

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., small modular reactors.

6.4 Capital Cost Estimates

Screening level, overnight EPC capital cost estimates were developed for all evaluated options and expressed in 2027 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 cost estimates include costs for equipment and materials, construction labor, engineering services, construction management, indirects, and other costs assuming

¹ 20 CSR 4240-22.040(1)

overnight build. The total project cost excluding Allowance for Funds Used During Construction (AFUDC) are 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.4.

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

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 Utility Interconnections: Natural gas service (if applicable) Gas system upgrades (if applicable) Electrical transmission Supply water Wastewater/sewer (if applicable) Fiber connections (if applicable) 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 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	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 Taxes/Advisory Fees/Legal: Taxes Market and environmental consultants Owner's legal expenses: • Power Purchase Agreement (PPA) • Interconnect agreements • Contracts--procurement & construction • Property transfer Owner's Contingency: Owner's uncertainty and costs pending final negotiation: • Unidentified project scope increases • Unidentified project requirements • Costs pending final agreement (e.g., interconnection contract costs) 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 Miscellaneous: All costs for above-mentioned Contractor-excluded items, if applicable
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6.5 Non-Fuel Fixed O&M Costs

First year fixed O&M costs (in 2027\$) were developed for each of the evaluated options, and for future years a 2% escalation rate was used. Fixed O&M costs include labor, materials, contracted services, and general & administrative (G&A) costs. Natural gas resources' 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, NLR 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.
 - 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. 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. 95% carbon capture
2. CO₂ Compressor, CO₂, pump, CO₂ drying package.
3. SCR for NO_x control
4. Triple-pressure HRSGs
5. Mechanical draft cooling tower

Simple Cycle

Performance, emissions, and cost estimates were prepared for a 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)

6.7.4 Nuclear Technology Option³

AP1000

Following assumptions have been made for this resource:

1. Design life - 60 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)

² 20 CSR 4240-22.040(1)

³ 20 CSR 4240-22.040(1)

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 2023 triennial funding update filing for Callaway Energy Center.

SMR

Following assumptions have been made for this resource:

1. Design life - 60 years
2. Thermal Output - 870 MWt, Electrical Output - 316 MWe (gross), 300 MWe (net to grid)
3. Uranium Dioxide Fuel Rods, (240 assemblies, 10x10 Lattice)
4. 12–24 month refueling interval, 10-15 day refueling outage duration, 25-day turbine outage every 10 years. Main condenser cooled by a circulating water system, which could be a close cycle with cooling towers.
5. Annual decommissioning fund contribution based on Ameren Missouri's 2023 triennial funding update filing for Callaway Energy Center.

6.8 Supporting Tables

Table 6A.2 – Resources, Capacity and Performance⁴

Resource Option	Resource	Operations Mode	Renewable Resource	Technology Description	Nameplate 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	24	42%	n/a
Solar	Solar	Intermittent	Yes	PV	100	n/a	n/a	n/a	Mature	18	18	27%	1%
Pumped Storage Hydro	Storage	Peaking	No	Hydro	1,000	n/a	n/a	n/a	Mature	27	48	25%	n/a
Li-Ion Battery (4h)	Storage	Peaking	No	Li-Ion	100	n/a	n/a	n/a	Mature	12	18	17%	1%
Li-Ion Battery (8h)	Storage	Peaking	No	Li-Ion	100	n/a	n/a	n/a	Mature	12	18	33%	1%
Hydro - Non-Powered Dam	Hydro	Baseload	Yes	Hydro	26	n/a	n/a	n/a	Mature	27	24	62%	3%
Combined Cycle	Natural Gas	Baseload	No	H or J Class CCCT	1,400	6,269	Natural Gas	No	Mature	18	36-42	80%	5%
Combined Cycle with CCS	Natural Gas	Baseload	No	H or J Class CCCT	2,100	7,239	Natural Gas	No	Developing	18	36-42	65%	5%
Simple Cycle	Natural Gas	Peaking	No	F Class SCCT	800	9,956	Natural Gas	Yes	Mature	18	24-30	20%	5%
Solid Oxide Fuel Cells	Natural Gas	Baseload	No	SOFC	59	6,995	Natural Gas	Yes	Mature	12	9	90%	2%
Nuclear - SMR	Nuclear	Baseload	No	Nuclear	1,200	11,990	Nuclear	No	Developing	60	60-84*	95%	5%
Nuclear - Conventional	Nuclear	Baseload	No	AP1000	1,100	10,443	Nuclear	No	Mature	60	72-96	95%	2%

*Nuclear - SMRs may be installed on a rolling basis, e.g. (4) 300 MW units.

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

Table 6A.3 – Cost Estimates, Non-Fuel O&M, Fuel, and Environmental Characteristics ^{5 6}

Resource Option	Resource	Tax Life Years	Economic Life Years	Total Project Cost Excluding AFUDC \$/kW	First Year Fixed O&M Cost \$/kW-yr	First Year Fixed O&M Cost \$1,000/yr	First Year Variable O&M Cost \$/MWh	First Year Variable O&M Cost \$1,000/yr	First Year Fuel Cost Wholesale \$/MMBtu	NOx lb/MMBtu	SO2 lb/MMBtu	CO2 lb/MMBtu	CO lb/MMBtu	PM10 lb/MMBtu
Wind	Wind	5	30	***	40.58	4,058	0.00	0	n/a	n/a	n/a	n/a	n/a	n/a
Solar	Solar	5	30	***	21.33	2,133	0.00	0	n/a	n/a	n/a	n/a	n/a	n/a
Pumped Storage ¹	Storage	20	100	***	13.60	13,601	4.01	8,772	n/a	n/a	n/a	n/a	n/a	n/a
Li-Ion Battery (4h)	Storage	5	20	***	15.61	1,561	0.00	0	n/a	n/a	n/a	n/a	n/a	n/a
Li-Ion Battery (8h)	Storage	5	20	***	28.41	2,841	0.00	0	n/a	n/a	n/a	n/a	n/a	n/a
Hydro - Non-Powered Dam	Hydro	20	60	10,486	139.70	3,696	0.00	0	n/a	n/a	n/a	n/a	n/a	n/a
Combined Cycle	Natural Gas	20	30	***	11.62	16,269	3.29	32,258	2.86	0.008	0.000	117	0.014	0.003
Combined Cycle with CCS	Natural Gas	20	30	***	54.19	113,805	9.98	118,529	2.86	0.008	0.000	5.85	0.014	0.003
Simple Cycle	Natural Gas	15	30	***	7.45	5,958	4.33	6,065	2.86	0.030	0.000	117	0.015	0.005
Solid Oxide Fuel Cells	Natural Gas	15	20	***	***	***	0.00	0	2.86	0.002	0.000	117	0.014	0.000
Nuclear - SMR	Nuclear	15	40	10,961	154.61	185,528	3.34	33,361	1.00	n/a	n/a	n/a	n/a	n/a
Nuclear - Conventional	Nuclear	15	40	10,961	166.18	182,799	4.09	37,442	0.83	n/a	n/a	n/a	n/a	n/a

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

*SO2 emissions are highly variable. Sulfur in bio-gas can range from 100 ppmvd to 12,000 ppmvd.

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

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

Table 6A.4 – 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%	6.96%	8.45%	7.01%	Yes	1	4.73
Solar	Solar	n/a	0	2%	6.96%	9.26%	8.55%	Yes	2	8.25
Pumped Storage	Storage	n/a		2%	6.96%	9.51%	25.74%	Yes	12	27.58
Li-Ion Battery (4h)	Storage	n/a	0	2%	6.96%	9.91%	9.45%	Yes	6	15.98
Li-Ion Battery (8h)	Storage	n/a	0	2%	6.96%	9.91%	9.45%	Yes	5	15.29
Hydro - Non-Powered Dam	Hydro	1	0	2%	6.96%	0.00%	16.48%	No	11	22.99
Combined Cycle	Natural Gas	Note 1	4,200 - 5,900	2%	6.96%	0.00%	21.32%	Yes	3	9.38
Combined Cycle with CCS	Natural Gas	Note 1	3,200 - 4,600	2%	6.96%	0.00%	21.32%	Yes	7	17.28
Simple Cycle	Natural Gas	Note 2	0 - 100	2%	6.96%	0.00%	15.48%	Yes	10	22.85
Solid Oxide Fuel Cells	Natural Gas	Note 3	Note 3	0%	6.96%	40.00%	4.40%	Yes	4	12.44
Nuclear - SMR	Nuclear		n/a	2%	6.96%	0.00%	20.94%	Yes	8	20.46
Nuclear - Conventional	Nuclear		19,413	2%	6.96%	0.00%	37.89%	Yes	9	22.06

* Resource options apply applicable ITCs or PTCs. ITC calculations assume 93% of capital costs are eligible. All tax credits are assumed sold at \$0.95 per dollar of credit.

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.

Note 3 - City/tap water at fuel cell yard fence line, used only during startup. Average flowrate, .13 gallon per minute. Approximately 293 gallons per 10 MWs.

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

Table 6A.5 – Transmission Interconnection Costs (2027\$)

Resource Option	Transmission Interconnection Cost \$/kW	
Wind	**	**
Solar	**	**
Li-Ion Battery	**	**

Compliance References

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