

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>
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6.5 Non-Fuel Fixed O&M Costs

First year fixed O&M costs (in 2023\$) 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

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