

Chapter 6 - Appendix A

Characterization Data – New Resources¹

6.1 Technology Characterization

Cost, performance, and operating characteristics were developed for renewable resources, energy storage, and thermal resources with input from Ameren Missouri's internal resources. Detailed characteristics data is presented in the Tables at the end of this appendix.

6.2 Capacity, Capacity Factor, and Operations Mode

The selection of practical size ranges for each of the technologies is based on Ameren Missouri's ability to plan for and reasonably implement the technology. New resources cover a broad range of operations modes: baseload, intermediate, peaking, and intermittent (e.g., wind, solar). Table 6A.2 lists capacity and operations mode for new resources.

6.3 Commercial Availability

The commercial status of each of the evaluated technologies was qualitatively assessed. Developing technologies consist of all other technologies that may have limited experience, have been utilized in demonstration projects, or consist of laboratory-tested conceptual designs; e.g., SMR.

6.4 Capital Cost Estimates

Screening level, overnight EPC capital cost estimates were developed for all evaluated options and expressed in 2023 dollars. The values presented are reasonable for today's market conditions, but, as demonstrated in recent years, the market is dynamic and unpredictable. Power plant costs are subject to continued volatility and the estimates in this report should be considered primarily for comparative purposes. The costs presented in this report were developed in a consistent manner and are reasonable relative to one another.

The EPC estimates include costs for equipment and materials, construction labor, engineering services, construction management, indirects, and other costs on an overnight basis and are representative of "inside the fence" project scope. The overall

¹ 20 CSR 4240-22.040(1)

capital cost estimates consist of three main components: EPC Capital Cost, Owner's Cost (excluding Allowance for Funds Used During Construction [AFUDC]), and Owner's AFUDC Cost. EPC estimates for all evaluated options are presented in Table 6A.3.

An allowance has been made for Owner's costs (excluding AFUDC). Items included in the Owner's costs include "outside the fence" physical assets, project development, and project financing costs. These costs can vary significantly, depending upon technology and unique project requirements. Owner's costs were developed as a percentage of the EPC capital cost as shown in the tables referenced above. Owner's costs are assumed to include project development costs, interconnection costs, spare parts and plant equipment, project management costs, plant startup/construction support costs, taxes/advisory fees/legal costs, contingency, financing and miscellaneous costs. Table 6A.1 shows a more detailed explanation of potential owner's costs. Project cost including owner's costs (excluding AFUDC) is presented in Table 6A.3.

For the purposes of characterizing all of the evaluated options, the AFUDC was calculated by applying the Company's current allowed ROE and long-term interest rate to the cash flows during permitting and construction period, with the construction duration being defined as the time period from Notice to Proceed (NTP) to Commercial Operation Date (COD). Project timeline is presented in Table 6A.2 and AFUDC percentage is presented in Table 6A.5.

Table 6A.1 Potential Items Included in Owner's Costs

| | |
|--|--|
| <p>Project Development: Site selection study Land purchase/options/rezoning Transmission/gas pipeline rights of way Road modifications/upgrades Demolition (if applicable) Environmental permitting/offsets Public relations/community development Legal assistance</p> <p>Utility Interconnections: Natural gas service (if applicable) Gas system upgrades (if applicable) Electrical transmission Supply water Wastewater/sewer (if applicable)</p> <p>Spare Parts and Plant Equipment: Air quality control systems materials, supplies, and parts Acid gas treating materials, supplies and parts Combustion turbine and steam turbine materials, supplies, and parts HRSG materials, supplies, and parts Gasifier materials, supplies, and parts Balance-of-plant equipment materials, supplies and parts Rolling stock Plant furnishings and supplies Operating spares</p> <p>Owner's Project Management: Preparation of bid documents and selection of contractor(s) and suppliers Provision of project management Performance of engineering due diligence Provision of personnel for site construction management</p> | <p>Plant Startup/Construction Support: Owner's site mobilization O&M staff training Supply of trained operators to support equipment testing and commissioning Initial test fluids and lubricants Initial inventory of chemicals/reagents Consumables Cost of fuel not recovered in power sales Auxiliary power purchase Construction all-risk insurance Acceptance testing</p> <p>Taxes/Advisory Fees/Legal: Taxes Market and environmental consultants Owner's legal expenses: <ul style="list-style-type: none"> • Power Purchase Agreement (PPA) • Interconnect agreements • Contracts--procurement & construction • Property transfer </p> <p>Owner's Contingency: Owner's uncertainty and costs pending final negotiation: <ul style="list-style-type: none"> • Unidentified project scope increases • Unidentified project requirements • Costs pending final agreement (e.g., interconnection contract costs) </p> <p>Financing: Development of financing sufficient to meet project obligations or obtaining alternate sources of funding Financial advisor, lender's legal, market analyst, and engineer Interest during construction Loan administration and commitment fees Debt service reserve fund</p> <p>Miscellaneous: All costs for above-mentioned Contractor-excluded items, if applicable</p> |
|--|--|

6.5 Non-Fuel Fixed O&M Costs

First year fixed O&M costs (in 2023\$s) were developed for each of the evaluated options, and for future years a 2% escalation rate was used after escalating the first year at 3.1%. Fixed O&M costs include labor, materials, contracted services, and G&A costs. Natural gas combined cycle resource fixed O&M costs include firm gas transportation cost. For hydro, wind, solar, and battery energy storage systems all O&M costs are considered to be fixed O&M.

All O&M cost estimates are presented in Table 6A.3. Non-Fuel variable O&M for thermal resources is discussed in Section 6.7.2.

6.6 Scheduled and Forced Outages

Scheduled maintenance intervals were obtained from original equipment manufacturers (OEMs) or estimated on the basis of Black & Veatch or Ameren Missouri subject matter expert experience for each of the technologies. Where information was not available, maintenance intervals were estimated using data gathered from comparable technologies.

Where available, generic equivalent forced outage rate were gathered for each of the technologies and are presented in Table 6A.2. The information was taken from the NERC GADS database and published literature to the extent that data were available. When information was not available, values were estimated using data gathered from comparable technologies.

6.7 Thermal Resource Characteristics

6.7.1 Thermal Performance

Natural gas and nuclear performance are based on EIA, NREL and EPRI data. Natural gas emission rates (SO₂, NO_x and CO₂, and PM₁₀) are based on EIA data.

Table 6A.2 lists heat rate data for thermal resources.

6.7.2 Non-Fuel Variable O&M

Variable O&M costs include water consumption, waste and water discharge treatment cost and consumables such as water treatment chemicals and lubricants. Combined cycle variable O&M includes catalyst replacement, ammonia, water, and water discharge treatment cost for emissions reduction equipment. Simple Cycle variable O&M includes starts based CT Major Maintenance VOM costs.

6.7.3 Natural Gas Technology Options²

Combined Cycle

The following assumptions have been made for this resource option:

1. AQCS:
 - Dry low NO_x burners and SCR for NO_x control.
 - CO oxidation catalyst for CO and VOC controls.
2. Inlet air evaporative cooling above 59° F.
3. Triple-pressure heat recovery steam generation (HRSG).
4. A mechanical-draft, counterflow, cooling tower assumed for heat rejection.
5. No HRSG bypass dampers and stacks.
6. No supplemental HRSG firing
7. Operation on Natural Gas (Dual Fuel Capable)

Combined Cycle with CCS

The following assumptions have been made for this resource option:

1. 98.5% carbon capture
2. CO₂ Compressor, CO₂, pump, CO₂ drying package.
3. SCR for NO_x control
4. Triple-pressure HRSGs
5. Natural draft cooling tower

Simple Cycle

Performance, emissions, and cost estimates were prepared for the following simple cycle technologies:

- One generic industrial frame Model F CT.

The following assumptions have been made for simple cycle option:

1. Dry low NO_x (DLN) burners would be included for NO_x control.
2. Operation on Natural Gas (Dual Fuel Capable)

² 20 CSR 4240-22.040(1)

6.7.4 Nuclear Technology Option³

AP1000

Following assumptions have been made for this resource:

1. Design life - 40 years
2. Thermal Output - 3,451 MWt, Electrical Output - 1,100 MWe
3. Uranium Dioxide Fuel Rods (157 fuel assemblies, 17ft x 17ft fuel lattice, 12ft fuel length)
4. 18 month refueling interval, 24 day refueling duration
5. Two natural draft cooling towers
6. Annual decommissioning fund contribution based on Ameren Missouri's 2020 triennial funding update filing for Callaway Energy Center.

SMR

Following assumptions have been made for this resource:

1. Design life - 40 years
2. Thermal Output - 3000 MWt, Electrical Output - 864 MWe
3. Uranium Dioxide Fuel Rods, (156 assemblies, 1 foot square by 6 feet long)
4. 10 day refueling every 2 years, 6-week turbine outage every 6 years⁵. A number of natural draft cooling towers appropriate to final design
6. Annual decommissioning fund contribution based on Ameren Missouri's 2020 triennial funding update filing for Callaway Energy Center.

³ 20 CSR 4240-22.040(1)

6.8 Supporting Tables

Table 6A.2 – Resources, Capacity and Performance⁴

| Resource Option | Resource | Operations Mode | Renewable Resource | Technology Description | Plant Output, MW | Heat Rate HHV, Btu/kWh | Assumed Fuel Type/ Source | Fuel Flexibility | Technology Maturity | Permitting, months | NTP to COD, months | Assumed Annual Capacity Factor, % | Forced Outage Rate, % |
|-------------------------|-------------|-----------------|--------------------|------------------------|------------------|------------------------|---------------------------|------------------|---------------------|--------------------|--------------------|-----------------------------------|-----------------------|
| Wind | Wind | Intermittent | Yes | Wind | 100 | n/a | n/a | n/a | Mature | 36 to 60 | 12 | 42% | n/a |
| Solar | Solar | Intermittent | Yes | PV | 100 | n/a | n/a | n/a | Mature | 12 to 18 | 6 | 26% | 1% |
| Pumped Storage | Storage | Peaking | No | Hydro | 600 | n/a | n/a | n/a | Mature | 21 to 27 | 48 | 25% | |
| Li-Ion Battery (4h) | Storage | Peaking | No | Li-Ion | 4 | n/a | n/a | n/a | Mature | 6 to 12 | 6 | 17% | 1% |
| Li-Ion Battery (8h) | Storage | Peaking | No | Li-Ion | 4 | n/a | n/a | n/a | Mature | 6 to 12 | 6 | 33% | 1% |
| Hydro | Hydro | Baseload | Yes | Hydro | 6 | n/a | n/a | n/a | Mature | 21 to 27 | 24 | 40% | 3% |
| Combined Cycle | Natural Gas | Intermediate | No | H Class CCCT | 1,200 | 6,148 | Natural Gas | No | Mature | 18 | 24 | 40% | 5% |
| Combined Cycle with CCS | Natural Gas | Intermediate | No | H Class CCCT | 1,135 | 7,138 | Natural Gas | No | Developing | 18 | 24 | 40% | 5% |
| Simple Cycle | Natural Gas | Peaking | No | F Class SCCT | 230 | 9,895 | Natural Gas | Yes | Mature | 18 | 22 | 5% | 5% |
| Nuclear - SMR | Nuclear | Baseload | No | Nuclear | 864 | 11,991 | Nuclear | No | Developing | 24 | 42 | 95% | 5% |
| Nuclear - Conventional | Nuclear | Baseload | No | AP1000 | 1100 | 10,440 | Nuclear | No | Mature | 24 | 72 | 94% | 2% |

⁴ 20 CSR 4240-22.040(1), 20 CSR 4240-22.040(2)(C)(1)

Table 6A.3 – Cost Estimates⁵

| Resource Option | Resource | Tax Life, years | Economic Life, years | Owner's Cost, % | EPC Capital Cost, \$1,000 | EPC Capital, Cost \$/kW | Project Cost - Includes Owners Cost, Excluding AFUDC \$1,000 | Total Project Cost- Includes Owners Cost, Excluding AFUDC, \$/kW |
|-------------------------|-------------|-----------------|----------------------|-----------------|---------------------------|-------------------------|--|--|
| Wind | Wind | 5 | 30 | 3% | ** | | | ** |
| Solar | Solar | 5 | 30 | 8% | ** | | | ** |
| Pumped Storage | Storage | 20 | 40 | 14% | 1,205,629 | 2,009 | 1,374,600 | 2,291 |
| Li-Ion Battery (4h) | Storage | 5 | 15 | 4% | ** | | | ** |
| Li-Ion Battery (8h) | Storage | 5 | 15 | 4% | ** | | | ** |
| Hydro | Hydro | 20 | 60 | 22% | 28,052 | 4,675 | 34,224 | 5,704 |
| Combined Cycle | Natural Gas | 20 | 30 | 12% | 1,307,143 | 1,089 | 1,464,000 | 1,220 |
| Combined Cycle with CCS | Natural Gas | 20 | 30 | 12% | 2,236,558 | 1,971 | 2,504,945 | 2,207 |
| Simple Cycle | Natural Gas | 15 | 30 | 13% | 202,319 | 880 | 228,620 | 994 |
| Nuclear - SMR | Nuclear | 15 | 40 | 20% | 6,114,240 | 7,077 | 7,337,088 | 8,492 |
| Nuclear - Conventional | Nuclear | 15 | 40 | 20% | 9,266,583 | 8,424 | 9,789,244 | 10,109 |

⁵ 20 CSR 4240-22.040(5)(B); 20 CSR 4240-22.040(5)(C)

Table 6A.4– Non-Fuel O&M, Fuel, and Environmental Characteristics⁶

| Resource Option | Resource | First Year Fixed O&M Cost, \$1,000/yr | First Year Fixed O&M Cost, \$/kW-yr | First Year Variable O&M Cost, \$1,000/yr | First Year Variable O&M Cost, \$/MWh | NOx, lbm/MMBtu | SO ₂ , lbm/MMBtu | CO ₂ , lbm/MMBtu | CO, lbm/MMBtu | PM ₁₀ , lb/MMBtu |
|-----------------------------|-------------|---------------------------------------|-------------------------------------|--|--------------------------------------|----------------|-----------------------------|-----------------------------|---------------|-----------------------------|
| Wind | Wind | 3,640 | 36 | 0 | 0.0 | n/a | n/a | n/a | n/a | n/a |
| Solar | Solar | 1,440 | 14 | 0 | 0.0 | n/a | n/a | n/a | n/a | n/a |
| Pumped Storage ¹ | Storage | 2,700 | 5 | 4,730 | 3.6 | n/a | n/a | n/a | n/a | n/a |
| Li-Ion Battery (4h) | Storage | 133 | 33 | 0 | 0.0 | n/a | n/a | n/a | n/a | n/a |
| Li-Ion Battery (8h) | Storage | 199 | 50 | 0 | 0.0 | n/a | n/a | n/a | n/a | n/a |
| Hydro | Hydro | 594 | 99 | 0 | 0.0 | n/a | n/a | n/a | n/a | n/a |
| Combined Cycle | Natural Gas | 74,400 | 62 | 11,353 | 2.70 | 0.008 | 0.000 | 117 | 0.014 | 0.003 |
| Combined Cycle with CCS | Natural Gas | 120,878 | 107 | 33,407 | 8.40 | 0.008 | 0.000 | 1.76 | 0.014 | 0.003 |
| Simple Cycle | Natural Gas | 1,863 | 8 | 524 | 5.20 | 0.090 | 0.000 | 119 | 0.015 | 0.005 |
| Nuclear - SMR | Nuclear | 105,494 | 122 | 27,754 | 3.86 | n/a | n/a | n/a | n/a | n/a |
| Nuclear - Conventional | Nuclear | 166,100 | 151 | 32,971 | 3.64 | n/a | n/a | n/a | n/a | n/a |

1- Excludes Charging/Pump Costs for Storage, Round-Trip-Efficiency and Market Price dependent

⁶ 20 CSR 4240-22.040(1), 20 CSR 4240-22.040(2)(A)

Table 6A.5– Economic Parameters and LCOE⁷

| Resource Option | Resource | Plant Maintenance Pattern, week/year | Water Consumption, gal/min | VOM Escalation Rate, % | Present Worth Discount Rate, % | Fixed Charge Rate, %* | AFUDC Rate, % | Candidate Option | Cost Rank | LCOE, ¢/kWh* |
|-------------------------|-------------|--------------------------------------|----------------------------|------------------------|--------------------------------|-----------------------|---------------|------------------|-----------|--------------|
| Wind | Wind | N/A | 0 | 2.0% | 6.59% | 8.60% | 5.40% | Yes | 1 | 4.16 |
| Solar | Solar | N/A | 0 | 2.0% | 6.59% | 8.45% | 3.70% | Yes | 2 | 6.14 |
| Pumped Storage | Storage | N/A | | 2.0% | 6.59% | 8.41% | 18.50% | Yes | 6 | 17.56 |
| Li-Ion Battery (4h) | Storage | N/A | 0 | 2.0% | 6.59% | 8.83% | 3.70% | Yes | 10 | 20.47 |
| Li-Ion Battery (8h) | Storage | N/A | 0 | 2.0% | 6.59% | 8.83% | 3.70% | Yes | 7 | 19.58 |
| Hydro | Hydro | 1 | 0 | 2.0% | 6.59% | 9.99% | 11.10% | No | 9 | 19.61 |
| Combined Cycle | Natural Gas | Note 1 | 4,200 - 5,900 | 2.0% | 6.59% | 9.99% | 6.10% | Yes | 3 | 6.77 |
| Combined Cycle with CCS | Natural Gas | Note 1 | 3,200 - 4,600 | 2.0% | 6.59% | 9.99% | 6.10% | Yes | 4 | 9.63 |
| Simple Cycle | Natural Gas | Note 2 | 0 - 100 | 2.0% | 6.59% | 9.82% | 6.30% | Yes | 11 | 33.02 |
| Nuclear - SMR | Nuclear | | | | 6.59% | 9.24% | 14.90% | Yes | 5 | 15.81 |
| Nuclear - Conventional | Nuclear | | 19,413 | 2.0% | 6.59% | 9.24% | 28.80% | Yes | 8 | 19.60 |

Note 1- Equivalent Operating Hours (EOH) based maintenance. Significant overhaul for CT every 25,000 EOH and major overhaul every 50,000 EOH.

Note 2- Equivalent starts-based maintenance. Significant overhaul every 900 equivalent starts, major overhaul every 2400 equivalent starts. 56 starts/year assumed.

* Wind and solar shown with full PTC, batteries, and pumped storage with 30% ITC.

⁷ 20 CSR 4240-22.040(2)(C)1, 20 CSR 4240-22.040(2)(C)2

6.9 Compliance References

| | |
|-----------------------------------|---------------|
| 20 CSR 4240-22.040(1) | 1, 5, 6, 7, 9 |
| 20 CSR 4240-22.040(2)(A) | 9 |
| 20 CSR 4240-22.040(2)(C)(1) | 7 |
| 20 CSR 4240-22.040(2)(C)1 | 10 |
| 20 CSR 4240-22.040(2)(C)2 | 10 |
| 20 CSR 4240-22.040(5)(B) | 8 |
| 20 CSR 4240-22.040(5)(C) | 8 |