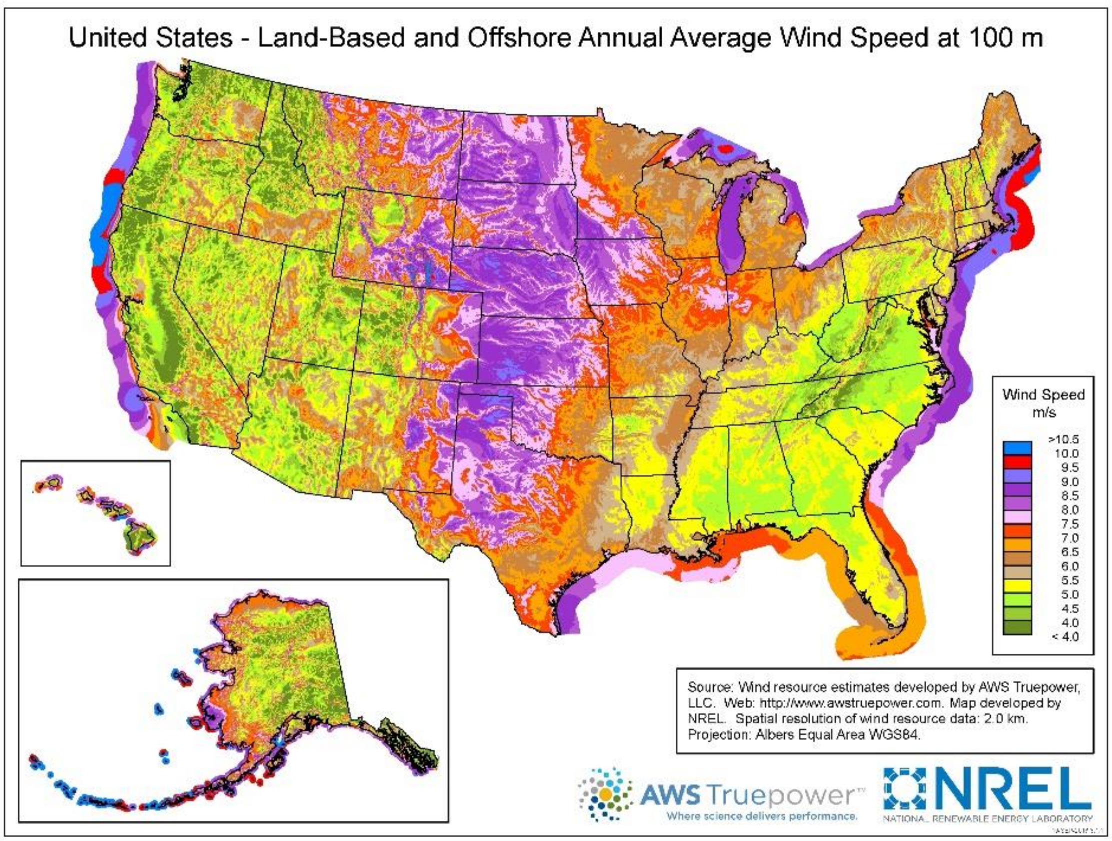
Parameter	Reciprocating Engines – Utility Scale (3 Engines)	Reciprocating Engines – Distributed
Earliest Feasible Year of Installation	2025	2025
Lead Time in Years (includes development and construction)	3.0	3.0
Equivalent Forced Outage Rate	5%	5%
Scheduled Outage Days per Year	18	18
ISO Net Output, Full Load MW	30	2
Full Load Net Heat Rate, Btu/kWh	8,298	9,250
Minimum Load Net Heat Rate, Btu/kWh	11,006	11,505
Capital cost, 2023 (2020$/kW)	1,562	1,703
Capital cost, 2028 (2020$/kW)	1,516	1,658
Capital cost, 2033 (2020$/kW)	1,473	1,617
Fixed O&M (2020$/kW-year)	25.0	25.0
Variable O&M (2020$/MWh)	7.0	7.0
Ongoing capex (2020$/kW-year)	4.1	4.1
CO_2 Emissions (lbs/MMBtu, HHV)	119	119

NP

4.1.4 Onshore Wind

Wind energy systems use the kinetic energy from wind to spin a large turbine blade, which in turn spins an electromagnetic generator shaft to produce electricity. The power output from a wind turbine depends largely on the speed of the wind and how often it blows. The SPP region has some of the strongest winds in the U.S., as shown in Figure 4-7, making it an optimal region to deploy wind energy systems.

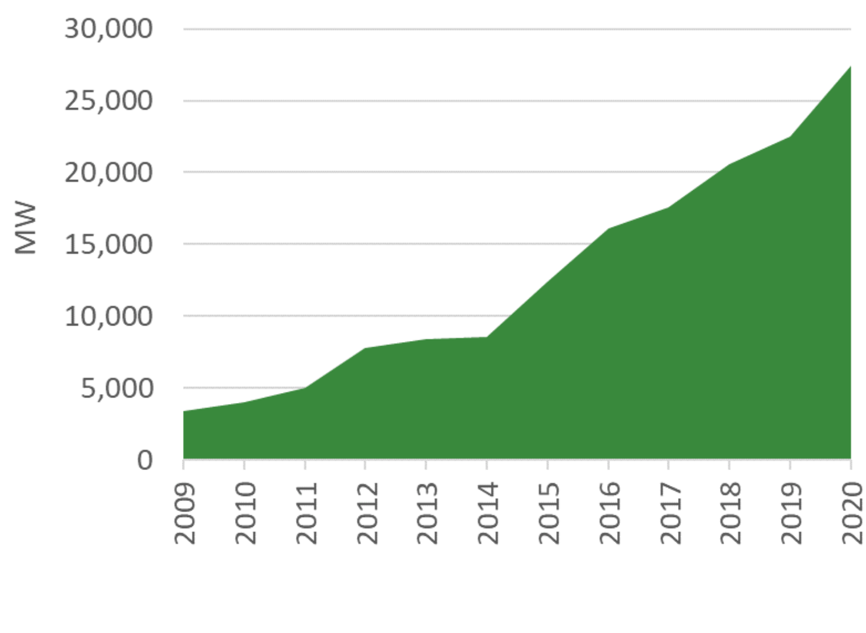
Figure 4-7 – Wind Speeds Across the U.S. (Source: NREL)



SPP has a relatively large number of wind energy systems. In 2020, wind generation accounted for 31.3% of total generation throughout the year in SPP. In February 2017, SPP became the first RTO in the U.S. to serve more than 50% of its load at a given time with wind energy. SPP has since reliably met as much as 73% of its instantaneous load with wind.

The past decade has seen a rapid deployment of wind systems in the region. In 2009, wind energy systems had a combined total capacity of 3,400 MW, which has increased more than eight times to 27,326 MW by the end of 2020, as displayed in Figure 4-8.[4] In 2020, wind surpassed coal as the largest source of energy production and is second only to gas in terms of generating capacity. SPP credits its successful and rapid deployment of wind to the region's high wind speeds, consolidated balancing authority responsibilities, and a robust transmission system. Generally, wind energy systems have become a more competitive resource nation-wide due to improvements in system designs such as larger rotor diameters, higher turbine heights, more aerodynamic designs, permanent-magnet direct-drive drivetrains, and stronger lighter-weight materials, as well as decreases in system component costs.

Figure 4-8 – SPP Installed Wind Capacity 2009-2020 (Source: SPP)



In 2017 and 2018, Liberty-Empire's Generation Fleet Savings Analysis and Customer Savings Plan demonstrated that wind resources represent a low-cost energy resource, especially when

[4] Southwest Power Pool (SPP). SPP Annual Report 2019. 2020. https://www.spp.org/documents/62057/2019%20annual%20report%2020200428%20web.pdf

incorporating the benefits of federal tax credits, which are being phased out in the near-term. Cost and performance estimates for the wind option in the 2022 IRP are shown in Table 4-16. Note that all cost estimates are provided prior to consideration of federal tax credits and their potential impact on Liberty-Empire's capital cost contribution if a tax equity partner is utilized. The details of federal tax incentives and the tax equity partner modeling assumptions included in the 2022 IRP analysis are summarized in Section 2.4.

Table 4-16 – Wind Performance Parameters

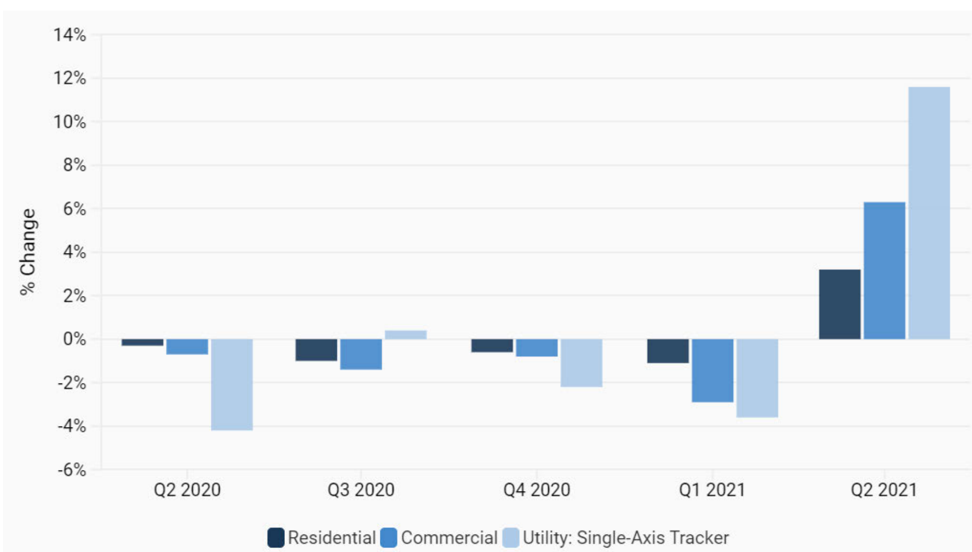
Parameter	Wind
Earliest Feasible Year of Installation	2025
Lead Time in Years (includes development and construction)	2.5
ISO Net Output, Full Load MW	100
Typical Capacity Factor, 2023	44%
Capacity Credit towards Peak	15% summer, 16% winter
Capital cost, 2023 (2020$/kW)	1,369
Capital cost, 2028 (2020$/kW)	1,214
Capital cost, 2033 (2020$/kW)	1,077
Fixed O&M (2020$/kW-year)	32.2
Ongoing capex (2020$/kW-year)	18.0

4.1.5 Solar

Solar energy is converted into electricity through the use of solar panels, which are made up of PV cells. Today, the majority of PV cells are made from either crystalline silicon or thin-film semiconductor material. Silicon cells tend to convert sunlight to electricity more efficiently but are more costly to manufacture. Thin-film materials are less costly to manufacture, but also less efficient. Some PV systems use a tracking system that orients the panels towards the sun to capture more solar radiation throughout the day. The downside of trackers is that they require systems to have less-dense configurations and cost more to install and maintain over their lifetime. Thus, for a tracker to make economic sense, the net gains from increased electricity production must exceed the added installation and maintenance cost net of tax credits. Liberty-Empire has also found this to be the case in its screening analysis. PV systems are also increasingly including battery storage to compensate for the intermittent nature of solar energy, taking advantage of declining prices for storage technologies, the ITC benefit, existing interconnection, and to store direct current electricity not from the grid.

Over the past decade, the cost of developing PV systems has dropped substantially with the improvement of technology, new materials, and lower installation costs. However, over much of 2021, shipping constraints and other supply chain challenges stemming from the global pandemic led to price increases across the U.S. solar industry. While many developers have sufficient inventory to prevent these increases from disrupting deployment in the short run, some projects may begin to see the effects early in 2022 if supply chain challenges don't abate. The quarterly change in U.S. solar PV installed prices by segment are shown in Figure 4-9. In the 2022 IRP, Liberty-Empire assumes that capital costs remain flat in real terms until 2025, then continue to decline thereafter, as presented in the capital cost tables earlier in this section.

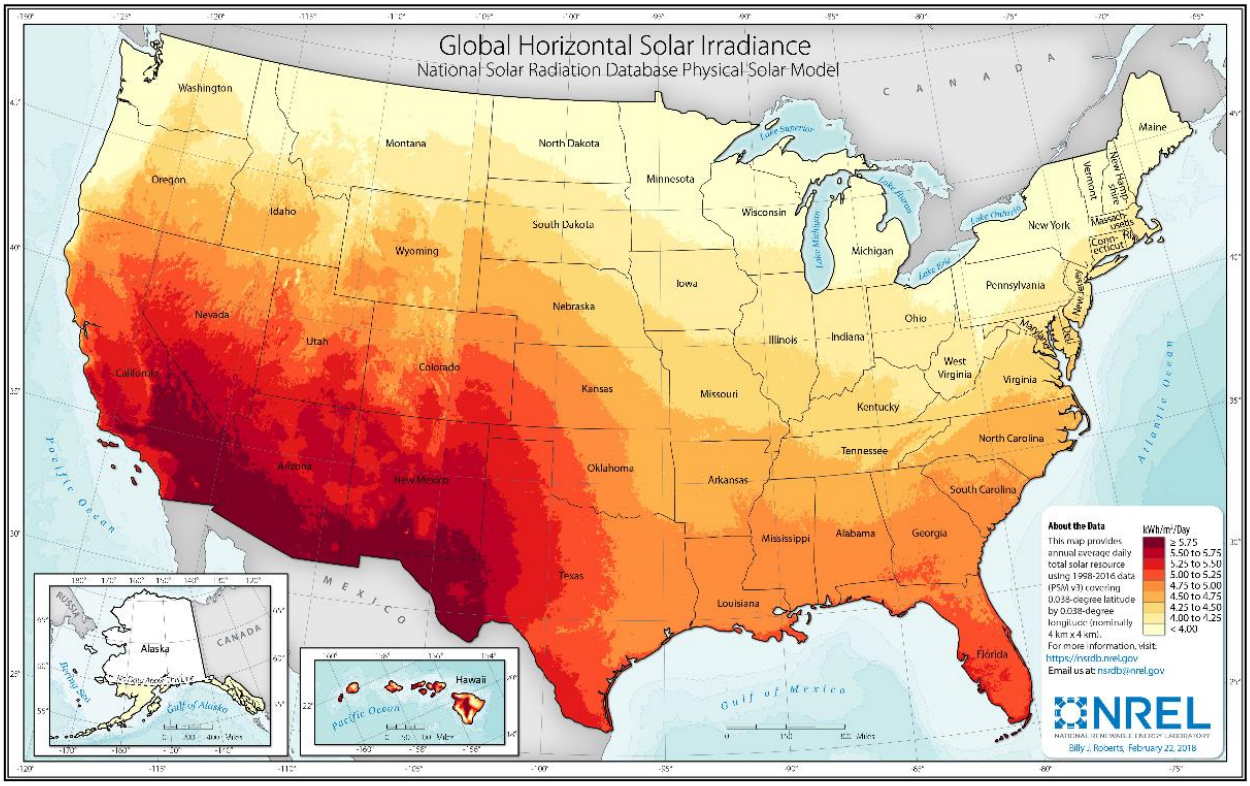
Figure 4-9 – Quarterly Change in U.S. Solar PV Installed Price by Segment (Source: SEEIA)[13]



[13] Solar Energy Industries Association (SEIA). Solar Industry Research Data. 2018. https://www.seia.org/solar-industry-research-data

Solar irradiation is generally the strongest in the Southwest and weakest in the Northeast. The irradiation levels in the SPP region fall roughly in the middle of these two extremes, leaving Liberty-Empire with a roughly average level of solar irradiation relative to the rest of the nation. Figure 4-10 presents nation-wide solar irradiation levels.

Figure 4-10 – Global Horizontal Solar Irradiance in the U.S. (Source: NREL)



Cost and performance estimates for the solar PV options (single axis tracking at both utility and community scale) are shown in Table 4-17. As with the wind estimates, all cost estimates are provided prior to consideration of federal tax credits and their potential impact on Liberty-Empire's capital cost contribution if a tax equity partner is utilized. The details of federal tax incentives and the tax equity partner modeling assumptions included in the 2022 IRP analysis are summarized in Section 2.4.

Table 4-17 – Solar PV Single Axis Tracking Performance Parameters

Parameter	Solar PV – Single Axis Tracking Utility Scale	Solar PV – Single Axis Tracking Community Scale
Earliest Feasible Year of Installation	2025	2025
Lead Time in Years (includes development and construction)	1.5	1.5
ISO Net Output, Full Load MW	50	5
Typical Capacity Factor	25%	25%
Capacity Credit towards Peak[14]	60% summer, 8% winter	60% summer, 8% winter
Capital cost, 2023 (2020$/kW)	1,200	1,680
Capital cost, 2028 (2020$/kW)	999	1,360
Capital cost, 2033 (2020$/kW)	842	1,106
Fixed O&M (2020$/kW-year)	12.0	14.0
Ongoing capex (2020$/kW-year)	0.0	0.0

Although the modeling assumes 1.5-year lead time for development, the GIA process at SPP has recently taken longer.

4.1.6 Nuclear Small Modular Reactor

Small Modular Reactors ("SMR") are a new type of nuclear fission technology utilizing smaller reactor designs, module factory fabrication, and passive safety features. Key features of an SMR include:

- Small physical footprints;
- Limited on-site preparation, leading to faster construction time and scalability;
- Siting flexibility including sites previously occupied other technologies; and
- Passive safety features, allowing the reactor to safely shutdown in an emergency without requiring human interventions.

[14] Summer capacity factor represents 2023 value. Liberty-Empire assumes declines in solar ELCC to 27-28% over the long term based on guidance from a recent SPP ELCC study and the level of solar penetration in the market from CRA's market modeling. Additional detail on CRA's market modeling and long-term capacity buildouts can be found in Volume 6.

SMR can be an alternative for providing baseload electricity without CO2 emissions. Its siting flexibility and improved safety features allow it to be sited closer to demand centers, reducing transmission investments.

SMR is still in the early stages of development, and uncertainties remain regarding the cost, performance, and availability of the technology. The cost assumptions for this IRP represent Nth-of-a-Kind ("NOAK"), reflecting an assumption that development of SMR by Liberty-Empire would occur after other similar projects were underway or operating. Table 4-18 shows the cost and performance estimates for SMR. It is assumed that SMR will be available for commercial deployment starting in 2035 for net-zero portfolios.

Table 4-18 – Small Modular Reactor Performance Parameters

Parameter	Small Modular Reactor
Earliest Feasible Year of Installation	2035
Lead Time in Years (includes development and construction)	9.0
Equivalent Forced Outage Rate	5%
Scheduled Outage Days per Year	18
ISO Net Output, Full Load MW	600
Full Load Net Heat Rate, Btu/kWh	10,455
Capital cost, 2035 (2020$/kW)	3,500
Fixed O&M (2020$/kW-year)	96.2
Variable O&M (2020$/MWh)	3.0
Ongoing capex (2020$/kW-year)	5.5
CO_2 Emissions (lbs/MMBtu, HHV)	0.0

4.1.7 Hydrogen

Hydrogen ("H2") can be utilized for combustion through the installation of a greenfield combustion turbine or combined cycle plant designed for hydrogen use or by retrofitting an existing CC plant to be hydrogen-enabled. Hydrogen CCs operate on the same principle as the NGCC systems discussed in Section 4.1.2 but with some differences in operating characteristics including:

- Energy density: H2 is one-third less energy dense than natural gas. Using hydrogen as a fuel will require a fuel accessory system configured to provide three times higher fuel flow rates into the turbine relative to using natural gas;
- Flame speed: H2 has about 4.5 times the flame speed of natural gas. The combustion systems have to be configured specifically for hydrogen to prevent the flame from propagating upstream;
- Flammability: H2 is more flammable than natural gas. The enclosure and ventilation system have to be designed to limit the concentration of hydrogen; and
- Flame temperature: H2 burns at a higher temperature than natural gas, resulting in higher NOx emissions. A selective catalytic reduction system is required to reduce NOx emissions.

H2 can play multiple roles within an electricity system. It can provide storage capacity during periods of high renewable generation and, depending on H2 prices, cycling capabilities for intermediate loads or generation capacity during periods of high electricity demand. As a gas turbine technology, hydrogen can also provide system services such as inertia, frequency response, voltage support, and regulating reserves.

Cost and performance estimates for new H2 CC and for H2 CC retrofits are shown in Table 4-19. The variable operating cost for a H2 CC is estimated to be two to three times the estimate for an NGCC, reflecting additional costs for maintaining a system with high levels of water and steam injection for emission control.

For purposes of the 2022 IRP, hydrogen is made available starting in 2035 for net-zero portfolios based on statements by various major power equipment providers committing to provide 100% H2-enabled turbines by the early-to-mid 2030s.

Table 4-19 – Hydrogen Resources Performance Parameters

Parameter	Hydrogen CC	Hydrogen Retrofit on CC
Earliest Feasible Year of Installation	2035	2035
Lead Time in Years (includes development and construction)	3.0	1.0
Equivalent Forced Outage Rate	5%	5%
Scheduled Outage Days per Year	18	18
ISO Net Output, Full Load MW	100	Same as underlying CC
Full Load Net Heat Rate, Btu/kWh	6,422	Same as underlying CC
Minimum Load Net Heat Rate, Btu/kWh	7,064	Same as underlying CC
Capital cost, 2035 (2020$/kW)	1,339	63
Fixed O&M (2020$/kW-year)	14.9	30.8
Variable O&M (2020$/MWh)	6.9	1.5
Ongoing capex, 2035 (2020$/kW-year)	6.2	28.3
CO_2 Emissions, lbs./MMBtu (HHV)	0.0	0.0

4.1.8 Storage Resources

Decreases in prices and improvements in manufacturing capacity have played important roles in the expansion of battery storage in recent years. Simultaneously, ongoing changes to industry regulation that allow or will allow stored energy resources to participate in wholesale electricity markets like SPP's Integrated Marketplace are likely to increase their value. The U.S. energy storage market continues to grow with 400 MWh of grid-connected energy storage deployments in 2019. Lithium-ion continues to be the leading technology, representing over 90% of new storage capacity in 2019.[5]

Lithium-ion batteries currently represent the industry standard option for utility-scale storage technology. These resources involve the transfer of lithium ions between electrodes during charging and discharging. There are variations in the exact chemistry of a lithium-ion battery. Generally, the cathode is made of lithiated metal oxides or phosphates and the anode is made of

[5] https://www.eia.gov/analysis/studies/electricity/batterystorage/pdf/battery_storage_2021.pdf

carbon or lithium titanate. The resulting electrodes are lightweight. Lithium is a highly reactive element, which means it can store a significant amount of energy in its atomic bonds and has high energy efficiency.

In the past few years, there has been a rapid build-out of lithium-ion manufacturing factories, including Tesla's Gigafactories, to meet the demand for batteries in EV applications, which are typically lithium-ion due to their light weight and high energy efficiency. Production costs have fallen significantly as a result of this increase in scale. Although lithium-ion batteries have a higher up-front cost than other alternatives like lead-acid batteries, they generally have important advantages over lead-acid batteries, such as their superior volumetric energy density and gravimetric energy density, meaning that they are smaller and lighter. Lithium-ion batteries are also more resilient, and thus have longer life cycles and are less likely to be harmed if discharged too quickly or if extreme weather occurs.

As discussed in Section 2.4.3, Liberty-Empire has identified a lithium-ion battery option as the best benchmark for potential storage resource additions in the short to medium term. Cost and performance estimates for the lithium-ion battery options are shown in Table 4-20. Assumptions for paired solar and battery storage systems were also developed for the candidate list. These paired systems use the costs and parameters associated with the single axis tracking solar PV options in Table 4-17 and the costs and parameters associated with the lithium-ion battery options in Table 4-20. For solar + storage resources, Liberty-Empire has assumed single axis tracking solar and lithium-ion batteries with a combined capital cost based on both a 4:1 ratio and a 2:1 ratio of solar to storage at the utility scale and a 2:1 ratio of solar to storage at the distributed scale due to the need to manage Liberty-Empire's winter peak. As with the standalone wind and storage estimates, all cost estimates are provided prior to consideration of federal tax credits and their potential impact on Liberty-Empire's capital cost contribution if a tax equity partner is utilized. The details of federal tax incentives and the tax equity partner modeling assumptions included in the 2022 IRP analysis are summarized in Section 2.4.

Table 4-20 – Lithium-Ion Battery Performance Parameters

Parameter	Lithium-Ion Battery – Utility Scale	Lithium-Ion Battery – Distributed Scale
Earliest Feasible Year of Installation	2025	2025
Lead Time in Years (includes development and construction)	1.5	1.5
ISO Net Output, Full Load MW	50	1
Storage duration (hours)	4	4
Round-trip efficiency (%)	87%	87%
Capital cost, 2023 (2020$/kW)	1,333	1,807
Capital cost, 2028 (2020$/kW)	1,016	1,377
Capital cost, 2033 (2020$/kW)	899	1,219
Capital cost, 2038 (2020$/kW)	840	1,139
Fixed O&M, 2023 (2020$/kW-year)	10.0	10.0
Ongoing capex, 2023 (2020$/kW-year)*	35.0	46.2

*Note that the ongoing capex assumes full replacement of cells after 15 years.

As discussed in Section 2.4.3, Liberty-Empire will also consider vanadium redox flow batteries with availability for 2035 and beyond for all portfolios and gravity concrete block storage only for longer-term net-zero portfolios.

Vanadium flow batteries store energy in vanadium-based electrolytes that can transfer electrons back and forth between four different oxidation states causing charge and discharge. The electrolytes are dissolved in water and stored in two tanks connected by an iron selective membrane. During discharge, an electrolyte is spent producing DC power which is converted to AC power using converters and controllers. Electrolytic fluid is then regenerated using DC power from the converter during a charge. Flow batteries are already being commercially deployed, but their supply chain is not as mature as that of lithium-ion batteries. Key benefits of flow batteries include siting flexibility, long duration capability, and no degradation during their lifetime.

The Energy Vault concrete block gravity storage system uses electric motors to lift 35-ton concrete blocks and stack them to form a tall tower. The stored potential energy involved in lifting the blocks is converted to electricity by dropping the stacked blocks one by one by a tether.

To date, Energy Vault has only built one energy storage system: a 5-MW commercial demonstrator project in Switzerland. However, given the modularity and simple underlying technology and operations, as well as significant investment activity in Energy Vault over the 2020-2021 period, Liberty-Empire evaluated this technology is a potentially viable option for longer-term net-zero portfolios with availability for 2035 and beyond.

Cost and performance estimates for flow battery and gravity storage options are shown in Table 4-21.

Table 4-21 – Flow and Gravity Storage Performance Parameters

Parameter	Flow Battery	Gravity
Earliest Feasible Year of Installation	2035	2035
Lead Time in Years (includes development and construction)	1.5	1.5
ISO Net Output, Full Load MW	50	50
Storage duration (hours)	8	8
Round-trip efficiency (%)	70%	82%
Capital cost, 2035 (2020$/kW)	2,048	1,577
Fixed O&M, 2035 (2020$/kW-year)	5.5	20.0
Ongoing capex (2020$/kW-year)	0.0	0.0

4.2 Elimination of Preliminary Supply-Side Resources Due to Interconnection or Transmission

(B) The utility shall indicate which, if any, of the preliminary supply-side candidate resource options identified in subsection (2)(C) are eliminated from further consideration on the basis of the interconnection and other transmission analysis and shall explain the reasons for their elimination.

None of the preliminary supply-side candidate resource options were eliminated from consideration based on interconnection or transmission analysis.

4.3 Interconnection Cost for Supply-Side Resource Options

(C) The utility shall include the cost of interconnection and any other transmission requirements, in addition to the utility cost and probable environmental cost, in the cost of supply-side candidate resource options advanced for purposes of developing the alternative resource plans required by 4 CSR 240-22.060(3).

For the purposes of Liberty-Empire's 2022 IRP, Liberty-Empire assigned transmission costs on a dollar per kilowatt basis for each candidate resource examined in this IRP. This cost was $225/kW in 2022 dollars and was assumed to remain flat on a real basis through the long-term horizon. The interconnection cost estimate for the Liberty-Empire region was derived from a survey of the latest available Definitive Interconnection System Impact Study ("DISIS") data. Many recent projects have been withdrawn from the transmission queue due to scarcity and prohibitive costs of interconnections. The higher cost DISIS projects in surrounding areas of Missouri, Arkansas, Oklahoma, and Kansas were found to have an average total allocated capital cost of $225/kW in real 2022 dollars. In the current environment and in the face of significant uncertainty, Liberty-Empire deemed this cost level to be representative of the marginal project local to Liberty-Empire's service territory.

Resources that utilize interconnection capacity of retiring units at existing sites and resources that are co-located at existing sites to utilize surplus or unused interconnection capacity would avoid paying this interconnection cost. Table 4-22 shows Liberty-Empire's interconnection rights at retiring sites or sites suitable for co-located resources. Distributed resources also avoid paying interconnection costs.

Table 4-22 – Interconnection Availability at Existing Sites

Plant	Plant Retirement	For Co-Location		For Replacement		
		Type	ICAP MW	Type	ICAP MW	Year Online
Riverton 10/11	2025	n/a	n/a	RICE	30	2025
Energy Center 1/2	2026 or 2035	Solar and/or storage	Up to 175	Any	Up to 175 (incremental to co-located)	2026 or 2035
Riverton CC (Net Zero only)	2035, 2045	n/a	n/a	Any	283	2035, 2045
State Line CC (Net Zero only)	2035, 2050	n/a	n/a	Any	329	2035, 2050
Neosho Ridge	n/a	Solar and/or storage	Up to 301	n/a	n/a	n/a
North Fork Ridge	n/a	Solar and/or storage	Up to 149	n/a	n/a	n/a
Kings Point	n/a	Solar and/or storage	Up to 149	n/a	n/a	n/a
Asbury	n/a	Solar and/or storage	Up to 30	n/a	n/a	n/a

4.3.1 Co-Location at Existing Sites

For the 2022 IRP, Liberty-Empire considered the ability to co-locate new resources at the following existing sites: Energy Center 1 and 2, North Fork Ridge Wind Farm, Kings Point Wind Farm, Neosho Ridge Wind Farm, and the Asbury site. Based on land and siting availability at these sites, Liberty-Empire assumed that solar and/or lithium-ion battery storage resources could be co-located at the sites prior to unit retirement up to the amount of the interconnection availability, with 2025 being the first feasible in-service year. Co-located resources could avoid paying generator interconnection costs and provide energy value to the portfolio by selling generation into the market and/or serving Liberty-Empire load in times of interconnection availability.

As discussed further in Volume 6 Section 3.2, resources co-located at the Energy Center site were assumed to not receive capacity credit from SPP until Energy Center 1 and 2 were retired because Energy Center 1 and 2 already provide capacity value up to the full amount of the interconnection availability. Thus, they were evaluated based on their ability to provide energy value to the portfolio without incurring transmission interconnection costs. Based on these modeling parameters, co-located resources were optimally picked up at select sites in the integrated portfolio modeling described in Volume 6.

To determine the amount of solar and/or paired storage resources that could be co-located at the existing wind sites of Neosho Ridge, North Fork Ridge, and Kings Point, CRA developed an optimization model that considered as inputs the expected 8760 wind generation profile at each site, the expected 8760 solar generation profile, key operational parameters for a storage asset (e.g., duration, efficiency, etc.), the capital costs to build and operate the new solar and storage assets, the value of capacity of the new solar and storage assets, and the hourly market power price defining the value of the generation.

For each wind site, the optimization model evaluated the optimal ICAP MW amount of solar and storage that could be co-located at the site, defined as the combined amount of solar and storage that, in conjunction with output from the wind resource, would maximize the value of the site over the 30-year life of the project. The model limited wind and solar curtailment such that the NPV of the lost value of curtailed energy over the 30-year life of the project was below $225/kW (i.e., the cost of interconnecting a resource at a greenfield site). To understand how the value of these resources might change over time, CRA developed outputs for all sites for a scenario where resources were installed in 2025 and for a scenario where resources were installed in 2035. The results of the analysis are shown in Table 4-23. For IRP modeling purposes, the solar and paired storage ICAP values represent the maximum amount of co-located capacity that would be lower cost than new greenfield development.

Table 4-23 – Co-Location Results at Wind Sites

Year Installed	Wind Site	Wind ICAP MW	Expected Annual Wind Capacity Factor	Solar ICAP MW	Paired Storage ICAP MW
2025	Neosho Ridge	301	50%	249	34
2025	North Fork Ridge	149	44%	142	13
2025	Kings Point	149	46%	137	13
2035	Neosho Ridge	301	50%	329	68
2035	North Fork Ridge	149	44%	185	33
2035	Kings Point	149	46%	178	31

More of each resource is attractive assuming 2035 installation versus 2025 installation because the market energy value is projected to increase over time. In addition, storage was found to become more valuable over time as market power prices are expected to increase and as capital costs are expected to decline.

SECTION 5 SUPPLY-SIDE UNCERTAIN FACTORS

(5) The utility shall develop, and describe and document, ranges of values and probabilities for several important uncertain factors related to supply-side candidate resource options identified in section (4). These cost estimates shall include at least the following elements, as applicable to the supply-side candidate resource option:

5.1 Fuel Forecasts

(A) Fuel price forecasts, including fuel delivery costs, over the planning horizon for the appropriate type and grade of primary fuel and for any alternative fuel that may be practical as a contingency option;

For purposes of the 2022 IRP, Liberty-Empire developed a set of coal price and natural gas price forecast ranges for use in the portfolio analysis for both existing and new resources. This section describes the existing natural gas-fired and coal-fired resources and fuel requirements in Liberty-Empire's existing portfolio, followed by a description and documentation of the fuel price ranges developed for the IRP.

5.1.1 Existing Coal and Natural Gas-Fired Unit Fuel Requirements

Coal Fuel Requirements

As discussed previously in Section 1.2, Liberty-Empire holds minority ownership shares in coal-fired resources at two locations: the Iatan and Plum Point facilities. Liberty-Empire's ownership share at the Iatan plant is 12 percent (approximately 84 MW of Unit 1 and 108 MW of Unit 2). Kansas City Power & Light ("KCP&L") is the operator of this plant and is responsible for arranging its fuel supply. The PRB coal burned at Iatan is transported by rail by the Burlington Northern and Santa Fe ("BNSF") Railway Company. Liberty-Empire owns, through an undivided interest, 7.52 percent (approximately 50 MW) of the coal-fired Plum Point Energy Station. Plum Point Services Company, LLC ("PPSC"), the project management company acting on behalf of the joint owners, is responsible for arranging its fuel supply. Liberty-Empire has a 15-year lease agreement, expiring in 2024, for 54 railcars for Liberty-Empire's ownership share of Plum Point.

In December 2010, Liberty-Empire entered into another 15-year lease agreement for an additional 54 railcars associated with the Plum Point PPA.

Natural Gas Fuel Requirements

As discussed previously in Section 1.2, Liberty-Empire owns natural gas-fired resources at three locations: the Riverton, Energy Center, and State Line generation facilities. The Riverton facility consists of a combined cycle unit (Riverton 12) fueled entirely by natural gas and two small simple cycle natural gas-fired units (Riverton 10 and 11) with dual fuel capability with fuel oil. The Energy Center generation facility consists of four natural gas-fired turbines. Two of the units, Energy Center 1 and 2, also have the capability to burn fuel oil as a backup fuel. Finally, the State Line facility consists of a natural gas-fired combustion turbine (State Line 1) with the capability to burn fuel oil and the jointly-owned natural gas-fired SLCC. During 2020, fuel consumption at the Energy Center was 99.8 percent natural gas on a generation basis and 99.9 percent natural gas at State Line 1. During 2021, fuel consumption at the Energy Center was 83 percent natural gas on a generation basis and 88 percent natural gas at State Line 1.

Liberty-Empire has firm transportation agreements with Southern Star Central Pipeline, Inc. with current expiration dates of December 1, 2025 for the transportation of natural gas to SLCC. Liberty-Empire has additional firm transportation agreements to supply Riverton Unit 12 through September 1, 2025. Liberty-Empire also has firm transportation agreements to supply Energy Center through June 1, 2025. These transportation agreements can also supply a portion of the natural gas required to State Line 1, the Energy Center facility, or the Riverton facility, as elected by Liberty-Empire on a secondary basis. Any remaining gas transportation requirements, although small, will be met by utilizing capacity release on other holder contracts or interruptible transport, or will be delivered to the plants by others.

The majority of Liberty-Empire's physical natural gas supply requirements will be met by short-term forward contracts and spot market purchases. Forward natural gas commodity prices and volumes are hedged several years into the future in accordance with Liberty-Empire's Risk

Management Policy in an attempt to lessen the volatility in Liberty-Empire's fuel expenditures and gain predictability.

5.1.2 Coal Price Forecast

Figure 4-11 and Table 4-24 summarize the delivered fuel price forecast for Southern PRB coal associated with Iatan and Plum Point Energy Center.

Figure 4-11 - Coal Price Forecast for Southern PRB Coal (Iatan and Plum Point Delivered)

****Confidential in its Entirety****

[redacted]

NP

Table 4-24 – Coal Price Forecast for Southern PRB Coal (Iatan and Plum Point Delivered)

****Confidential in its Entirety****

[redacted]

Coal price forecasts for Liberty-Empire's jointly-owned units were based on the operator's most recent 5-year fuel projection in the near term, which incorporates the most recent coal contracts at each of the plants for those years. In the medium to longer term, the coal price forecasts were escalated based on forecasted growth rates for PRB coal costs as developed by Horizons Energy, combined with transportation adders for Liberty-Empire's coal units.

For the 2022 IRP, Liberty-Empire did not develop high or low scenario forecasts for PRB coal prices for two primary reasons. First, Liberty-Empire's coal-fired resources consist only of Iatan and Plum Point, both of which are minority-owned and are not operated by the Company. Second, Liberty-Empire does not plan to consider any new coal resources to the portfolio in the future.

5.1.3 Natural Gas Forecast

For the 2022 IRP, Liberty-Empire contracted with its IRP consultant, CRA, to develop a set of market fundamentals-based natural gas price scenario forecasts (Base Case, High Case, and Low Case) for use in the portfolio analysis for both existing and new natural gas-fired resources. Natural gas prices were developed by CRA using a set of fundamental market models, including the Natural Gas Fundamentals ("NGF") model, which produces bottom-up natural gas price and production projections in North America. Inputs to NGF include the latest views from public sources (e.g. EIA and PGC) on natural gas demand by sector, production forecasts, drilling costs, and oil prices under various fundamental potential market conditions. These inputs are further described later in this section.

CRA also forecasted seasonal and regional basis over the long-term using the Gas Pipeline Competition Model ("GPCM") model, blended with market forwards over the near term to maintain consistency with observed market prices.

Figure 4-12 and Table 4-25 show the forecasted Henry Hub natural gas prices for the Base, High, and Low Case price scenarios on a monthly basis.
Figure **4-13** and Table 4-25 show the forecasted Southern Star Delivered natural gas prices for the Base, High, and Low Case price scenarios on a monthly basis.

NP

Figure 4-12 - Forecasted Base, High, and Low Natural Gas Prices (Henry Hub)

****Confidential in its Entirety****

[redacted]

Figure 4-13 - Forecasted Base, High, and Low Natural Gas Prices (Southern Star Delivered)

****Confidential in its Entirety****

[redacted]

NP

Table 4-25 – Forecasted Base, High, and Low Natural Gas Prices (Henry Hub and Southern Star)

****Confidential in its Entirety****

[redacted]

5.1.4 Natural Gas Price Forecasting Methodology

Liberty-Empire's 2022 IRP natural gas price forecasts are driven by several key market assumptions regarding the major supply and demand dynamics in the North American natural gas market. Figure 4-14 provides a high-level overview of CRA's natural gas price development approach over the study horizon. Figure 4-15 provides an overview of the key inputs that drive CRA's fundamental forecast in its Natural Gas Fundamentals ("NGF") model.

Figure 4-14 – Overview of CRA's Natural Gas Price Development Approach

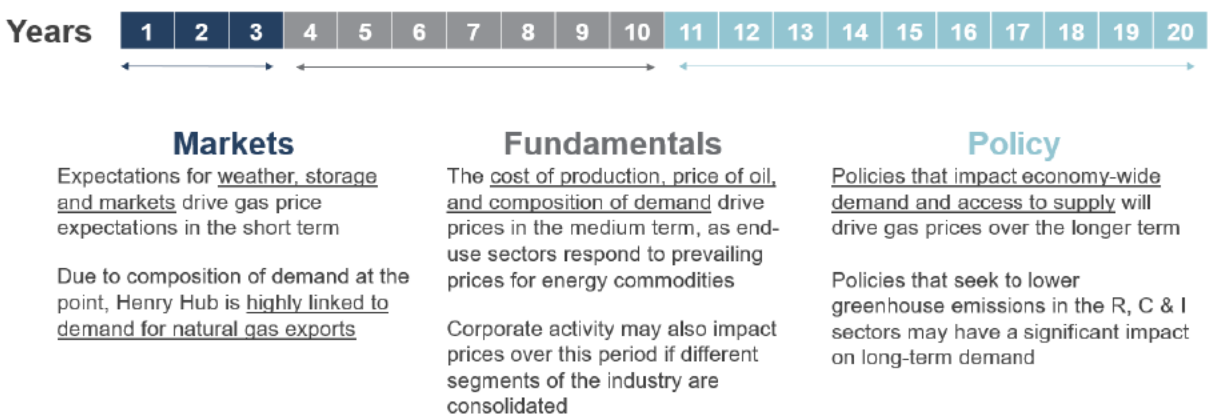
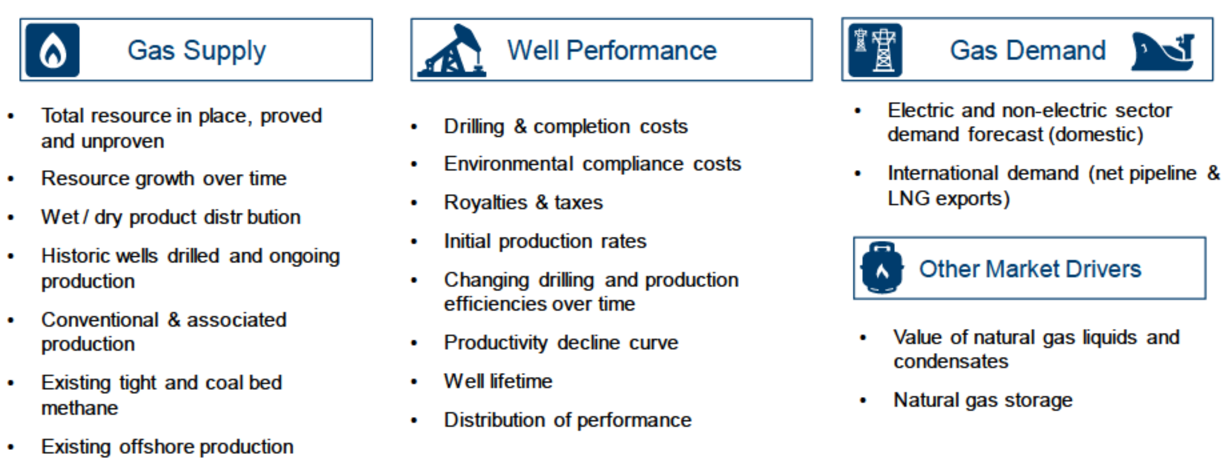


Figure 4-15 – Overview of CRA's NGF Model Inputs



5.1.5 Natural Gas Price Forecast – Base Case Drivers

CRA's Base Case natural gas price forecast is based on a fundamental evaluation of key supply and demand side drivers as described in more detail below.

Resource Size

In developing long-term estimates for natural gas resource size, CRA relied on the Potential Gas Committee (PCG) "minimum" value as the starting value for recoverable shale reserves, with the resource base growing over time at a steady rate until the PGC "most likely" value is reached in 2050. The minimum value is based on a 100% probability that the resource is recoverable, and the most likely value adds additional resource with reasonable assumptions about source rock, yield factor, and reservoir conditions.

Well Productivity

Natural gas well productivity assumptions are important drivers of ultimate production efficiency, especially since the bulk of the natural gas resource is currently unproven, meaning that the geology of that resource is currently unknown. In developing assumptions for this variable, CRA generated productivity distributions for each production basin based on drilling data in regions that producers expected to have favorable geology. CRA's view is that historical data has a bias towards higher producing sub-regions, since the wells that are completed and ultimately produce gas do not reflect a random sampling of the underlying geology in each basin. Therefore, to reflect the expectation that the remaining resource is more likely to be lower quality over time as the premium acreage is depleted, CRA assumes a "Poor Heavy" productivity distribution for future undiscovered resource in the Base Case.

Well Costs

CRA develops drilling cost assumptions by evaluating reported costs from major producers within a supply region. Producers reported improvements in drilling and O&M costs across most, but not all, shale basins in 2020, and CRA broadly assumes that these improvements will continue over time.

For going forward costs, CRA relies on the EIA's AEO projections for improvements in drilling and O&M costs. EIA's approach incorporates annual improvements to key well inputs that account for ongoing innovation in upstream technologies and reflects the average annual growth rate in natural gas and crude oil resources from historical time periods. Drilling costs are expected to decline by 1% per year for tight oil and shale gas formations and decline by 0.25% per year for all other basins. Equipment and operating costs are expected to decline by 0.5% per year for tight oil and shale gas formations and decline by 0.25% per year for all other basins.

Domestic Demand

In projecting domestic natural gas demand growth, CRA relies on the AEO's projections for residential, commercial, industrial, and transport demand and develops an independent electric sector demand forecast using its hourly Aurora dispatch model of the entire United States. Figure 4-16 presents historical and forecast domestic demand assumptions through 2040 from these sources. Electric sector demand is expected to be relatively flat throughout the forecast horizon. The AEO's growth expectations for other sectors are also relatively flat, with some growth expected in the industrial sector over time.

Figure 4-16 – Domestic Natural Gas Demand Assumptions – Reference Case

****Confidential in its Entirety****

[redacted]

Exports – LNG and to Mexico

CRA develops projections for natural gas exports to Mexico via pipeline and to other international markets through LNG by reviewing estimates published by sources like the AEO and conducting analysis of specific export projects under development.

While several LNG export projects are now online or under construction, due to softening prices and increased competition, CRA expects that few, if any, currently proposed projects will be completed after Calcasieu Pass and Golden Pass come online in 2023 and 2024. CRA's Reference Case projection for LNG exports grows to just under 20 bcf/day by 2024.

While CRA expects that exports to Mexico will also increase over time, actual exports to Mexico are not keeping pace with the expansion of cross-border export capacity. Numerous pipeline projects within Mexico have faced construction delays, and completed projects are operating well below capacity. For example, the 1.1 Bcf/d Comanche Trail pipeline has been utilized only 10% on average since completion in June 2017, and the 1.4 Bcf/d Trans-Pecos pipeline completed in 2017 currently has operated at 10-15% of total capacity since completion. Therefore, in the

Reference Case, CRA projects modest additional growth in export volume, but expects that pipeline capacity will continue to be underutilized.

Base Case Natural Gas Price Forecast Summary

As a part of its commodity price development process, CRA blends short-term gas price forwards with the fundamental forecast to capture current market dynamics. At the time of forecast development, natural gas spot prices and short-term forwards were significantly higher than recent history, driven by increased demand for gas exports and relatively low storage inventories heading into the 2021/2022 winter season. While CRA incorporated the effect of the higher spot prices in its near-term forecast, the observed run-up in natural gas prices does not affect CRA's long-term price forecast based on the expectation that the drivers will be moderated over time. This sentiment was reflected in the broader market, with market forwards as of October 2021 showing a return to prices comparable with recent history following the 2022/2023 winter season largely due to the following factors:

- LNG Exports: The spike in international demand is driven by short-term factors that are expected to moderate over the longer term. Even if US production does not increase in response to higher prices, other sources of LNG (e.g., Qatar) can ramp up production in response to higher prices.
- Low Storage: CRA expects that over the longer term, US production will increase in response to these price signals. Higher US prices are already driving a modest increase in rig counts and drilling activity.

CRA's long-term Base Case price forecast was developed based on each of the supply-demand inputs discussed above and is shown in Figure 4-17. The Base Case expects prices to fall from current forward levels over the next few years and then rise back towards $4/MMBtu (real) over the long-term. A brief summary of the key drivers of the Base Case Henry Hub and regional forecasts follows:

- Increased discipline in shale drilling programs has brought production growth more in line with demand growth. Natural gas producers have not immediately responded to higher gas prices with increased production, and prices will remain somewhat elevated in the next couple of years relative to recent history.
- CRA's Base Case view reflects expectations for industry consolidation as well as modest restrictions on supply access driven by the Biden Administration's ban on further drilling in federal lands.
- LNG exports and pipeline exports to Mexico grow over time and combine with strong domestic demand to increase prices modestly over the forecast period as the lowest-cost production regions are exhausted.
- Expectations for downward price pressure driven by improvements in drilling and O&M costs are expected to be moderated by lower domestic oil prices and associated gas volumes.
- CRA has observed limited productivity improvements in 2020 relative to prior years, primarily driven by crowding into prime regions, not technical advancements.
- Policy shifts at FERC will add cost and schedule to pipeline expansions, although a new pipeline certificate policy has not been implemented. In the Base Case, limited pipeline expansion is assumed in states which have withheld permits for pipeline expansions. This has caused a slight widening of basis between supply basins and market hubs.

Figure 4-17 illustrates the Base Case for Henry Hub and Southern Star in 2020$/MMBtu.

Figure 4-17 – Base Gas Natural Gas Price Forecast

****Confidential in its Entirety****

[redacted]

5.1.6 Natural Gas Price Forecast – High Case Drivers

Under the High Case, natural gas prices rise more quickly over the forecast period as restrictions on drilling limit the available resources. Producers are expected to realize fewer improvements in drilling efficiency and cost over time, and international demand for U.S. natural gas remains robust. These factors drive Henry Hub natural gas prices up to $6-7/MMBtu in real 2020$ in the long term. Figure 4-18 illustrates the High Case for Henry Hub and Southern Star in 2020$/MMBtu.

NP

Figure 4-18 – High Case Natural Gas Price Forecast

****Confidential in its Entirety****

[redacted]

5.1.7 Natural Gas Price Forecast – Low Case Drivers

Under the Low Case view, long-term prices remain flat or fall modestly due to a more favorable view of the long-term resource base. Improvements in drilling efficiency and costs advance more rapidly than in the Base Case view, and international demand for U.S. gas is lower over time as Mexican energy reform stalls and competitors capture more of the LNG market. These factors keep Henry Hub natural gas prices below $3/MMBtu in real 2020$ in the long term. Figure 4-19 illustrates the Low Case for Henry Hub and Southern Star in 2020$/MMBtu.

Figure 4-19 – Low Case Natural Gas Price Forecast

****Confidential in its Entirety****

[redacted]

5.1.8 Natural Gas Risk Management Policy

Liberty-Empire works diligently to mitigate the price volatility associated with changes in natural gas pricing. In 2001, Liberty-Empire developed and implemented a Risk Management Policy ("RMP") to manage this volatility. The policy was revised and formally adopted on July 19, 2019. The RMP serves to minimize Liberty-Empire's exposure to the impacts of fluctuating natural gas prices. In general terms, Liberty-Empire's current RMP allows the use of forward contracts to help manage price volatility, however, some financial hedges for the review period may have been in place as a result of the legacy natural gas hedging policy. The RMP includes a minimum annual quantity of natural gas whose price must be established in advance through physical gas contracts. The natural gas hedging policy also addresses how far in the future procurement may take place and for which months the hedging may apply. Liberty-Empire has currently established the price on the following quantities of natural gas for the upcoming calendar years in Table 4-26.

Table 4-26 – Liberty-Empire Natural Gas Hedges

****Highly Confidential in its Entirety****

[redacted]

5.2 Capital Costs of Supply-Side Candidate Options

(B) Estimated capital costs including engineering design, construction, testing, startup, and certification of new facilities or major upgrades, refurbishment, or rehabilitation of existing facilities;

The capital costs modeled for each resource option assumes an EPC contracting strategy. Each option includes an allowance for typical owner's costs, an on-site switchyard, transmission interconnect, natural gas interconnect, and water interconnect, as applicable. Ranges for high and low capital costs were developed for candidate supply-side resources as part of the larger process of developing cost and operational parameters. These ranges are shown in Table 4-27**.**

Table 4-27 – Capital Cost Ranges over Time for Candidate Supply Side Options

Capital Costs (2020$/kW)						
Case	Year	Combined Cycle	Combustion Turbine-Frame	Combustion Turbine-Aero-derivative	RICE - Utility Scale	RICE - Distributed
Base	2023	1,081	735	1,191	1,562	1,703
Base	2028	1,064	716	1,157	1,516	1,658
Base	2033	1,042	698	1,127	1,473	1,617
Low	2023	957	623	1,077	1,147	1,221
Low	2028	942	607	1,047	1,112	1,191
Low	2033	922	592	1,020	1,081	1,163
High	2023	1,255	828	1,282	1,968	2,518
High	2028	1,235	805	1,246	1,910	2,449
High	2033	1,209	785	1,213	1,856	2,386

Capital Cost (2020$/kW)									
Case	Year	Solar PV - Single Axis Track-ing	Solar PV - Dist.	Li-Ion Storage - Utility-Scale	Li-Ion Storage - Dist.	Solar PV + Storage (4:1) - Utility Scale	Solar PV + Storage (2:1) - Utility Scale	Solar PV + Storage (2:1) - Distribu ted	Wind
Base	2023	1,200	1,680	1,333	1,807	1,227	1,244	1,722	1,369
Base	2028	999	1,360	1,016	1,377	1,002	1,005	1,365	1,214
Base	2033	842	1,106	899	1,219	853	861	1,144	1,088
Low	2023	1,100	1,247	870	1,179	1,054	1,023	1,224	1,123
Low	2028	858	924	561	761	798	759	870	905
Low	2033	671	682	444	601	625	595	655	731
High	2023	1,491	2,094	1,618	2,194	1,516	1,533	2,127	1,586
High	2028	1,423	1,980	1,373	1,861	1,413	1,406	1,941	1,428
High	2033	1,307	1,796	1,276	1,730	1,319	1,296	1,774	1,303

Capital Cost (2020$/kW)						
Case	Year	Hydrogen CC	Small Modular Nuclear	Hydrogen Retrofit	Flow Battery (8-hr)	Gravity
Base	2035	1,339	3,500	63	2,048	1,577
Base	2038	1,328	3,389	59	1,966	1,514
Base	2041	1,316	3,282	55	1,884	1,451
Low	2035	1,226	3,089	58	1,360	706
Low	2038	1,216	2,991	54	1,270	659
Low	2041	1,204	2,896	50	1,181	613
High	2035	1,518	4,567	84	2,859	3,407
High	2038	1,506	4,423	79	2,859	3,407
High	2041	1,492	4,282	74	2,859	3,407

5.3 Fixed and Variable Costs of Supply-Side Candidate Options

(C) Estimated annual fixed and variable operation and maintenance costs over the planning horizon for new facilities or for existing facilities that are being upgraded, refurbished, or rehabilitated;

Base Case O&M costs for the candidate options are included in the tables in the previous sections. Costs are broken out by fixed costs, variable costs, and major maintenance costs depending on the type of technology being evaluated.

5.4 Emission Allowance Forecasts

(D) Forecasts of the annual cost or value of emission allowances to be used or produced by each generating facility over the planning horizon;

5.4.1 CO2 Prices

Although several legislative and executive actions related to carbon emissions have been attempted over the last decade, there is currently no price on carbon and no binding emission limits at the federal level. As of the time of the development of Liberty-Empire's 2022 IRP assumptions, the Biden Administration had begun to take executive actions related to carbon emission reductions and had introduced several climate-related legislative proposals as part of its overall infrastructure package. However, no policies directly regulating carbon emissions were signed into law as of March 2022.

Given a history of federal proposals to regulate carbon emissions, Liberty-Empire's Base Case incorporates a modest price on carbon emissions of $9-10/short ton starting in 2026, which can be seen as a proxy for several different potential pathways for legislative action or executive regulation (not explicitly a carbon tax). CRA's analysis suggests that pricing between $9-15/ton (in real 2020$) between 2026 and 2040 would achieve 70-80% carbon-free generation from the U.S. power sector over the long term relative to a recent historical year baseline, depending on other market factors and dynamics. Such a carbon price would likely result in significant additional coal-to-gas switching nationwide and pressure approximately 80% of the existing coal fleet across the country to retire by 2040. The price would also improve the economics of renewable and other clean energy generation.

Liberty-Empire also evaluated a High Case carbon scenario, representing a much more stringent federal carbon policy that starts earlier than the Base Case view in 2024, then ramps up in stringency over time, pushing the power market toward a net-zero-type target in the long term. The High Case carbon scenario is based on the premise that the Biden Administration and Congress lay the groundwork for a carbon emission reduction program via a tax or cap-and-trade regime, with future governments implementing stricter CO2 policy to establish net zero power sector targets by 2040. Based on CRA's analysis, a carbon price increase to the $80-90/ton range (in real 2020$) could make certain alternative technologies required to achieve net zero emissions by the 2035-2040 time period (such as hydrogen, CCS, and nuclear) economically feasible.

Finally, Liberty-Empire also evaluated a Low Case carbon scenario which assumes no carbon price through the horizon. A zero-carbon regulation policy could be due to either less stringent environmental regulation at the federal level or environmental regulation that does not directly regulate carbon emissions. Figure 4-20 shows the projected CO_2 costs ($/short ton) for all scenarios in both nominal and real 2020 dollars.

Figure 4-20 – CO_2 Price Forecast

****Confidential in its Entirety****

[redacted]

5.4.2 NOx and SO_2 Prices

NO_X and SO_2, along with many other pollutants, are regulated by a number of state and federal statutes that complicate price projections for the costs of emissions, the limits on the emissions themselves, and the projected future levels of emissions. Figure 4-21 presents SO_2 price forecasts for the states of Missouri and Kansas, respectively. Figure 4-22 displays an annual price forecast for NO_X.

NP

Figure 4-21 - SO_2 Group 1 (MO) Price Forecast

****Confidential in its Entirety****

[redacted]

Figure 4-22 - NO_X Annual Price Forecast

****Confidential in its Entirety****

[redacted]

5.5 Power Prices

Based on the three fuel price scenarios and three carbon price scenarios, Liberty-Empire developed nine permutations of power market outcomes and resulting market power price trajectories to be used as inputs in the integrated resource planning analysis. Power prices were determined through long-term capacity expansion ("LTCE") modeling of the power market using the Aurora market model. The nine power price scenarios, summarized for SPP South Hub, are shown in Figure 4-23 on an annual average basis.

Figure 4-23 – SPP South Hub All Hours Power Prices

****Confidential in its Entirety****

[redacted]

The Base Gas & Base Carbon power price scenario was used as the price inputs for simulation of day-ahead dispatch for Liberty-Empire's alternative resource portfolios for the Base Case. The remaining eight scenarios were used in the Critical Uncertain Factor analysis. Based on SPP guidance, ELCC trajectories for solar and storage resources also differed by power market outcome scenario based on a declining trajectory related to renewable and storage penetration levels in the broader SPP market. The ELCC decline curves are summarized in the following graphics for solar and storage resources.

Figure 4-24 – Solar Capacity Credit by Power Market Outcome Scenario

****Confidential in its Entirety****

[redacted]

Figure 4-25 – Storage Capacity Credit by Power Market Outcome Scenario

****Confidential in its Entirety****

[redacted]

ESOP

Because the core Aurora market and portfolio model is fundamentally based on a day-ahead hourly simulation, Liberty-Empire performed additional analysis to estimate the incremental value streams that flexible resources can achieve by participating in markets beyond day-ahead energy. To do this, CRA employed its proprietary Energy Storage Operations ("ESOP") model, an optimization model that computes revenues through participation in energy and ancillary service markets with five-minute granularity. Given simulated energy and ancillary service pricing information, ESOP solves for optimal dispatch decisions unique to a price-taking resource's technological characteristics and a regional market's participation rules. Liberty-Empire evaluated the potential ancillary service value and sub-hourly energy revenue that highly flexible, fast-ramping supply-side resources (e.g. storage and gas peaking) could provide in these markets through simulation of co-optimized unit dispatch in sub-hourly energy and ancillary service markets.

For the 2022 IRP, the SPP five-minute real-time markets for energy, reg-up, reg-down, and spinning reserves were evaluated, with a focus on the performance of 4-hour lithium-ion battery storage, 8-hour flow battery storage, gravity storage, paired solar + storage (4:1 ratio), paired solar + storage (2:1 ratio), CT – aeroderivative, CT – frame, and RICE in order to evaluate specific tradeoffs of these capacity-advantaged resource options in Liberty-Empire's portfolio. CRA estimated real-time sub-hourly energy and ancillary service price forecasts based on historical relationships between day-ahead energy and real-time energy and ancillary service prices. These relationships were used to "shape" each of CRA's nine day-ahead power price scenarios into 5-minute real-time energy price projections for use in ESOP. While long-term market developments (e.g. market rules changes, actual real-time prices, SPP storage and renewable capacity buildouts) are highly uncertain, CRA's modeling provided a reasonable estimate for this value. An illustrative example of simulated real-time sub-hourly dispatch of a 4-hour lithium-ion battery, produced from ESOP, is shown below for a sample 2025 winter day under the Base Carbon & Base Gas case.

Figure 4-26 – ESOP Real-Time Li-Ion Battery Dispatch Example (2025 Winter Day)

****Confidential in its Entirety****

[redacted]

Liberty-Empire assumed that units operated in the market according to assumed asset-specific characteristics reviewed by Black & Veatch (e.g. ramp rates, cycle limits, etc.). Liberty-Empire developed ESOP results for each of the power market outcome scenarios and for each of the technology types described previously. The incremental real-time sub-hourly energy and ancillary service value was then included as an offset to costs for purposes of portfolio optimization and revenue requirement modeling.

5.6 Leased or Rented Facilities Fixed Charges

(E) Annual fixed charges for any facility to be included in the rate base, or annual payment schedule for leased or rented facilities; and

Liberty-Empire has no leased or rental facilities.

5.7 Interconnection or Transmission Costs for Supply-Side Candidates

(F) Estimated costs of interconnection or other transmission requirements associated with each supply-side candidate resource option.

As discussed in Section 4.3, interconnection costs for all supply-side candidate resource options is assumed to be $225/kW ($2022) in the Base Case. These costs are assumed to apply for all utility scale supply-side resources, but not distributed resources (solar, storage, RICE). The assumed scenario trajectories for potential high and low interconnection costs are shown in Figure 4-27. The high case represents a scenario where system-wide renewable build-out accelerates and interconnection becomes scarcer, resulting in a cost level reflective of the upper end of observed SPP interconnection projects. The low case represents a lower interconnection demand and cost levels associated with the lower end of observed SPP projects.

Figure 4-27 – Generator Interconnection Cost

****Confidential in its Entirety****

[redacted]