Chapter 6 - Appendix A

Characterization Data – New Resources[1]

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. Only mature technologies proven and well established within the electric power generation industry were considered for this IRP; e.g., combined cycle. 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., coal with carbon capture.

6.4 Capital Cost Estimates

Screening level, overnight EPC capital cost estimates were developed for all evaluated options and expressed in 2019 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 EPC costs presented in this report were developed in a consistent manner and are reasonable relative to one another.

[1] 20 CSR 4240-22.040(1)

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 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 owners 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.2and AFUDC percentage is presented in Table 6A.5.

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)

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

6.5 Non-Fuel Fixed O&M Costs

First year fixed O&M costs (in 2019$s) 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 G&A costs. Natural Gas 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 experience for each of the technologies. Where information was not available, maintenance intervals were estimated using data gathered from comparable technologies. The maintenance patterns are presented in Table 6A.5.

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 data.[2] Natural gas capacity and heat rate include an additional location adjustment factor to account for ambient air temperature, relative humidity, and elevation. Natural gas emission rates (SO_2, NO_x and CO_2, and PM10) are based on EIA data.

Landfill gas and biomass thermal performance and emissions are based on studies previously commissioned by Ameren Missouri.

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

[2] U.S. Energy Information Administration Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generation Technologies, February 2020.

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 incudes starts based CT Major Maintenance VOM costs.

6.7.3 Waste Generation

Wastewater and waste solids must be processed and properly disposed. Technologies fueled by natural gas produce negligible solid waste, but can produce wastewater streams. Table 6A.5 presents a summary of the production of wastewater for the evaluated options. See Section 6.7.5 for AP1000 solid nuclear waste information.

6.7.4 Natural Gas Technology Options[3]

Combined Cycle, One 2x2x1

Performance, emissions, and cost estimates were prepared for the following combined cycle technology:

- One 2-on-1 GE combined cycle based on a 7HA.02 CT.

The following assumptions have been made for this combined cycle option:

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

Combined Cycle, Two 1x1x1

Performance, emissions, and cost estimates were prepared for the following combined cycle technology:

- Two 1-on-1 combined cycle based on a generic industrial frame Model H CT.

[3] 20 CSR 4240-22.040(1)

The following assumptions have been made for this combined cycle option:

1. One CTG, one HRSG, and one STG at each of two unit sites.
2. AQCS:
    - Dry low NO_x burners and SCR for NO_x control.
    - CO oxidation catalyst for CO and VOC controls.
3. Inlet air evaporative cooling above 59° F.
4. Triple-pressure HRSGs.
5. A mechanical-draft, counterflow, cooling tower assumed for heat rejection.
6. No HRSG bypass dampers and stacks.
7. No supplemental HRSG firing
8. Operation on Natural Gas (Dual Fuel Capable)

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. Units that are dispatched at a capacity factor of 5 percent would not include an SCR system or CO oxidation catalyst.
3. Operation on Natural Gas (Dual Fuel Capable)
4. 56 starts

6.7.5 Nuclear Technology Option[4]

AP1000

Following assumptions have been made for this resource:

1. Design life - 40 years
2. Thermal Output - 3,451 MW, Electrical Output - 1,100 MW
3. Uranium Dioxide Fuel Rods (157 fuel assemblies, 17ft x 17ft fuel lattice, 12ft fuel length)
5. 18 month refueling interval, 24 day refueling duration
6. Two natural draft cooling towers

[4] 20 CSR 4240-22.040(1)

7. Annual decommissioning fund contribution based Ameren Missouri's 2019 triennial funding update filing for Callaway Energy Center.

AP1000 Waste Generation

Based on the South Carolina Electric & Gas Combined License ("COL") Application for Summer 2&3, Westinghouse estimates that one AP1000 would generate approximately 5,760 cubic feet of low-level radioactive waste annually. Following volume reduction and compaction, the estimated low-level radioactive waste disposal volume is 1,960 cubic feet per year for each new unit.

AP 1000 Water Impacts

Consumptive use of water is primarily attributable to evaporation losses from cooling water systems, blowdown, and cooling tower drift. The AP1000 will utilize two natural-draft cooling towers with evaporative losses of approximately 14,550 gallons per minute ("gpm"). Blowdown from the new cooling towers will be approximately 4,850 gpm each. The unit will consume a total of approximately 19,413 gpm including estimated cooling tower drift (12.5 gpm).

In comparison to average annual flow of the Missouri River over 50 years, such losses are estimated to require less than 0.1 percent of river flow. The water resources so committed for plant operation will have no material effect on other users downstream from the plant.

6.8 Supporting Tables

Table 6A.2 – Resources, Capacity and Performance[5]

Resource Option	Resource	Operations Mode	Renwable 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	1	n/a	n/a	n/a	Mature	12 to 18	6	20%	1%
Solar	Solar	Intermittent	Yes	PV	10	n/a	n/a	n/a	Mature	12 to 18	6	27%	1%
Solar	Solar	Intermittent	Yes	PV	100	n/a	n/a	n/a	Mature	12 to 18	6 to 12	27%	1%
Solar + Storage	Solar	Intermittent/ Peaking	Yes	PV+Li-Ion	13	n/a	n/a	n/a	Mature	12 to 18	6	27%	1%
Solar + Storage	Solar	Intermittent/ Peaking	Yes	PV+Li-Ion	125	n/a	n/a	n/a	Mature	12 to 18	6 to 12	27%	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 (2h)	Storage	Peaking	No	Li-Ion	4	n/a	n/a	n/a	Mature	6 to 12	6	13%	1%
Co-firing (St. Louis Region)	Biomass	Baseload	Yes	Existing Host	28.8	10,125	Wood	Yes	Mature	12 to 18	12	85%	8%
Mississippi L&D 21	Hydro	Baseload	Yes	Hydro	6	n/a	n/a	n/a	Mature	21 to 27	24	62%	3%
Clearwater	Hydro	Baseload	Yes	Hydro	5	n/a	n/a	n/a	Mature	21 to 27	24	40%	3%
Pomme De Terre	Hydro	Baseload	Yes	Hydro	4.6	n/a	n/a	n/a	Mature	21 to 27	24	60%	3%
IESI Champ (expansion)	LFG	Baseload	Yes	CT	3.7	12,250	LFG	No	Mature	12 to 18	15	90%	8%
Newton County 1	AD	Baseload	Yes	RICE	4.5	12,000	Digester Gas	No	Mature	12 to 18	12	90%	8%
Greenfield Combined Cycle- One 2x2x1	Natural Gas	Intermediate	No	H Class CCCT	1,067	6,364	Natural Gas	No	Mature	18	24	40%	2%
Greenfield Combined Cycle- Two 1x1x1	Natural Gas	Intermediate	No	H Class CCCT	824	6,425	Natural Gas	No	Mature	18	22	40%	2%
Simple Cycle	Natural Gas	Peaking	No	F Class SCCT	689	9,895	Natural Gas	No	Mature	18	22	5%	5%
Brownfield Nuclear	Nuclear	Baseload	No	AP1000	1100	10,608	Nuclear	No	Mature	24	60	94%	2%

[5] 20 CSR 4240-22.040(1), 20 CSR 4240-22.040(2)(C)(1)

Table 6A.3 – Cost Estimates[6]

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%	150,529	1,505	155,000	1,550
Solar	Solar	5	25	8%	1,852	1,852	2,000	2,000
Solar	Solar	5	25	8%	12,157	1,216	13,130	1,313
Solar	Solar	5	25	8%	115,741	1,157	125,000	1,250
Solar + Storage	Solar	5	25	8%	18,519	1,481	20,000	1,600
Solar + Storage	Solar	5	25	8%	162,037	1,296	175,000	1,400
Pumped Storage	Storage	20	40	14%	911,314	1,519	1,039,037	1,732
Li-Ion Battery (4h)	Storage	5	15	4%	6,250	1,563	6,500	1,625
Li-Ion Battery (2h)	Storage	5	15	4%	4,423	1,106	4,600	1,150
Co-firing (St. Louis Region)	Biomass	7	20	26%	24,969	867	31,460	1,092
Mississippi L&D 21	Hydro	20	60	22%	27,582	4,597	33,650	5,608
Clearwater	Hydro	20	60	22%	19,472	3,674	23,755	4,482
Pomme De Terre	Hydro	20	60	22%	15,966	3,471	19,478	4,234
IESI Champ (expansion)	LFG	7	20	25%	14,634	3,955	18,292	4,944
Newton County 1	AD	7	15	26%	17,556	3,901	22,121	4,916
Greenfield Combined Cycle- One 2x2x1	Natural Gas	20	30	12%	1,027,795	963	1,151,130	1,079
Greenfield Combined Cycle- Two 1x1x1	Natural Gas	20	30	12%	915,690	1,111	1,025,573	1,245
Simple Cycle	Natural Gas	15	30	13%	485,559	705	548,682	796
Brownfield Nuclear	Nuclear	15	40	20%	8,157,703	7,416	9,789,244	8,899

[6] 20 CSR 4240-22.040(5)(B); 20 CSR 4240-22.040(5)(C)

Table 6A.4– Non-Fuel O&M, Fuel, and Environmental Characteristics[7]

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	First Year Fuel Cost, $/MMBtu	NOx, lbm/MMBtu	SO2, lbm/MMBtu	CO2, lbm/MMBtu	CO, lbm/MMBtu	PM10, lb/MMBtu
Wind	Wind	3,100	31	0	0.0	n/a	n/a	n/a	n/a	n/a	n/a
Solar	Solar	7	7	0	0.0	n/a	n/a	n/a	n/a	n/a	n/a
Solar	Solar	50	5	0	0.0	n/a	n/a	n/a	n/a	n/a	n/a
Solar	Solar	400	4	0	0.0	n/a	n/a	n/a	n/a	n/a	n/a
Solar + Storage	Solar	88	7	0	0.0	n/a	n/a	n/a	n/a	n/a	n/a
Solar + Storage	Solar	750	6	0	0.0	n/a	n/a	n/a	n/a	n/a	n/a
Pumped Storage[1]	Storage	9,720	16	0	0.0	0	n/a	n/a	n/a	n/a	n/a
Li-Ion Battery (4h)[1]	Storage	4	1	0	0.0	0	n/a	n/a	n/a	n/a	n/a
Li-Ion Battery (2h)[1]	Storage	8	2	0	0.0	0	n/a	n/a	n/a	n/a	n/a
Co-firing (St. Louis Region)[2]	Biomass	1,557	54	0	0.0	3.43	0	<0.030	carbon neutral		0.015
Mississippi L&D 21	Hydro	157	26	0	0.0	n/a	n/a	n/a	n/a	n/a	n/a
Clearwater	Hydro	139	26	0	0.0	n/a	n/a	n/a	n/a	n/a	n/a
Pomme De Terre	Hydro	120	26	0	0.0	n/a	n/a	n/a	n/a	n/a	n/a
IESI Champ (expansion)	LFG	0	125	381	13.06	2.82	0.200	*	carbon neutral		0.030
Newton County 1	AD	4,916	1,092	0	0.00	n/a	0.200	*	carbon neutral		0.030
Greenfield Combined Cycle- One 2x2x1	Natural Gas	25,244	24	6,992	1.87	2.51	0.008	0.001	117	0.014	0.003
Greenfield Combined Cycle- Two 1x1x1	Natural Gas	21,138	26	7,363	2.55	2.51	0.008	0.000	117	0.014	0.003
Simple Cycle	Natural Gas	5,625	8	3,290	10.90	2.51	0.030	0.000	117	0.015	0.005
Brownfield Nuclear	Nuclear	133,804	122	21,467	2.37	0.86	0.000	0.000	0	0.000	0.000

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

2- Costs are shown as incremental

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

[7] 20 CSR 4240-22.040(1), 20 CSR 4240-22.040(2)(A)

Table 6A.5– Economic Parameters and LCOE[8]

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%	6.04%	8.95%	1.28%	Yes	3	4.87
Solar	Solar	N/A	0	2.0%	6.04%	8.10%	0.00%	Yes	10	9.73
Solar	Solar	N/A	0	2.0%	6.04%	8.10%	0.00%	Yes	2	4.75
Solar	Solar	N/A	0	2.0%	6.04%	8.10%	0.00%	Yes	1	4.49
Solar + Storage	Solar	N/A	0	2.0%	6.04%	9.05%	0.00%	Yes	7	6.48
Solar + Storage	Solar	N/A	0	2.0%	6.04%	9.05%	0.00%	Yes	4	5.66
Pumped Storage	Storage	N/A		2.0%	6.04%	8.79%	16.43%	Yes	12	12.53
Li-Ion Battery (4h)	Storage	N/A	0	2.0%	6.04%	11.89%	0.00%	Yes	17	17.55
Li-Ion Battery (2h)	Storage	N/A	0	2.0%	6.04%	11.89%	0.00%	No	16	16.76
Co-firing (St. Louis Region)	Biomass	3-3-3-3-3-8	0	2.0%	6.04%	9.25%	0.00%	No	5	6.28
Mississippi L&D 21	Hydro	1	0	2.0%	6.04%	9.42%	9.55%	Yes	11	10.15
Clearwater	Hydro	1	0	2.0%	6.04%	9.42%	9.55%	Yes	13	12.80
Pomme De Terre	Hydro	1	0	2.0%	6.04%	9.42%	9.55%	Yes	9	8.10
IESI Champ (expansion)	LFG	1-1-3	0	2.0%	6.04%	9.25%	0.00%	No	14	13.22
Newton County 1	AD	1-1-3	0 to 20	2.0%	6.04%	10.92%	0.00%	No	19	29.04
Greenfield Combined Cycle- One 2x2x1	Natural Gas	Note 1	4,200 - 5,900	2.0%	6.04%	9.42%	3.57%	No	6	6.37
Greenfield Combined Cycle- Two 1x1x1	Natural Gas	Note 1	3,200 - 4,600	2.0%	6.04%	9.42%	3.57%	Yes	8	7.01
Simple Cycle	Natural Gas	Note 2	0 - 100	2.0%	6.04%	9.26%	3.95%	Yes	18	24.81
Brownfield Nuclear	Nuclear		19,413	2.0%	6.04%	8.65%	25.00%	Yes	15	14.89

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.

* No Incentives

[8] 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, 8
20 CSR 4240-22.040(2)(A) 10
20 CSR 4240-22.040(2)(C)(1) 8
20 CSR 4240-22.040(2)(C)1 11
20 CSR 4240-22.040(2)(C)2 11
20 CSR 4240-22.040(5)(B) 9
20 CSR 4240-22.040(5)(C) 9