6. New Supply Side Resources

Highlights

- *Solar is included among the candidate resource options due to its continued cost improvements and its recognized ability to provide substantial capacity benefits in MISO. Large scale solar resources exhibit the lowest cost on a levelized cost of energy ("LCOE") basis among all candidate resource options without tax incentives.*
- *Ameren Missouri has evaluated options for development of wind resources and has assessed the impact on costs of federal production tax credits ("PTC").*
- *Battery storage has been identified as a candidate resource option in addition to pumped storage.*
- *Ameren Missouri selected two natural gas technologies as final candidate resource options – Gas Combined Cycle and Gas Simple Cycle Combustion Turbine. Gas Combined Cycle exhibits the lowest LCOE basis among conventional generation resources.*

The supply-side screening analysis of various coal, gas, and renewable power generation technologies used in the 2017 IRP was reviewed by Ameren Missouri subject matter experts and updated for use in the 2020 IRP. Regulatory requirements, along with technology advancement and financial incentives, have provided significant downward pressure on wind and solar technology unit-costs, and other environmental and sociopolitical pressures have moved the focus to less carbon-intensive generation and storage options. Additionally, high costs and development stagnation have lessened the potential for coal gasification, carbon capture, and sequestration projects. This IRP focuses on solar, wind, battery storage, and natural gas (both simple cycle and combined cycle) as potential new supply-side resources. Nuclear generation is also included due to its ability to provide around-the-clock carbon-free energy.

Ameren Missouri continues to monitor the universe of storage resource options, including pumped hydro storage, compressed air energy storage ("CAES"), and a number of battery energy storage system ("BESS") technologies. Pumped hydroelectric storage is still an energy storage resource included in our evaluation of alternative resource plans as a major supply-side resource. However, with the advancements in BESS, including various lithium-ion and flow battery technologies, BESS is the primary energy storage resource included as a major supply-side resource.

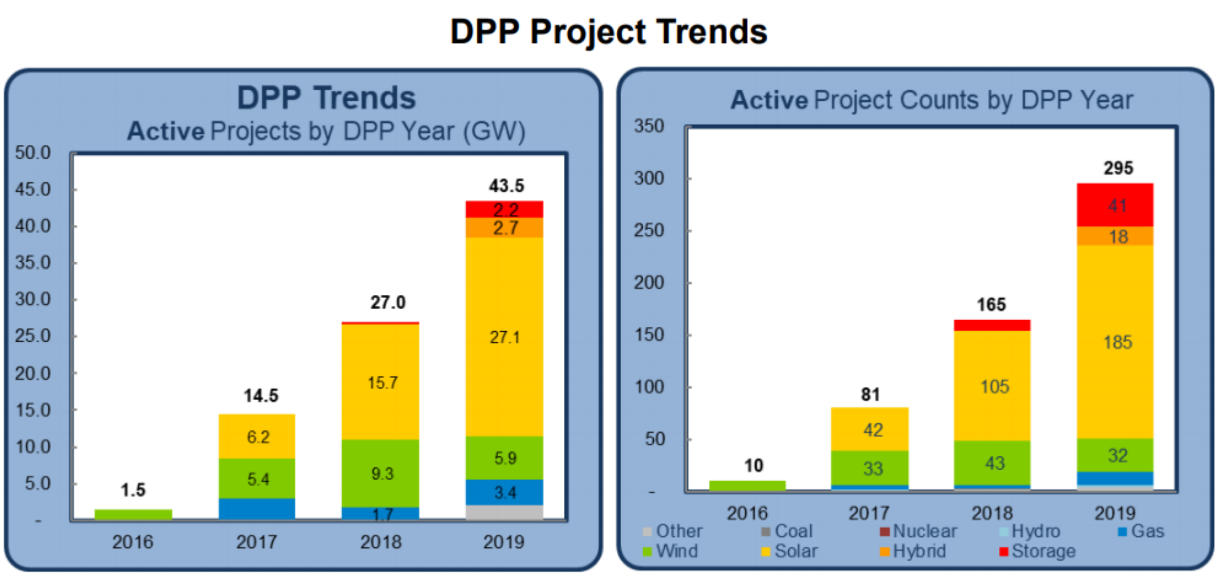
While some of these technologies have not been selected for integration analysis, it is important to note that the use cases for such technologies continue to develop, as does the consideration of appropriate market treatment for the services that these technologies can provide. Such ongoing developments will continue to be considered as part of our ongoing resource planning, including consideration of technologies and services provided by and to the transmission and distribution systems.

Capital costs for all of the preliminary candidate supply-side options include any necessary transmission interconnection costs. No preliminary candidate supply-side resource option was eliminated from further consideration due to interconnection or other transmission analysis.[1]

6.1 Potential Intermittent Renewable Resources[2]

As of November 2019, the Midcontinent Independent System Operator ("MISO") has trended an increase of solar project generation interconnection ("GI") requests while the number of wind project GI requests has started to contract. All GI requests proceed through the Definitive Planning Phase ("DPP") process as MISO and the appropriate transmission owners evaluate how the generation projects will affect the bulk electric system.

Figure 6.1[3] MISO Generator Interconnection: Overview



There are a total of three DPP iterations and GI requests may proceed to the next phase or withdraw their application depending on business case decisions for each project. See Figure 6.1. Furthermore, as detailed below, Ameren Missouri expects this trend to continue as prices for solar photovoltaics declines and the investment tax credit applied

[1] 20 CSR 4240-22.040(4)(B); 20 CSR 4240-22.040(4)(C)
[2] 20 CSR 4240-22.040(1); 20 CSR 4240-22.040(2); 20 CSR 4240-22.040(4)(A)
[3] https://cdn.misoenergy.org/GIQ%20Web%20Overview272899.pdf

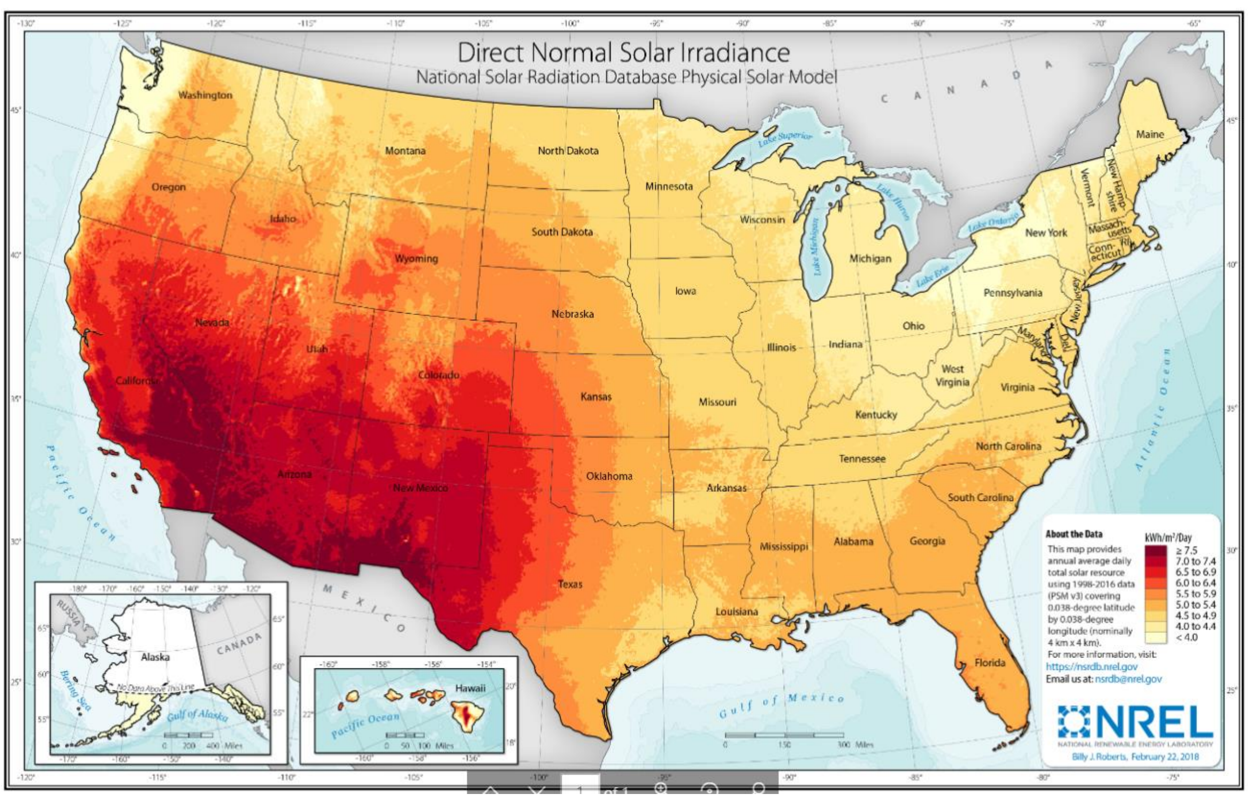
to solar projects sunsets. A detailed characterization of the information gathered through Ameren Missouri's subject matter experts for use in the 2020 IRP can be found in Chapter 6 – Appendix A.

6.1.1 Potential Solar Resources

Based on a review of available solar technologies and Ameren Missouri's service territory, flat-plate solar photovoltaic ("PV") is the most practical technology for implementation.

The solar resource has three primary components: direct, diffuse, and ground reflected. Often the sum of this resource is measured as Global Horizontal Incident ("GHI"), which is the sum of all irradiance observed by a flat plane over time. Solar PV technologies use GHI. Concentrating solar technologies, including parabolic through, power tower, dish engine, linear Fresnel and concentrating PV ("CPV") all use a direct component of insolation, called direct normal insolation ("DNI"). Given Missouri's low DNI resource, currently, PV is the most cost-effective form of solar technology.

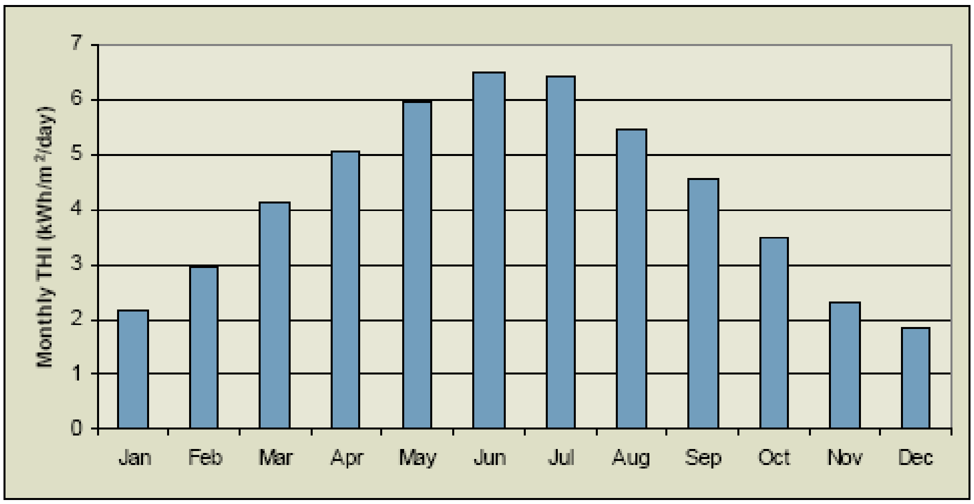
Figure 6.2 U.S. Global Horizontal Insolation Map



Global Insolation

Solar PV works by converting sunlight directly into electricity. Unlike solar thermal and concentrating photovoltaics technologies which use DNI, flat plate PV uses global insolation, which is the vector sum of the diffuse and direct components of insolation. A map of the GHI for the U.S. is shown in Figure. Note that while the desert southwest has the best insolation, there is ample insolation across much of the U.S. for photovoltaic systems. St. Louis has an annual average GHI value of 4.24 kWh/m^2-day. Figure shows the monthly average GHI for St. Louis.

Figure 6.3 Monthly Average Global Horizontal Insolation for St. Louis



Flat Plate Photovoltaics

In September 2019, the Solar Energy Industries Association ("SEIA") reported there was nearly 37 GW of large-scale PV solar (>1MW) operating in the U.S., and 74 GW under development. Of the utility-scale solar contracts signed in 2018, only 11% were under a mandated renewable portfolio standard, while more than 80% of projects were signed under voluntary procurement by a utility or corporate off-taker.[4] As mentioned above, the number and capacity of MISO GI requests has steadily increased for solar.

While the economic life of a utility-scale PV solar facility is 25 years in Missouri, there is operational and warranty evidence that these PV solar facilities have a much greater usable life. There are currently available solar PV modules that offer a 30-year limited performance warranty which guarantees an actual power output of 80% of the labeled power output or better at the end of the warranty term. Additionally, the design of the solar facility can provide technical justification for usable life beyond 25 years. As the DC-AC

[4] Solar Energy Industries Association ("SEIA") – Solar Market Insight Report 2019 Q3

ratio of solar modules to inverter output is increased, the overall capacity factor and annual energy production increases as well as the total solar facility AC output performance.

Another strategy to enable longer life from solar PV facilities is a similar concept applied to wind facilities: repowering. Essentially, the solar PV modules are replaced at, or near, end-of-life to maintain the power output of the overall facility. This strategy takes advantage of the steady improvements to efficiency that panel modules have demonstrated as well as continued reduction in module costs. Ameren Missouri continues to evaluate how this strategy may provide value for customers.

Ameren Missouri Photovoltaics

In addition to the solar assets currently in operation at Ameren Missouri, the company also plans to build additional solar resources through the Community Solar Pilot Program expansion, the Neighborhood Solar Program, and multiple Solar + Storage projects. Furthermore, as Ameren Missouri transitions its generation mix from predominantly coal-fueled generation to other resources, the company continues to consider deployment of utility-scale solar PV in Missouri and the surrounding region.

Table 6.1 lists the primary characteristics of solar resources. Chapter 6 – Appendix A contains more detailed information.

Table 6.1 Forecasted Potential Solar Resources[5]

Resource Option	Plant Output (MW-AC)	Project Cost with Owners Cost, Excluding AFUDC ($/kW-AC)	First Year Fixed O&M Cost ($/kW-AC)	First Year Variable O&M Cost ($/MWh)	Assumed Annual Capacity Factor (%)	LCOE without Incentives (¢/kWh)
Solar	1	$2,000	$7.0	$0.0	20%	9.73
Solar	10	$1,313	$5.0	$0.0	27%	4.75
Solar	100	$1,250	$4.0	$0.0	27%	4.49
Solar + Storage	10 (solar) 2.5 (BESS)	$1,600	$7.0	$0.0	27%	6.48
Solar + Storage	100 (solar) 25 (BESS)	$1,400	$6.0	$0.0	27%	5.66

5 EO-2020-0047 1.R

Ameren Missouri expects that on average the cost of solar will continue to decline, and therefore, is using a declining curve as is found in National Renewable Energy Laboratory ("NREL") 2019 Annual Technology Baseline ("ATB") data.

6.1.2 Potential Storage Resources[6]

Ameren Missouri identified a universe of storage resource options, including pumped hydro storage, CAES, and a number of battery technologies. A high-level fatal flaw analysis was conducted as part of the first stage of the supply-side selection analysis for storage resources. Options that did not pass the high-level fatal flaw analysis consist of those that could not be reasonably developed or implemented by Ameren Missouri. Two options passed the initial screen: pumped hydroelectric energy storage, and lithium-ion battery energy storage. Table 6.2**Error! Reference source not found.** lists primary characteristics of storage resources. Chapter 6 – Appendix A contains detailed resource characteristics.

Pumped Hydroelectric Energy Storage

Pumped hydroelectric energy storage is a large-scale, mature, commercial utility-scale technology used at many locations in the United States and worldwide. Conventional pumped hydroelectric energy storage uses two water reservoirs, separated vertically. During lower priced hours (historically off-peak periods), water is pumped from the lower reservoir to the upper reservoir. During high priced periods, (typically on-peak hours), the water is released from the upper reservoir to generate electricity. Church Mountain, located about midway between Taum Sauk State Park and Johnson Shut-ins State Park, was identified as the potential site for a new 600 MW pumped hydro plant. Multiple design factors can materially impact the costs of a pumped storage facility, including geography, installed capacity, and storage time. Costs used in the 2017 IRP were escalated for inflation, adjusted for the transmission interconnection cost and were used for the Levelized Cost of Energy ("LCOE") calculation in Table 6.2 Potential Energy Storage Resources.

Battery Energy Storage Systems

Battery Energy Storage Systems have been identified and deployed throughout the United States as a supply-side and a demand-side resource. BESS are capable of providing services such as frequency regulation, frequency response, load shifting, and renewable energy smoothing, to name a few. Ameren Missouri has evaluated BESS over the last several years and intends to consider deploying BESS as part of the Solar + Storage facilities mentioned in Section 6.1.1. Furthermore, as more intermittent renewable generation is deployed within Ameren Missouri's service territory and surrounding regions, BESS will become more valuable as a controllable grid resource.

[6] 20 CSR 4240-22.040(1); 20 CSR 4240-22.040(2); 20 CSR 4240-22.040(4)(A); EO-2020-0047 1.A (ii)

Ameren Missouri continues to analyze different BESS chemistries.[7] Technologies such as sodium-sulfur, while mature, have limited capabilities when compared to emerging technologies, such as lithium-ion and redox flow batteries. Advanced lead-acid batteries also continue to improve and face a challenging market with the continued pressure from lithium-ion battery products. Some of the challenges Ameren Missouri has observed for advanced lead-acid batteries include lower energy density as compared to lithium-ion chemistries, larger footprint requirements for similar performance to lithium-ion applications, and performance and cyclic-life limitations. Lead-acid battery technology is very mature and has mature recycling opportunities to address overall performance, however, this application of energy storage has not demonstrated that it is a commercially viable and widely deployed technology for the reasons mentioned above.

Redox flow batteries also show great promise with regard to cyclic life and performance but have not demonstrated commercial viability at the time of this IRP filing. Ameren Missouri continues to monitor and network with other utilities, such as San Diego Gas & Electric ("SDG&E"), as they operate their vanadium-redox flow battery at their Miguel Substation. The SDG&E redox flow battery currently tests voltage, frequency and power outage support as well as shifting energy demand.

Lithium-ion Batteries

In addition to electric vehicle and backup systems for residential and commercial applications, lithium-ion (Li-ion) systems have emerged as the preferred choice for new grid-scale storage systems in the United States. Li-ion battery prices have fallen an average of more than 22% year-over-year since 2013.[8] Furthermore, just within MISO, the capacity of energy storage interconnection requests has increased dramatically from 140 MW in 2017 to 480 MW in 2018, to 2,221 MW in 2019. Many of the MISO interconnection requests for energy storage are also paired with an intermittent renewable resource, such as solar.

Li-ion batteries have also been deployed in the PJM regional transmission organization and the New York Independent System Operator to provide frequency regulation. The California Independent System Operator ("CA-ISO") demonstrates the need for energy storage to provide capacity and demand management. For background, California public utilities expect a capacity shortfall in Southern California and have responded to an order from the California Public Utilities Commission to meet this need. Furthermore, Tesla has received much notice for installing a 100-MW battery in Australia that provides grid stabilizing services.

Table 6.2 shows the energy storage technologies that were evaluated. Lithium-ion battery energy storage was selected as an energy storage resource to be evaluated in the

[7] 20 CSR 4240-22.040(2)(C)2

[8] *SEPA 2019 Utility Energy Storage Market Snapshot*

remaining resource planning process as a major supply-side resource in addition to pumped hydro storage. Ameren Missouri expects that on average the cost of batteries will continue to decline, and therefore has assumed a 50% decline every ten years in the analysis period.

Table 6.2 Potential Energy Storage Resources

Resource Option	Plant Output, MW	Project Cost with Owner's Cost, Excluding AFUDC ($/kW)	First Year Fixed O&M Cost ($/kW-year)	First Year Variable O&M Cost ($/MWh)	Assumed Annual Capacity Factor (%)	LCOE (¢/kWh)
Pumped Storage 8-hour duration	600	$1,732	$3.8	$3.1	25.0%	12.53
Li-Ion Battery 4-hour duration	4	$1,625	$1.0	$0.0	16.7%	17.55
Li-Ion Battery 2-hour duration	4	$1,150	$2.0	$0.0	12.5%	16.76

6.1.3 Potential Wind Resources

Ameren Missouri Wind

Ameren Missouri first purchased wind through a Purchase Power Agreement ("PPA") for the output of the 102 MW Pioneer Prairie II wind farm located in Mitchell County in Northeast Iowa. This is a 15-year agreement with EDPR that began in September 2009 and will expire in August 2024. The company uses the generation from this facility to aid in complying with the Missouri Renewable Energy Standard ("MoRES") that became effective in January 2011.

In addition to this PPA, as was referenced in the 2017 IRP, Ameren Missouri surveyed wind developers via a Request for Proposal ("RFP") for both Power Purchase Agreements and Build Transfer Agreements ("BTA") for wind farms in Dec. 2015. The preference was for Missouri projects, but MISO projects in Iowa and Illinois were also considered. The RFP was the first step in identifying the most viable and economic path to achieve compliance with the MoRES once the portfolio requirement reaches 15% of retail sales in 2021. Based on the outcome of the 2017 IRP and along with responses from this RFP, it was determined that obtaining 700-800 MW of wind through a BTA was the most economical way to comply with this additional requirement. Ameren Missouri engaged in negotiations with developers for three projects all located in Missouri starting in 2017.

- Terra-Gen High Prairie (Schuyler and Adair counties)

- Tradewind Outlaw (Atchison County)
- EDF Brickyard Hills (Atchison County)

The agreement for EDF Brickyard Hills was subsequently cancelled, leaving the High Prairie and Outlaw projects to be built and acquired through the respective BTAs.

Using the prices negotiated for the two remaining projects as a reference point, Ameren Missouri subject matter experts revised the cost and operational characteristics of wind resources to be used in the 2020 IRP as can be seen in Table 6.3. Chapter 6 – Appendix A contains more detailed information. Energy Information Administration ("EIA")[9] projects the unsubsidized LCOE of wind to stay flat over the period from 2023 – 2040 in the range of ¢3.0/kWh - ¢6.5/kWh. Ameren Missouri expects that on average the installed cost of wind will continue to decline in real terms, and therefore is using a declining curve as is found in NREL 2019 Annual Technology Baseline ("ATB") data.

Table 6.3 Forecasted Potential Wind Resources[10]

Resource Option	Plant Output (MW)	Project Cost with Owner's Cost, Excluding AFUDC ($/kW)	First Year Fixed O&M Cost, ($/kW)	First Year Variable O&M Cost, ($/MWh)	Assumed Annual Capacity Factor (%)	LCOE without Incentives (¢/kWh)
Wind	100	$1,550	$31.0	$0.0	42%	4.87

6.1.4 Potential Hydroelectric Projects

Ameren Missouri previously performed studies to identify potential hydroelectric supply-side resources and projects. In addition to cost, several factors contribute to the feasibility of these projects, including accessibility of a water resource, environmental constraints, and regulatory definitions that define what types and sizes of hydropower are considered “renewable." For instance, the state of Missouri defines “renewable” hydropower in the Renewable Energy Standard ("RES"), which states hydropower generators can only be considered renewable energy sources if they meet the criteria, “hydropower (not including pumped storage) that does not require a new diversion or impoundment of water and that has a nameplate rating of 10 megawatts or less.”

Table 6.4 contains details of potential hydroelectric projects. These projects were evaluated assuming a 60-year economic life. Because the cost estimates for these resources are screening level estimates and because obtaining necessary licenses from

[9] *US Energy Information Administration, Annual Energy Outlook 2019*
[10] EO-2020-0047 1.R

the FERC can be complex, a more detailed evaluation of specific projects would be necessary before moving forward with a decision to construct.

Table 6.4 Potential Hydroelectric Resources

Resource Option	Plant Output (MW)	Project Cost with Owner's Cost, Excluding AFUDC ($/kW)	First Year Fixed O&M Cost ($/kW)	First Year Variable O&M Cost ($/MWh)	Assumed Annual Capacity Factor (%)	Current FERC Permit	LCOE (¢/kWh)
Mississippi L&D 21	6	$5,608	$26.2	$0.0	62%	No	10.15
Clearwater	5	$4,482	$26.2	$0.0	40%	No	12.80
Pomme de Terre	5	$4,234	$26.2	$0.0	60%	No	8.10

6.1.5 Potential Landfill Gas Projects

Landfill gas ("LFG") is produced by the decomposition of the organic portion of waste stored in landfills. LFG typically has methane content in the range of 45 to 55% and is considered an environmental issue. Methane is a potent greenhouse gas, 25 times more harmful than CO_2 by some estimates. In many landfills, a collection system has been installed, and the LFG is being flared rather than being released into the atmosphere. By adding power generation equipment to the collection system (reciprocating engines, small gas turbines, or other devices), LFG can be used to generate electricity. LFG energy recovery is currently regarded as one of the more mature and successful waste-to-energy technologies. There are currently nearly 600 operational LFG energy systems in the United States.[11]

Ameren Missouri continues to operate the Maryland Height Renewable Energy Center ("MHREC") at the IESI Landfill in Maryland Heights, Missouri. Previous studies have identified other landfills within the Ameren Missouri service territory that could support another LFG facility. At this time, however, other renewable resource are more abundant and more cost effective. Ameren Missouri will continue to monitor this technology for opportunities for future deployment.

[11] https://www.epa.gov/lmop/landfill-gas-energy-project-data-and-landfill-technical-data

6.1.6 Potential Biomass Projects

A study on potential biomass project feasibility had previously been conducted for Ameren Missouri. The study included identification of potential sites, technologies, resource locations, characteristics and availability, and costs. Several factors, including resource location and geographical constraints related to potential biomass projects, coupled with the cost structure and technology stagnation, especially in comparison to significant improvements in other renewable technologies, have reduced the focus on biomass as a new supply-side resource in this IRP.[12] Ameren Missouri will continue to monitor this resource potential for technological advancements and cost structure improvements.

6.1.7 Innovative Renewables Deployment[13]

Ameren Missouri is exploring various methods to incorporate and deploy more renewable generation throughout its service territory. Among those methods are:

Community Solar Pilot Program Expansion: In May 2020, Ameren Missouri received approval to expand the Community Solar Pilot Program.[14] Ameren Missouri expects to file an application for a Certificate of Convenience and Necessity ("CCN") in late 2020 to support the expansion. The current program waitlist can support the addition of approximately 5 MW (AC) to the program, but the exact capacity of the intended expansion will not be finalized until the CCN filing is made.

Neighborhood Solar Program: The Neighborhood Solar Program follows a similar approach to the Solar Partnerships program by siting utility-owned solar generation on customer property. Ameren Missouri will own and operate all systems for the benefit of all customers; host participants provide site access to the partnership. To date, Ameren Missouri has received more than 100 applications from interested customers for the program, and is currently reviewing applications in order to select sites that offer a wide array of customer benefits. As part of the Smart Energy Plan, Ameren Missouri intends to spend at least $14 million on the program, and anticipates the first Neighborhood Solar sites will be in service in 2021. Ameren Missouri is identifying and selecting partner sites that will inclusively benefit our customers through renewables education, visibility, and workforce opportunities. When selecting partner sites, we keep in mind the following goals:

- Strategic investment in communities that are under-served and represent a diversity of regions in our service territory

[12] 20 CSR 4240-22.040(2)(C)2
[13] EO-2020-0047 1.A
[14] ET-2020-0022

- Opportunity for renewables visibility (i.e., to foot or vehicle traffic) and intentional education/awareness for students, clients, or constituents of the site
- Equitable workforce development in our region that opens doors to careers in the growing renewables sector:
  - We are piloting an addition to vendor bidding and selection that incentivizes vendors to develop high quality workforce development plans.
  - Including this type of criterion on vendor scoring allows Ameren Missouri to drive employer priorities on Diversity, Equity & Inclusion as well as tangibly connect under-represented workers with renewables job opportunities.

Green Tariff Program(s): A variety of Ameren Missouri customers, from residential to large industrial, are requesting access to 100% renewable energy prior to Ameren Missouri's transition plan. Many of these customers are willing to pay a premium to gain access to cleaner energy, and are considering a variety of paths to achieve their goals.

As one step to meet these customer needs, Ameren Missouri's green tariff program, Renewable Choice, was approved by the Missouri Public Service Commission in 2018. Through the program, Ameren Missouri is authorized to sign up 400 MW of customer subscriptions for wind resources. Although customer interest in the program has been robust, to date Ameren Missouri has been unable to meet all the needs of the program and therefore has yet to move forward with a specific wind project. In part because of the challenges surrounding the Renewable Choice program, a new subscriber renewable program is under development, which will likely replace the Renewable Choice Program if challenges continue. In addition, as required under the settlement agreement of Ameren Missouri's most recent rate case, the Pure Power Program can no longer accept new participants, and current customers must be transitioned to a "future Community Solar program of sufficient size."[15] At this point, both wind and solar are being considered to support the program, and it is expected to include several hundred megawatts of new renewable generation capacity. Barring unforeseen circumstances, Ameren Missouri intends to file this green tariff program in late 2020 or early 2021.

Solar + Storage Projects: Pairing solar generation with BESS has become a utility industry trend that can produce various benefits and support numerous use cases, which can include generation related benefits (energy, capacity, ancillary services) or distribution system reliability benefits, or both. The pairing of the solar and battery components can differ through the connection type: AC-coupled or DC-coupled.

The AC-coupled configuration is similar to the descriptions of a solar PV asset, in Section 6.1.1, connected on the same circuit or co-located with a BESS asset, as described in Section 6.1.2. This application can use the solar and BESS as a single energy and

[15] ER-2019-0335

capacity asset. The renewable solar energy can charge the battery system when not needed by the grid. The stored energy can then be discharged during times of high demand or during outages to provide improved reliability. Presently, AC-coupled solar and storage systems offer operational flexibility and are technically simpler to integrate into the existing grid than DC-coupled systems. For this reason Ameren Missouri believes AC-coupled systems installed selectively in specific areas can be used to optimize energy demand and improve the delivery of renewable energy, while also providing the highest level of improved reliability to electrical circuits and the customers they serve.

The DC-coupled configuration is different in that the solar PV equipment and battery must be co-located and share the same interconnection, are connected on the same DC bus, utilize the same inverter, and are dispatched together as a single facility. DC coupling systems are expected to reduce efficiency losses and potentially reduce cost due to a reduced need for inverters, however, at the time of this filing this technology has not been shown to be commercially or technically viable. Ameren Missouri is actively monitoring coupling technologies and strategies and would expect both technologies to be utilized in the future. Installing multiple smaller-scale (5MW – 10MW) paired solar and storage resources would assist in future development and refinement for larger-scale paired solar and storage resources.

6.2 New Thermal Resources

6.2.1 Potential Natural Gas Options

Discussion of multiple natural gas supply-side resource options was included in the 2017 IRP, addressing base, intermediate, and peaking load requirements. The Ameren Missouri generation portfolio currently includes over 2,800 MW of simple cycle natural gas generation capacity. While simple cycle generation continues to be a new generation investment option for planning purposes the traditional comparative advantages of new peaking investments are limited given our current fleet's capabilities and our expected peak load profiles

Considering Ameren Missouri's existing and planned generation portfolio and forecasted demand, the 2020 IRP focuses on new gas supply-side resource options for base and intermediate load service. The retirement of coal resources over the planning period, along with the addition of non-dispatchable renewable resources, has led to an emerging focus on replacing and expanding robust ramp rate capabilities. In light of this new focus on intermittent supply from the expanding renewable generation, EIA data for historical and projected project costs, and Ameren Missouri's drive to reduce carbon emissions, this IRP focuses on the natural gas combined cycle technology as a potential new supply-side resource.

Ameren Missouri previously studied combined cycle technology, including the evaluation of potential combined cycle generating configurations, and potential facility locations. Any future investment will require an updated evaluation to consider the latest technologies, costs, and developments that may impact a new energy center location. For example, since our last IRP, a new 24-inch natural gas pipeline has been constructed, bringing gas from the Rockies Express Pipeline in Illinois into Missouri, through St. Charles and north St. Louis counties. Multiple combined cycle configurations are possible, providing the opportunity and flexibility to tailor a supply-side resource solution to future requirements and constraints in a cost-effective manner.

Table 6.5 contains details of potential natural gas projects. These projects were evaluated assuming a 30-year economic life. Because the cost estimates for these resources are screening level estimates developed from EIA data,[16] a more detailed scope and evaluation of specific projects would be necessary before moving forward with a decision to construct.

Table 6.5 Potential Natural Gas Resources

Resource Option	Plant Output (MW)	Total Project Cost Including Owners Cost, Excluding AFUDC ($/kW)	First Year Fixed O&M Cost ($/kW-year)	First Year Variable O&M Cost ($/MWh)	Assumed Annual Capacity Factor (%)	LCOE (¢/kWh)
Combined Cycle - (1) 2x2x1	1,067	$1,079	$23.7	$1.9	40%	6.37
Combined Cycle - (2) 1x1x1	824	$1,245	$25.7	$2.6	40%	7.01
Simple Cycle	689	$796	$8.2	$10.9	5%	24.81

Ameren Missouri's focus on natural gas combined cycle ("CC"), solar PV, and wind supply-side resources for the 2020 IRP are in accordance with the EIA's forecast for power plant capacity additions in the United States through 2050. The EIA expects the CC technology to be the marginal source (basis of comparison) for new electricity generation through 2050.[17]

Other thermal technologies remain as potential candidates for new supply-side resources, including reciprocating engines. Ameren Missouri will continue to monitor these arenas for technological advancement and cost structure improvements.

[16] U.S. Energy Information Administration Capital Cost and Performance Characteristic Estimates for Utility Scale Electric Power Generation Technologies, February 2020.
[17] https://www.eia.gov/todayinenergy/detail.php?id=38612

6.2.2 Potential Coal and Nuclear Resources

Due to recent and ongoing cost and schedule overruns on domestic gasification projects, stagnation in the carbon capture and sequestration technology development, and continued regulatory, environmental, and sociopolitical headwinds challenging coal projects, ultra-supercritical pulverized coal was not considered for this IRP.[18] Ameren Missouri will continue to monitor these projects and developments in these technologies for potential future supply-side resources. Despite similar challenges to new nuclear domestic projects, new nuclear was considered in this IRP for carbon-neutral around-the-clock generating capabilities. Details are shown in Table 6.6.

Table 6.6 Potential Nuclear Resources

Resource Option	Plant Output (MW)	Total Project Cost Including Owners Cost, Excluding AFUDC ($/kW)	Annual Decommissioning Costs ($1,000)	First Year Fixed O&M Cost ($/kW-year)	First Year Variable O&M Cost ($/MWh)	Assumed Annual Capacity Factor (%)	LCOE (¢/kWh)
AP1000	1,100	$8,899	$19,306	$121.6	$2.37	94%	14.89

6.3 Power Purchase Agreements

After discussions with Ameren Missouri's Asset Management and Trading organization it was determined that there were no pending potential long-term power purchases for consideration at the time of the analysis. Furthermore, Ameren Missouri learned from its experience in developing the 2008 and 2011 IRPs that soliciting the market for long-term power purchases or sales is not productive for bidders given the data at this stage of the analysis is generic, and potential respondents are reluctant to share information on potential agreements without a reasonable expectation for an executed contract. Evaluation of generic power purchase agreements would not be expected to yield different results in terms of relative performance of resource types, as the only reasonable assumption that could be made absent specific information would be that such an agreement would be effectively cost-based.

6.4 Final Candidate Resource Options[19]

Error! Reference source not found. 6.4 demonstrates the LCOE with incentives (e.g., investment tax credits or production tax credits, if applicable) for a range of potential

[18] 20 CSR 4240-22.040(2)(C)2
[19] 20 CSR 4240-22.040(4); 20 CSR 4240-22.040(4)(C)

supply side resources. It is important to note that levelized cost of energy figures, while useful for convenient comparisons of resource alternatives, do not fully capture all of the relative strengths of each resource type. For example, wind resources are intermittent resources and therefore cannot be counted on for meeting peak demand requirements in the same way a nuclear or gas-fired resource can. Similarly, using an energy cost measure to evaluate peaking resources such as simple cycle Combustion Turbine Generators ("CTGs") does not fully reflect their value as a capacity resource or their quick-start capability. Table 7 shows the component analysis for the levelized cost of energy figures.

Figure 6.4 Levelized Cost of Energy

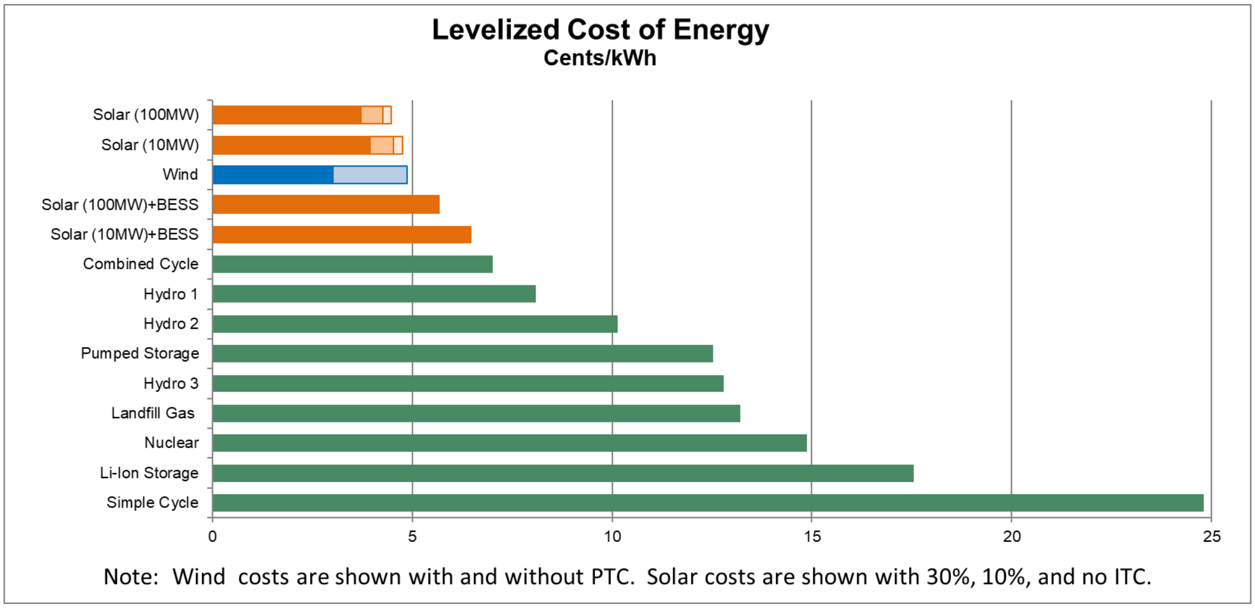


Table 6.7 Levelized Cost of Energy Component Analysis[20]

Potential Resource	Levelized Cost of Energy (¢/kWh)								
	Capital	Fixed O&M	Variable O&M	Fuel	Resource Specific Cost*	CO_2	SO_2	NO_X	Total Cost
Solar (100MW)	4.28	0.20	--	--	--	--	--	--	**4.49**
Solar (10 MW)	4.50	0.26	--	--	--	--	--	--	**4.75**
Wind	3.82	1.05	0.00	--	--	--	--	--	**4.87**
Solar + BESS (100MW+25MW)	5.36	0.31	0.00	--	--	--	--	--	**5.66**
Solar + BESS (10MW+2.5MW)	6.12	0.36	0.00	--	--	--	--	--	**6.48**
Combined Cycle: Two 1x1x1	3.47	0.91	0.32	2.02	--	0.30	0.00	0.00	**7.01**
Hydro: Pomme de Terre	7.40	0.69	0.00	--	--	--	--	--	**8.10**
Hydro: Mississippi L&D 21	9.48	0.67	0.00	--	--	--	--	--	**10.15**
Storage: Pumped Hydro	8.09	0.23	0.40	--	3.81	--	--	--	**12.53**
Hydro: Clearwater	11.76	1.04	--	--	--	--	--	--	**12.80**
Landfill Gas	5.80	1.85	1.53	4.03	--	--	0.00	0.00	**13.22**
Nuclear	11.69	1.93	0.31	0.75	0.21	--	--	--	**14.89**
Storage: Li-Ion Battery (4h)	14.50	0.08	0.00	--	2.98	--	--	--	**17.55**
Simple Cycle	17.50	2.32	1.35	3.18		0.46	0.00	0.00	**24.81**

***** Nuclear Decommissioning, Hydro Pumping, Battery Charging

The LCOE for future resource options is an important measure for assessing these options. However, it is not the only factor that must be considered in making resource decisions. Facts and conditions surrounding future environmental regulations, commodity market prices, economic conditions, economic development opportunities, and other factors must be considered as well. A robust range of uncertainty exists for many of these factors, all of which leads to one overriding conclusion – maintaining effective options to pursue alternative resources in a timely fashion is a prudent course of action.

[20] 20 CSR 4240-22.040(2)(B); 20 CSR 4240-22.040(2)(C)1

6.5 Compliance References