Technology Screening and Application Standards

2022 Integrated Resource Plan

Technology Screening

Georgia Power (the "Company") and Southern Company performs detailed expansion planning and production cost analysis in the development of each Integrated Resource Plan ("IRP"). This detailed analysis requires complex and time-consuming computation and input preparation. Therefore, the Company completes a technology screening assessment of new generation technologies to derive a manageable list of technologies that are the most likely to be economically competitive in the various planning scenarios. This technology screening assessment evaluates both established and emerging generating technologies. The objective is to assess the cost, maturity, safety, operational reliability, flexibility, economic viability, environmental acceptability, fuel availability, construction lead times, and other relevant factors of new supply-side generation options.

The technology screening process includes three main steps before the quantitative analysis that involves production cost modeling and expansion plan optimization. These three steps are Technology Identification, Preliminary Screening, and Detailed Qualitative Screening Analysis. Supply-side options retained after these steps are then considered in the quantitative analysis, or expansion plan modeling.

Figure 1 – Technology Screening Process

Step 1: Technology Identification

Developing the supply-side generation options starts with identifying and defining an expansive portfolio of generating technologies. A clear working definition of each option is important for the effective consideration and communication of its attributes necessary for the screening steps. The list of all identified options is provided in Table 1 and their definitions can be found in Attachment A.

Table 1 – Expansive Portfolio of Generation Technology in Screening Step 1

FOSSIL FUEL	**ENERGY STORAGE**
Combustion Turbine (CT)	Pumped Storage Hydroelectric (PSH)
Combined Cycle (CC)	Underground Pumped Storage Hydroelectric
Fuel Cell	Compressed Air Energy Storage (CAES) - Diabatic
Fuel Cell Combined Cycle (FCCC)	Compressed Air Energy Storage (CAES) – Adiabatic
Reciprocating Internal Combustion Engines (RICE)	Lithium-ion Battery Storage (Li-ion)
Pulverized Coal (PC)	Alternative Chemistry Battery Storage
Advanced Ultrasupercritical Pulverized Coal (AUSC)	Flow Battery
Fluidized Bed Combustion	Power-to-gas
Integrated Gasification Combined Cycle (IGCC)	Flywheel
Direct-fired Supercritical CO_2 Cycle	Cryogenic (Liquid Air) Energy Storage (LAES)
Magnetohydrodynamics (MHD)	Thermal Energy Storage (TES)
	Gravity
NUCLEAR	Thermochemical
Light Water Reactor (LWR)	Pumped Thermal Energy Storage (PTES)
Generation IV Nuclear	
Small Modular Reactor (SMR)	
RENEWABLE	
Solar Photovoltaic (PV)	
Concentrated Solar Power (CSP)	
Onshore Wind Power	
Offshore Wind Power	
Municipal Solid Waste	
Dedicated Biomass	
Co-fired Biomass or Wood Waste	
Landfill gas (LFG)	
Geothermal	
Hydroelectric	
Ocean Energy and Hydrokinetic Generation	
Ocean Thermal Generation	

Step 2: Preliminary Screening

After identifying and defining an expansive collection of supply-side technologies, an initial screening then considers the commercial viability of each technology's deployment in electricity markets and in the service territory. Factors that are considered in this step include but are not limited to safety, the level of technical development, known commercial availability, environmental impacts, applicability to the Company's Service Territory, cost and performance uncertainties, and the potential advantages compared to other technologies. The preliminary screening status for each is provided in Table 2 and is characterized in Attachment A.

Table 2 – Preliminary Screening Results in Step 2

TECHNOLOGY	PRELIMINARY SCREENING STATUS
FOSSIL FUEL	
Combustion Turbine (CT)	Retained
Combined Cycle (CC)	Retained
Fuel Cell	Retained
Fuel Cell Combined Cycle (FCCC)	Not Retained
Reciprocating Internal Combustion Engines (RICE)	Retained
Pulverized Coal (PC)	Not Retained
Advanced Ultrasupercritical Pulverized Coal (AUSC)	Not Retained
Fluidized Bed Combustion	Not Retained
Integrated Gasification Combined Cycle (IGCC)	Not Retained
Direct-fired Supercritical CO_2 Cycle	Retained
Magnetohydrodynamics (MHD)	Not Retained
NUCLEAR	
Light Water Reactor (LWR)	Retained
Generation IV Nuclear	Not Retained
Small Modular Reactor (SMR)	Retained
RENEWABLE	
Solar Photovoltaic (PV)	Retained
Concentrated Solar Power (CSP)	Not Retained
Onshore Wind Power	Retained
Offshore Wind Power	Retained
Municipal Solid Waste	Not Retained
Dedicated Biomass	Retained
Co-fired Biomass or Wood Waste	Retained
Landfill gas (LFG)	Retained
Geothermal	Not Retained

Hydroelectric	Not Retained
Ocean Energy and Hydrokinetic Generation	Not Retained
Ocean Thermal Generation	Not Retained
ENERGY STORAGE	
Pumped Storage Hydroelectric (PSH)	Retained
Underground Pumped Storage Hydroelectric	Not Retained
Compressed Air Energy Storage (CAES) - Diabatic	Retained
Compressed Air Energy Storage (CAES) – Adiabatic	Retained
Lithium-ion Battery Storage (Li-ion)	Retained
Alternative Chemistry Battery Storage	Retained
Flow Battery	Not Retained
Power-to-gas	Retained
Flywheel	Not Retained
Cryogenic (Liquid Air) Energy Storage (LAES)	Retained
Thermal Energy Storage (TES)	Retained
Gravity	Not Retained
Thermochemical	Not Retained
Pumped Thermal Energy Storage (PTES)	Not Retained

Step 3: Qualitative Screening Analysis

After an initial screen over a wide range of options, the Company initiates a more detailed qualitative screening analysis based on technical, environmental, safety, regulatory, and constructability factors, as well as any other uncertainties that would significantly affect the potential to deploy a technology in the Company's service territory. Every energy supply option that passes this step will be considered a proven technology and will have a defined business case. This step also considers whether a technology can be practically scaled and repeated in a way that could result in material impacts to an overall integrated resource plan. Table 3 shows the candidate technologies that are retained after a qualitative screening analysis that considers these criteria.

Table 3 – Results of Qualitative Screening Analysis in Step 3

Technology	Status	Exclusion Criteria
Combustion Turbine (CT)	**RETAINED** for further screening	Not Applicable
Combined Cycle (CC)	**RETAINED** for further screening	Not Applicable
Fuel Cell	**NOT RETAINED** for further screening	Execution, Business Case Uncertainties
Reciprocating Internal Combustion Engine (RICE)	**RETAINED** for further screening	Not Applicable
Direct-fired Supercritical CO_2 Cycle	**NOT RETAINED** for further screening	Technical, Execution Uncertainties
Generation III+ Large Light Water Reactors (LLWR)	**NOT RETAINED** for further screening	Execution, Business Case Uncertainties
Generation III+ Small Modular Reactors (SMRs)	**NOT RETAINED** for further screening	Regulatory, Technical, Execution Uncertainties
Solar Photovoltaic (PV)	**RETAINED** for further screening	Not Applicable
Onshore Wind Power	**RETAINED** for further screening	Not Applicable
Offshore Wind Power	**NOT RETAINED** for further screening	Regulatory, Execution, Technical Uncertainties
Biomass (wood, etc.)	**NOT RETAINED** for further screening	Regulatory, Business Case, Supply Chain, and Scalability Uncertainties
Co-fired Biomass or Wood Waste	**NOT RETAINED** for further screening	Limited Scalability
Landfill Gas (LFG)	**NOT RETAINED** for further screening	Regulatory Uncertainty, Limited Scalability
Pumped Storage Hydroelectric (PSH)	**NOT RETAINED** for further screening	Limited Siting Opportunities, Limited Repeatability
Compressed Air Energy Storage (CAES) - Diabatic	**NOT RETAINED** for further screening	Limited Siting Opportunities, Limited Repeatability
Compressed Air Energy Storage - Adiabatic (A-CAES)	**NOT RETAINED** for further screening	Technical, Siting, Execution Uncertainties
Lithium-ion Battery Storage	**RETAINED** for further screening	Not Applicable
Alternative Chemistry Battery Storage	**NOT RETAINED** for further screening	Technical, Commercial Availability Uncertainties
Power-to-gas	**NOT RETAINED** for further screening	Technical, Execution Uncertainties
Cryogenic (Liquid Air) Energy Storage (LAES)	**NOT RETAINED** for further screening	Technical, Execution Uncertainties
Thermal Energy Storage (TES)	**NOT RETAINED** for further screening	Technical, Execution Uncertainties

If a candidate option has potentially desirable economic, environmental, and other characteristics, but only under unique circumstances, or if it is not persistently scalable and repeatable, then it will not become a generic expansion plan candidate for the quantitative portion of the expansion resource mix selection. Technologies that have desirable characteristics under unique application settings, such as specific customer requirements or geographic requirements, are retained separately to be evaluated for future projects should the right set of circumstances present themselves. For instance, the Company will evaluate opportunities to deploy new cogeneration assets when they arise, but all cogeneration projects are unique so that it is not feasible to establish cost and performance parameters that are either generic or repeatable.

The Company accounts for the potential value of multiple supply-side resource attributes that include but are not limited to flexibility, environmental traits, forecasted improvements in cost and/or performance in future years. Such attributes are considered in the screening process and can contribute to a technology's retainment. Furthermore, some generation technology options may be retained with environmental controls that are not yet considered to be fully commercially demonstrated and mature, such as CC with Carbon Capture and Sequestration ("CCS") controls and CT with Selective Catalytic Reduction ("SCR") controls, due to planning scenario assumptions that anticipate these controls in the future. The Company does not consider these for deployment in early years of the planning timeframe but anticipates that they could become available farther in the future.

Step 4: Candidate Technologies for Detailed Analysis

The final results of the screening process are designated as the Company's Technology Application Standards ("TAS") and consist of new generation technology inputs into the expansion planning analysis. The TAS contain both cost and performance information for generic expansion units as included in Attachment B. The Company's expansion planning analysis informs individual resource evaluations through a detailed production cost modeling and economic optimization study. Table 4 provides the final list of new generating technologies included in the TAS that are offered as expansion planning candidates after the screening process is complete.

Table 4 – New Generation Technologies Retained after Complete Screening Process

Combined Cycle (CC)
Combined Cycle with Carbon Capture & Sequestration (CC w CCS)
Combustion Turbine (CT)
Combustion Turbine with Future Emission Controls (CT w SCR)
Reciprocating Internal Combustion Engines (RICE)
Solar Photovoltaic (PV) - Single Axis Tracker (SAT)
Onshore Wind Power (On-system)
Lithium-ion Battery Energy Storage System (BESS)

Technology Advancement View in Planning

Through the comprehensive planning process, modified or advanced candidate technology options may be needed to achieve certain planning scenario goals. However, some of these technologies studied in future years of the scenarios may not currently be commercially available at utility scale or may not currently meet the cost and performance targets analyzed. The main applications for these more advanced and lower cost technology options are in the technology view of Scenario 10, also named the "Tech" scenario. Technology advancements utilized in the lower CO_2 abatement technology cost view draw from candidate options already identified in the screening process. This view assumes steep declines in the costs of certain technologies and includes others that were screened out because they are not commercially available. Estimates of cost and performance for these future technologies have been included in the expansion planning process to fulfill scenario needs.

The Company identified energy storage, carbon capture, renewable generation improvements, and new nuclear as emerging resource technology categories to consider for studying technological advancements that could help achieve significant carbon emission reductions. Certain aspects of these technology categories or specific technology applications may not be commonly considered commercially or economically deployable, which prevented them from being considered in normal technology screening processes. However, these general technology categories could experience improvements that enable commercial and economic addition of these resources in the future. Therefore, the Company considers potential impacts of energy technology research, development, and commercialization to its supply-side options with the inclusion of these technology categories in the Tech scenario. The Company will continue to monitor and evaluate emerging technologies and update its assumptions as a component of its continuous planning process. Figure 2 summaries the categories modeled for this scenario.

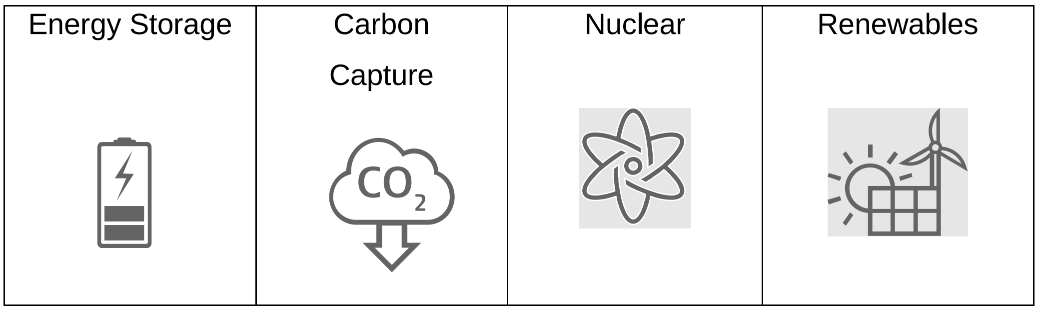

Figure 2 – Technology Advancement Categories

In order to facilitate modeling energy technology advancement, the Company assumes a specific technology that it is monitoring within each broader category. The resulting assumptions are not meant to imply that this specific technology is the only emerging option that represents a specific category, but rather it serves as a proxy for certain goals of the major research, development, and commercialization efforts taking place today within the power sector. These proxies are chosen based on the Company's assessment of their potential value to a decarbonized energy sector and their status of technical and commercial development, which is informed by ongoing planning, research, and development efforts. For example, the Company assumes the cost and performance attributes associated with direct-fired supercritical CO_2 with CCS technology for the carbon capture category. Other technologies could mimic or compete with the grid value of direct-fired supercritical CO_2 with CCS, such as major improvements in post-combustion carbon capture for NGCC, and may also be considered for this category. Table 5 outlines the advancements in technologies that are offered as expansion planning candidates in the Tech scenario. Attachment C to this Appendix lists the cost and performance assumptions for these emerging technologies as well as the capital cost forecasts for wind and BESS as compared to the forecast in the standard view.

Table 5 – Candidate Technology Advancements in the Tech Scenario

Technology	Advancement Type
Onshore Wind Power (On-system)	In-service capital cost declines
Battery Energy Storage System (BESS)	In-service capital cost declines
Natural Gas Direct-fired Supercritical CO_2 Cycle with CCS (Supercritical CO_2)	Funded demonstration & full commercialization
Generation III+ Small Modular Reactors (SMRs)	Funded demonstration & full commercialization
Generation IV Nuclear (Gen IV)	Funded demonstration & full commercialization
Solar Photovoltaic (PV)	Power purchase agreement pricing cost declines

Attachment A: Technology identification, definition, and preliminary screening in step 1.

Technology	Description	Status
Combustion Turbine (CT)	CTs use liquid or gaseous fuel to heat compressed air that then expands across a turbine to generate power. Many conventional units exist in the system. The technology is mature, but advanced designs offer even higher turbine inlet temperatures for improved efficiencies. Increasing maximum temperatures bring reliability questions that will be investigated with each new generation of CT. CTs can be applied as peaking capacity and in combined cycle plants using natural gas or oil. Advancements are being closely monitored. New units would include the latest emission control systems to ensure compliance with all applicable environmental regulations and permit requirements.	**RETAINED** for further screening.
Combined Cycle (CC)	CCs involve one or more CT and at least one heat recovery steam generator (HRSG) that uses the high temperature CT exhaust to produce steam. That steam creates power through a steam turbine. Units are currently in operation on the system and the technology is mature. Vendors are now offering new CT designs with increased turbine inlet temperatures for improved CC efficiencies. Each of the major Original Equipment Manufacturers ("OEMs") now offer packaged CC plants, based on advanced gas turbine technology, which offer greater thermal efficiencies and increased operational flexibility when compared to previous units. New units would include the latest emission control systems to ensure compliance with all applicable environmental regulations and permit requirements. A number of advanced CT-based cycles such as the Cascaded Humidified Advanced Turbine (CHAT) and Kalina cycles have the potential for higher thermal efficiencies, but they have not been commercially demonstrated.	**RETAINED** for further screening.
Fuel Cell	Fuel cells are electrochemical systems that typically use hydrogen, a catalyst material, and an electrolyte substance. Fuel cells are typically characterized by their separator type (and the ion which passes across the separate), such as proton exchange membrane (PEM), phosphoric acid, and solid oxide fuel cells. Natural gas can be used as the feedstock in a hydrogen reformation system built into the fuel cell module. Fuel cells feature modular construction, low environmental impact, siting flexibility, and high efficiencies at small sizes. While they also come at a high cost compared to other technologies at large scale, they may fit applications at the distributed level to provide resiliency.	**RETAINED** for further screening.

Fuel Cell Combined Cycle (FCCC)	Some types of fuel cells operate at high temperatures (600-1000˚C), such as molten chloride and solid oxide fuel cells. The high temperature exhaust gas from these cells can then be used to generate steam for an additional power generation cycle or cogeneration applications. Fuel cells could be paired with reciprocating engines or microturbines for an additional cycle and increased efficiency. Ongoing research is exploring the power efficiency increase gained by pairing fuel cells with RICE as a first and second stage, respectively.	**NOT RETAINED** for further screening at this time due to the level of development and cost uncertainties.
Reciprocating Internal Combustion Engines (RICE)	Reciprocating Internal Combustion Engines (RICE) use liquid or gaseous fuel to produce power through internal combustion, similar to the engines present in automobiles and heavy machinery. Engines can range in size from a few kW to 20 MW. Typical utility applications range from 5-20 MW. RICE are capable of fast and frequent starts, very fast ramp rates, and generally good efficiency. In addition to peaking usage, they are also used as blackstart units and occasionally as co-generation/combined-heat-and-power (CHP) units. This is a mature technology.	**RETAINED** for further screening.
Pulverized Coal (PC)	PC plants use coal-fired boilers to produce steam to power a turbine. This technology is mature, and there are a large number of units on the system. New units would include the latest emission control systems to ensure compliance with all applicable environmental regulations and permit requirements.	**NOT RETAINED** for further screening at this time due to cost relative to other options and future environmental uncertainty.
Advanced Ultrasupercritical Pulverized Coal (AUSC)	This technology represents the targeted design of current AUSC research and embodies pulverized coal-fueled generation to steam energy conditions higher than that achieved by existing pulverized coal technology for higher thermal efficiency (steam conditions approaching 5000 psia and 1400˚F). The environmental performance would be similar to, though slightly better than, other typical pulverized coal generation due to efficiency gains. This technology is close to demonstration status but domestic host sites are nonexistent. The cost of the high temperature components has a high impact on the plant capital cost due to the materials and the amount needed for main steam and reheat piping. While the efficiency of an AUSC unit is higher, it does not necessarily eliminate the need for emissions controls technologies.	**NOT RETAINED** for further screening at this time due to cost relative to other options and future environmental uncertainty.

Fluidized Bed Combustion (FBC)	For utilities, FBC is used to produce steam to power a turbine similar to PC plants. FBC technologies have the potential for sulfur removal without add-on flue gas scrubbers. FBC also generally produces less NOx than other similar boilers due to a lower temperature inside of the boiler. FBC has historically been the technology of choice for low grade, high ash coals but is also capable of using biomass.	**NOT RETAINED** for further screening at this time due to cost relative to other options and future environmental uncertainty.
Integrated Gasification Combined Cycle (IGCC)	Integrated Gasification Combined Cycle (IGCC) technology utilizes a fossil or biomass-based fuel for gasification to synthesis gas (a mixture of mostly hydrogen, carbon monoxide, and carbon dioxide). Synthesis gas and waste heat from the gasification process are used to generate power from a combined cycle. This concept has potential for improved efficiency and environmental performance over pulverized coal-firing. Pre-combustion carbon capture technology can be integrated into the plant design to achieve further carbon emissions reductions from the concentrated CO_2 in the synthesis gas stream.	**NOT RETAINED** for further screening at this time due to cost relative to other options and future environmental uncertainty.
Direct-fired Supercritical CO_2 cycle	The “Allam Cycle” is a direct-fired, semi-closed Brayton power cycle using supercritical CO_2 as the working fluid, which has unique thermodynamic advantages in this state. The technology is fired with gaseous fuel, and due to the nature of the cycle, creates pipeline-ready CO_2 for a zero- or near-zero emissions plant. The technology has the potential to result in higher plant efficiencies, with CO_2 capture included, compared to adding CO_2 capture to combined cycle technology (CC) fired with NG or coal syngas. Material and mechanical design present execution and supply chain challenges today. There is ongoing industry work which has moved this technology to a 25 MWe Demonstration that is operating in La Porte, TX.	**RETAINED** for further screening at this time due to current level of development.
Magnetohydrodynamics (MHD)	Magnetohydrodynamic (MHD) power generation is a direct energy conversion process in which positive ions and free electrons in a high-temperature gas plasma flowing at high speed through a channel under a strong magnetic field induce an electric current. Although MHD technology development in the 1960s through the early 1990s focused on application as a “topping cycle” on conventional pulverized coal (PC) plants to boost efficiency, interest today is chiefly focused on use with oxy-combustion processes with carbon capture and storage (CCS) in both topping- and bottoming-cycle configurations. MHD’s appeal is high efficiency and inherent SO_2, nitrogen oxide (NO_x), and particulate control. However, progress with MHD remains slow to	**NOT RETAINED** for further screening at this time due to the level of development and cost uncertainties.

	stagnant, and conceptual estimates indicate a very high cost.	
Generation III+ Large Light Water Reactors (LLWR)	Generation III+ Large Light Water Reactors (LLWR) are light-water cooled nuclear fission reactors that typically have an output greater than 300MWe. Compared to the existing nuclear fleet (Generation II), Generation III+ reactors incorporate improvements in areas such as passive safety systems, controls, materials, construction techniques, and a streamlined regulatory approval process. LLWR technology is mature and additional efficiencies will be realized as the industry gains construction experience. Southern Company is pursuing Generation III+ technology as construction continues of two Westinghouse AP1000 (1000 MWe) nuclear units at Plant Vogtle. Commercial operation is anticipated in 2022 and 2023 for Units 3 and 4, respectively. In addition to the AP1000 design, this category includes the NRC certified design Korean Hydro and Power 1400 MWe Advanced Pressurized Reactor (APR 1400) and General Electric Economic Simplified Boiling Water Reactor (ESBWR).	**RETAINED** for further screening.
Generation IV Advanced Reactors (AR)	Generation IV Advanced Reactors (AR) are nuclear fission reactors that differ substantially from light-water cooled reactor designs. ARs offer a range of operational and economic benefits, including inherent and passive safety features, high temperature operation, and load following capability. ARs could also play a significant role in closing the nuclear fuel cycle. The high temperature operation of ARs enables flexibility across a broad range of polygeneration applications, including thermal energy storage, hydrogen production, and direct heat applications. ARs range in capacity from 20 MWe to over 1 GWe with many designs leveraging a modular approach to maintain flexibility in total plant output. A subset of ARs coined “microreactors” are typically designed for less than 20 MWe output and offer benefits such as factory fabrication, transportability, simple installation, and flexible operations. Microreactors are not considered as a part of this exercise.	**NOT RETAINED** for further screening at this time due to development status.
Generation III+ Small Modular Reactors (SMRs)	Generation III+ Small Modular Reactors (SMR) are light-water cooled nuclear fission reactors that typically have an output of less than 300 MWe. These designs are similar to LLWRs; however, they offer additional benefits. The modular component of these designs refers to two attributes of the designs: (1) the ability of the reactor to be manufactured mostly in a factory setting and (2) each reactor is considered a separate module, thus allowing for phased installations at each site. The benefits of these designs over LLWRs include advanced safety design,	**RETAINED** for further screening.

	smaller footprints and components, and smaller fuel inventories. Several potential uses have been identified, including a bridging strategy for retiring coal plants as well as incremental base load generation. NuScale and General Electric are the primary technology developers of SMR designs.	
Solar Photovoltaic (PV)	Cost has dropped significantly in recent years and research continues to increase efficiency and reduce cost. Issues include the site-specific solar insolation resource which yields intermittencies in production and large land area requirements. Cost declines can continue to make this technology an even more attractive alternative. The technology has excellent environmental aspects.	**RETAINED** for further screening.
Concentrated Solar Power (CSP)	CSP is commonly referred to as a "power tower", where an array of mirrors is focused on a specific area on a tower that contains a receiver (boiler) where steam is made directly. It works most effectively in direct sunlight. Diffuse solar insolation due to clouds and haze in the Southeast reduces its value, and the high capital cost and large land area requirements are significant concerns. This technology has good environmental characteristics.	**NOT RETAINED** for further screening at this time due to cost uncertainties, level of development, and limited applicability in Southern Company's territory.
Onshore Wind Power	Rising capacity factors produced by taller hub heights and turbine efficiency improvements are allowing onshore wind to become more competitive vs other options.	**RETAINED** for further screening.
Offshore Wind Power	The Southeastern U.S coast offers the potential for offshore wind. As experience with the technology increases offshore wind could become competitive as costs decline.	**RETAINED** for further screening.
Municipal Solid Waste ("MSW")	MSW could be utilized in a variety of processes such as combustion, gasification, pyrolysis, and anerobic digestions. Most often MSW is sent to landfills which is a form of anaerobic digestions. Only a fraction of the organic waste material will be converted to biogas in this process. Whereas with, combustion, gasification, and pyrolysis the cellulosic and synthetic organic (i.e. plastics) could be converted into useful energy or value-added chemicals. Utilizing combustion, gasification, and pyrolysis offer the opportunity to limit the amount of material that is sent to a landfill and provide an end-of-life solution to the accumulation of plastics in the environment.	**NOT RETAINED** for further screening at this time due to limited development opportunities.
Biomass (wood, etc.)	Biomass (wood, wood waste, agricultural residues) is widely available in the Southeast. Major consideration is obtaining fuel under a long-term contract at a reasonable (and low) price. The plant may rely on gasification of biomass, followed by a CT to convert the gas to electricity. Raw biomass tends to have a high	**RETAINED** for further screening.

	transportation cost, due to its low energy-density in raw form, therefore local sourcing is important to keep delivered cost low. This places an upper limit on the size of a dedicated biomass-consuming power plant.	
Co-fired Biomass or Wood Waste	Co-firing of switchgrass and wood waste has been demonstrated at several system power stations. Co-firing of these materials is now routine in AL and MS for green power pricing programs. Co-firing at up to 10% is probably the upper limit with traditional woody biomass. Co-firing at higher levels with advanced fuels such as pellets and torrefied wood is possible but care must still be taken to ensure no adverse environmental or reliability consequences.	**RETAINED** for further screening.
Landfill Gas (LFG)	Capped landfills produce methane gas through anaerobic digestion of the landfill contents. The gas has about half the energy of natural gas per cubic foot and can be sold as renewable natural gas, burned in engines, or co-fired in natural gas boilers or turbines. Many environmental advantages with possible economic viability are present. A single large landfill may provide 1300 scfm of gas.	**RETAINED** for further screening.
Geothermal	Geothermal resources in the Southeastern U.S. are not adequate to support utility scale of this technology. Technologies are being monitored on a research level for potential niche applications.	**NOT RETAINED** for further screening at this time due to limited applicability in Southern Company's territory.
Hydroelectric	Hydroelectric power plants capture kinetic and/or gravitational potential energy of water bodies using turbines that power electric generators. This method usually involves the construction of dams or other structures to divert water flows. While hydroelectric power represents one of the oldest and most mature methods of generating electricity, the environmental impacts and long permitting lead times involved in constructing new hydroelectric plants has limited most recent development activities to expanding the capacity of existing resources.	**NOT RETAINED** for further screening at this time due to limited development opportunities in Southern Company's territory.
Ocean Energy & Hydrokinetic Generation	Ocean energy and hydrokinetic generation includes power generation from waves, ocean current, tides, and river current. Specific research has begun to be conducted in these areas defining the resources and developing technologies that can utilize these resources. They have the potential to negatively affect estuarine environments.	**NOT RETAINED** for further screening at this time due to cost uncertainties, level of development, and limited applicability in Southern Company's territory.

Ocean Thermal Generation	The temperature difference between surface and deep ocean waters can be used to drive an ammonia or other low-temperature power cycle to produce power. In most situations, tropical locations with deep ocean near shore are sought. There are environmental concerns with releasing cold bottom water at the ocean surface and with the potential for ammonia release.	**NOT RETAINED** for further screening at this time due to cost uncertainties, level of development, limited applicability Southern Company's territory, and potential environmental considerations.
Pumped Storage Hydroelectric	Pumped hydroelectric energy storage is a large, mature, and commercial utility-scale technology used at many locations in the United States and around the world. Southern Company currently applies this technology on its system. This application has the highest capacity of the energy storage technologies assessed, since its size is limited only by the size of the available upper reservoir. Facilities of this type must deal with environmental issues related to land use and the availability of the water source.	**RETAINED** for further screening.
Underground Pumped Storage Hydroelectric (UPH)	Underground pumped storage hydro could avert the environmental and licensing problems of conventional above ground facilities. The high excavation costs and long lead times of UPH significantly reduce its attractiveness. Gravity Power, LLC is also developing a variant of UPH which provides motive force to a hydro turbine by displacing water in a deep shaft by means of a very large piston. Suitable sites for a unit are more prevalent than sites for pumped hydro since no elevation change is needed. The Gravity Power plant footprint is smaller as well and the pumping and power generation equipment are in the form of a conventional Francis hydro turbine-generator. The biggest developmental challenge is the large piston, made from either reinforced solid rock or a steel shell filled with crushed rock and/or concrete, and its sealing system. Gravity Power expects the efficiency to be 78–84% (based on traditional PSH).	**NOT RETAINED** for further screening at this time due to high cost relative to other options and the stage of technology development.
Compressed Air Energy Storage (CAES) - Diabatic	A Diabatic CAES unit is essentially a simple Brayton cycle with the gas turbine's compressor and expander decoupled so that they can operate independently, offering load management advantages. Hardware is commercially available. The first CAES (290 MW) plant was constructed in Germany in 1978. A 100 MW plant was constructed by Alabama Electric Cooperative ("PowerSouth") and began commercial operation in June 1991. CAES cycles can utilize either above ground (low MWh) or below ground (high MWh) energy storage	**RETAINED** for further screening.

	options. The potential for large scale energy storage depends on suitable geology for constructing the air storage reservoir. The preferred geology for Southern Company would be salt dome sites in Mississippi and Alabama. CAES has the potential for better local environmental characteristics than pumped hydro.	
CAES - Adiabatic	Adiabatic CAES is a variation on the diabatic cycle which captures and reuses the heat of compression, via thermal energy storage, to improve efficiency and/or eliminate the use of fuel which would also eliminate air emissions.	**RETAINED** for further screening.
Lithium-ion Battery Storage	Lithium-ion (Li-ion) technology is mature based upon the use of the technology in electronics and EVs. Applications of Li-ion batteries for utility scale, stationary applications are quickly emerging with deployments in California leading the way. Advanced Li-ion chemistries and batteries are being developed to achieve higher energy and/or power density, higher reliability, lower maintenance and longer life, at a cost that can be competitive with other storage approaches. Potential applications include system-wide renewable integration, load management and peak shaving applications to defer T&D upgrades, deferral of power plant construction for peaking capacity, and backup power for T&D substations. Environmental impact on the local area is expected to be very low when the charging source is not considered.	**RETAINED** for further screening.
Alternative Chemistry Battery Storage	Lead/acid technology is mature, but life at elevated operating temperatures with heavy duty cycles is of concern. Advanced batteries are being developed to achieve higher energy and/or power density, higher reliability, lower maintenance and longer life at a cost that can be competitive to conventional lead acid batteries. Potential applications include load management/peak shaving applications to defer the power plant construction for peaking capacity and backup power for T&D substations. Environmental impact on the local area is expected to be very low when the charging source is not considered.	**RETAINED** for further screening.
Flow Battery	Flow batteries have attracted a lot of interest from investors and developers from stationary energy storage. Flow batteries offer the ability to store energy for long periods of time without losing their charge, relative ease in scaling up, and relative high cycle life. Flow batteries can be categorized into different classes, with true redox and hybrid redox further along the commercialization path. Other classes of flow batteries, such as membraneless, organic, metal hydride, and nano-network are in the early R&D stage.	**NOT RETAINED** for further screening at this time due to stage of technology development.

Power-to-gas	Power-to-gas is a large category of technologies that utilize power to produce gaseous chemicals used as energy carriers. Examples of power-to-gas processes include electrolysis of water for hydrogen production, electrochemical production of CO and H_2 from CO_2 and water, methanization of CO_2 to CH_4 with utilization of hydrogen. Most, if not all, power-to-gas processes involve an electrochemical process. This technology also has many relevant applications outside of the power sector.	**RETAINED** for further screening.
Flywheel Energy Storage	Flywheels store mechanical energy. The amount of energy stored depends on the inertia and rotational speed of the flywheel. Southern Company has successfully demonstrated the utility of flywheels in short term, low voltage ride-through for power quality (PQ) applications. Acceptable total system costs have been achieved with the PQ units, and the ability to integrate the mechanical and power electronic components has been demonstrated. Systems for high energy storage applications, such as peak shaving and load leveling, reside in the research and development stage. Monitoring of activity in the MW-class systems continue, and further quality improvements and cost reductions for composite materials, magnetic bearings, and power electronics will improve the chances for future electrical energy storage applications.	**NOT RETAINED** for further screening at this time due to high costs relative to other options and better suitability for dispersed applications.
Cryogenic (Liquid Air) Energy Storage (LAES)	LAES is essentially a variant of CAES in which the pressurized air is refrigerated to cryogenic temperatures for compact storage in above-ground insulated steel tanks at modest elevated pressure rather than in high-pressure underground geologic formations. LAES allows for greater siting flexibility and the ability to heat-integrate hot or cold thermal sources for higher efficiency. As the process does not use fuel, it is also emissions free. The system can be designed to fill the cryogenic liquid tanks within a specified liquefaction time based on the desired charging rate needed, from hours to days.	**RETAINED** for further screening.
Thermal Energy Storage (TES)	There are many different types of thermal energy storage (TES) which use different storage media. Some of the most common types proposed use: molten salt, sand, concrete, and phase change materials. TES systems can be integrated with any heat source or existing plant (fossil, nuclear, concentrated solar). Plant integration and system footprint are critical to project execution.	**RETAINED** for further screening.
Gravity Storage	Gravitational energy storage describes a rapidly growing suite of technologies that utilize the potential and kinetic energy of various weights and masses against gravity to collect, store, and release electrical energy. Once connected to the grid a gravity energy storage (ES) system converts electrical energy into mechanical	**NOT RETAINED** for further screening at this time due to stage of technology development.

	energy via work to raise a weight. The controlled descent of the weight is converted back to electrical energy which is then released to the grid. Gravity ES systems often rely on well understood mechanical processes and technologies used in other industries. Storage capacity depends heavily on the type of gravity technology being studied and the available land and geography of a planned site.	
Thermochemical	Thermochemical energy storage is a concept in which an endothermic reaction is driven forward with excess energy, and that energy is recovered by the reverse exothermic reaction. These systems typically have higher energy density than energy storage systems in which the exchange of thermal energy is driven primarily by physical changes (ie, ice-water energy storage systems). Avoiding side reactions and maintaining high efficiency are very important in these systems.	**NOT RETAINED** for further screening at this time due to stage of technology development.
Pumped Thermal Energy Storage	Also known as Pumped Heat Energy Storage (PHES), there are several variations of this technology which employ different working fluids and storage media. In charge mode the cycle operates as a heat pump, and in discharge mode it operates as a heat engine. One variation employs a transcritical CO_2 thermodynamic cycle (i.e. the working fluid operates both above and below the critical pressure) in a “pumped heat” configuration with insulated tanks utilizing hot and cold thermal storage media. These systems can have relatively small footprints, charge with only electricity, and produce no emissions.	**NOT RETAINED** for further screening at this time due to stage of technology development.

Attachment B: Technology Application Standards ("TAS") Data Summaries

Values represent "New and Clean" versions of technology deployments **Degradation factors are provided in data summary**		1x1 Combined-Cycle (CC)			Simple Cycle Combustion Turbine (CT) - 2 Unit Block, Dual Fuel		
		Winter Peaking	Average Base Mode	Summer Peaking	Winter Peaking	Average Base Mode	Summer Peaking
Output[1]	kW	**REDACTED**	**REDACTED**	**REDACTED**	**REDACTED**	**REDACTED**	**REDACTED**
Heat Rate[2]	Btu/kWh	**REDACTED**	**REDACTED**	**REDACTED**	**REDACTED**	**REDACTED**	**REDACTED**
Annual Capacity Factor	%		**REDACTED**			**REDACTED**	
Asset Life	years		**REDACTED**			**REDACTED**	
Total Overnight Plant Cost	$/kW	**REDACTED**		**REDACTED**	**REDACTED**		**REDACTED**
	$x1000		**REDACTED**			**REDACTED**	
EPC Cost	$/kW	**REDACTED**		**REDACTED**	**REDACTED**		**REDACTED**
	$x1000		**REDACTED**			**REDACTED**	
Land & External Infrastructure Cost[3]	$/kW	**REDACTED**		**REDACTED**	**REDACTED**		**REDACTED**
	$x1000		**REDACTED**			**REDACTED**	
Owner's Cost[4]	$/kW	**REDACTED**		**REDACTED**	**REDACTED**		**REDACTED**
	$x1000		**REDACTED**			**REDACTED**	
Fixed O&M	$/kW-yr	**REDACTED**		**REDACTED**	**REDACTED**		**REDACTED**
	$x1000		**REDACTED**			**REDACTED**	
Variable O&M	$/MWh		**REDACTED**			**REDACTED**	
	$x1000		**REDACTED**			**REDACTED**	
Capital Expenditures for Maintenance	$/kW-yr	**REDACTED**		**REDACTED**	**REDACTED**		**REDACTED**
	$x1000		**REDACTED**			**REDACTED**	
Downtime for Planned Outages	wk/yr		**REDACTED**			**REDACTED**	
Run Hours	hrs/yr		**REDACTED**			**REDACTED**	
Starts/Yr	starts/yr		**REDACTED**			**REDACTED**	
EUOR / EFORd[5]	%		**REDACTED**			**REDACTED**	
Unit Ramp Rate	MW/min		**REDACTED**			**REDACTED**	
Cold Start (to MECL)[6]	min		**REDACTED**			**REDACTED**	
Warm Start (to MECL)	min		**REDACTED**			**REDACTED**	
Hot Start (to MECL)	min		**REDACTED**			**REDACTED**	
Minimum Up Time	hr		**REDACTED**			**REDACTED**	
Minimum Down Time	hr		**REDACTED**			**REDACTED**	
Unit Minimum Load (MECL)[7]	% of max		**REDACTED**			**REDACTED**	
Degradation Factor (Lifetime) - Maximum Output	%		**REDACTED**			**REDACTED**	
Degradation Factor (Lifetime) - Heat Rate	%		**REDACTED**			**REDACTED**	
Capital Escalation Rate[8]	%/yr		**REDACTED**			**REDACTED**	
O&M Escalation Rate[9]	%/yr		**REDACTED**			**REDACTED**	
Startup Fuel Required (Per Unit, Gas, CC Cold Start, SC Normal Start)	MMBtu		**REDACTED**			**REDACTED**	

Notes

1. **REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED**
2. Heat rate is defined at the identified output; not applicable to energy storage or solar technologies
3. The scope of external infrastructure includes transmission tie line from the plant boundary, gas lateral from the plant boundary, rail spur for fuel and equipment delivery, land cost, and/or intake and discharge water lines from the plant boundary
4. The scope of owner's cost includes development activities, permitting, legal and regulatory support, and project-level contingency
5. EUOR, "Equivalent Unplanned Outage Rate", is applied to baseload and intermediate load units, and EFORd, "Demand Equivalent Forced Outage Rate", is applied to peaking units
6. **REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED**
7. Minimum load is set at the minimum emission compliance load (MECL). For gas technologies MECL can vary with ambient temperature. The included value is an approximation.
8. **REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED**
9. Gross Domestic Product Implicit Price Deflator (GDP-IPD) for most supply-side O&M options

Values represent "New and Clean" versions of technology deployments **Degradation factors are provided in data summary**		Simple Cycle Combustion Turbine with Future Emission Controls (CT w SCR), 2-Unit Block, Dual Fuel[10]			Reciprocating Engine Internal Combustion Engine (RICE), 12 Unit Block			1x1 Combined-Cycle with Carbon Capture and Sequestration (CC w CCS)		
		Winter Peaking	Average Base Mode	Summer Peaking	Winter Peaking	Average Base Mode	Summer Peaking	Winter Peaking	Average Base Mode	Summer Peaking
Output[1]	kW	REDACTED	REDACTED	REDACTED	REDACTED	REDACTED	REDACTED	REDACTED	REDACTED	REDACTED
Heat Rate[2]	Btu/kWh	REDACTED	REDACTED	REDACTED	REDACTED	REDACTED	REDACTED	REDACTED	REDACTED	REDACTED
Annual Capacity Factor	%	REDACTED			REDACTED			REDACTED		
Asset Life	years	REDACTED			REDACTED			REDACTED		
Total Overnight Plant Cost	$/kW	REDACTED		REDACTED	REDACTED		REDACTED	REDACTED		REDACTED
	$x1000	REDACTED			REDACTED			REDACTED		
EPC Cost	$/kW	REDACTED		REDACTED	REDACTED		REDACTED			
	$x1000	REDACTED			REDACTED					
Land & External Infrastructure Cost[3]	$/kW	REDACTED		REDACTED	REDACTED		REDACTED			
	$x1000	REDACTED			REDACTED					
Owner's Cost[4]	$/kW	REDACTED		REDACTED	REDACTED		REDACTED			
	$x1000	REDACTED			REDACTED					
Fixed O&M	$/kW-yr	REDACTED		REDACTED	REDACTED		REDACTED	REDACTED		REDACTED
	$x1000	REDACTED			REDACTED			REDACTED		
Variable O&M	$/MWh	REDACTED			REDACTED			REDACTED		
	$x1000	REDACTED			REDACTED			REDACTED		
Capital Expenditures for Maintenance	$/kW-yr	REDACTED		REDACTED	REDACTED		REDACTED	REDACTED		REDACTED
	$x1000	REDACTED			REDACTED			REDACTED		
Downtime for Planned Outages	wk/yr	REDACTED			REDACTED			REDACTED		
Run Hours	hrs/yr	REDACTED			REDACTED			REDACTED		
Starts/Yr	starts/yr	REDACTED			REDACTED			REDACTED		
EUOR / EFORd[5]	%	REDACTED			REDACTED			REDACTED		
Unit Ramp Rate	MW/min	REDACTED			REDACTED			REDACTED		
Cold Start (to MECL)[6]	min	REDACTED			REDACTED			REDACTED		
Warm Start (to MECL)	min	REDACTED			REDACTED			REDACTED		
Hot Start (to MECL)	min	REDACTED			REDACTED			REDACTED		
Minimum Up Time	hr	REDACTED			REDACTED			REDACTED		
Minimum Down Time	hr	REDACTED			REDACTED			REDACTED		
Unit Minimum Load (MECL)[7]	% of max	REDACTED			REDACTED			REDACTED		
Degradation Factor (Lifetime) - Maximum Output	%	REDACTED			REDACTED			REDACTED		
Degradation Factor (Lifetime) - Heat Rate	%	REDACTED			REDACTED			REDACTED		
Capital Escalation Rate[8]	%/yr	REDACTED			REDACTED			REDACTED		
O&M Escalation Rate[9]	%/yr	REDACTED			REDACTED			REDACTED		
Startup Fuel Required (Per Unit, Gas, CC Cold Start, SC Normal Start)	MMBtu		REDACTED						REDACTED	

Notes

1. REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED
2. Heat rate is defined at the identified output; not applicable to energy storage or solar technologies
3. The scope of external infrastructure includes transmission tie line from the plant boundary, gas lateral from the plant boundary, rail spur for fuel and equipment delivery, land cost, and/or intake and discharge water lines from the plant boundary
4. The scope of owner's cost includes development activities, permitting, legal and regulatory support, and project-level contingency
5. EUOR, "Equivalent Unplanned Outage Rate", is applied to baseload and intermediate load units, and EFORd, "Demand Equivalent Forced Outage Rate", is applied to peaking units
6. REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED
7. Minimum load is set at the minimum emission compliance load (MECL). For gas technologies MECL can vary with ambient temperature. The included value is an approximation.
8. REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED REDACTED
9. Gross Domestic Product Implicit Price Deflator (GDP-IPD) for most supply-side O&M options
10. REDACTED

Values represent "New and Clean" versions of technology deployments **Degradation factors are provided in data summary**		Solar Photovoltaic (Single Axis Tracking Solar PV)	Solar Photovoltaic (Fixed Tilt Solar PV)	Onshore Wind
Maximum Output[1]	kW_{AC}	**REDACTED**	**REDACTED**	**REDACTED**
Annual Capacity Factor	%	**REDACTED**	**REDACTED**	**REDACTED**
Asset Life	years	**REDACTED**	**REDACTED**	**REDACTED**
Total Overnight Plant Cost	$/kW	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
EPC Cost	$/kW	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Land and External Infrastructure Cost[2]	$/kW	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Owner's Cost[3]	$/kW	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Fixed O&M	$/kW-yr	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Variable O&M	$/MWh	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Capital Expenditures for Maintenance	$/kW-yr	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Downtime for Planned Outages	wk/yr	**REDACTED**	**REDACTED**	**REDACTED**
EUOR / EFORd / Unavailability Rate[4]	%	**REDACTED**	**REDACTED**	**REDACTED**
Degradation (Lifetime) - AC Energy Output	%	**REDACTED**	**REDACTED**	**REDACTED**
Capital Escalation Rate[5]	%/yr	**REDACTED**	**REDACTED**	**REDACTED**
O&M Escalation Rate[6]	%/yr	**REDACTED**	**REDACTED**	**REDACTED**
Inverter Loading Ratio (ILR), or DC:AC Ratio		**REDACTED**	**REDACTED**	**REDACTED**
Technology Basis		**REDACTED**	**REDACTED**	**REDACTED**

Notes
1. Net AC Rating for solar; nameplate rating for wind power
2. The scope of external infrastructure includes transmission tie line from the plant boundary and land cost
3. The scope of owner's cost includes development activities, permitting, legal and regulatory support, and project-level contingency
4. Unavailability rate for renewables is the % of energy annual energy loss due to unplanned equipment outages, equipment malfunctions, unplanned derates, etc.
5. The capital escalation rate (declining) is not linear
6. Gross Domestic Product Implicit Price Deflator (GDP-IPD) for most supply-side O&M options

Values represent "New and Clean" versions of technology deployments Degradation factors are provided in data summary		2-hour Battery Energy Storage System (BESS)	4-hour Battery Energy Storage System (BESS)	8-hour Battery Energy Storage System (BESS)
Maximum Output[1]	kW_{AC}	**REDACTED**	**REDACTED**	**REDACTED**
Useable Discharge Energy Available per Cycle	kWh	**REDACTED**	**REDACTED**	**REDACTED**
Roundtrip Efficiency[2] (RTE)	%	**REDACTED**	**REDACTED**	**REDACTED**
Annual Capacity Factor	%	**REDACTED**	**REDACTED**	**REDACTED**
Asset Life	years	**REDACTED**	**REDACTED**	**REDACTED**
Total Overnight Plant Cost	$/kW	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
EPC Cost	$/kW	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Land and External Infrastructure Cost[3]	$/kW	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Owner's Cost[4]	$/kW	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Fixed O&M	$/kW-yr	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Variable O&M	$/MWh	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Capital Expenditures for Maintenance	$/kW-yr	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Downtime for Planned Outages	wk/yr	**REDACTED**	**REDACTED**	**REDACTED**
Run Hours	hrs/yr	**REDACTED**	**REDACTED**	**REDACTED**
Starts	starts/yr	**REDACTED**	**REDACTED**	**REDACTED**
EUOR / EFORd[5]	%	**REDACTED**	**REDACTED**	**REDACTED**
Ramp Rate	MW/min	**REDACTED**	**REDACTED**	**REDACTED**
Start Duration	min	**REDACTED**	**REDACTED**	**REDACTED**
Minimum Up Time	hr	**REDACTED**	**REDACTED**	**REDACTED**
Minimum Down Time	hr	**REDACTED**	**REDACTED**	**REDACTED**
Minimum Load	% of max	**REDACTED**	**REDACTED**	**REDACTED**
Degradation Rate - Maximum Output	%/yr	**REDACTED**	**REDACTED**	**REDACTED**
Degradation Rate - RTE	%/yr	**REDACTED**	**REDACTED**	**REDACTED**
Capital Escalation Rate[6]	%/yr	**REDACTED**	**REDACTED**	**REDACTED**
O&M Escalation Rate[7]	%/yr	**REDACTED**	**REDACTED**	**REDACTED**
Technology Basis		**REDACTED**	**REDACTED**	**REDACTED**

Notes
1. Net AC Rating
2. Roundtrip efficiency here is defined as AC-to-AC and includes station service such as HVAC
3. The scope of external infrastructure includes transmission tie line from the plant boundary and land cost
4. The scope of owner's cost includes development activities, permitting, legal and regulatory support, and project-level contingency
5. EUOR, "Equivalent Unplanned Outage Rate", is applied to baseload and intermediate load units, and EFORd, "Demand Equivalent Forced Outage Rate", is applied to peaking units
6. The capital escalation rate (declining) is not linear
7. Gross Domestic Product Implicit Price Deflator (GDP-IPD) for most supply-side O&M options

Attachment C: Technology Advancement View Data Summaries

Values represent "New and Clean" versions of technology deployments Degradation factors are provided in data summary		Supercritical CO_2 Cycle with CCS	Generation III+ Small Modular Reactors	Generation IV Nuclear
Output[1]	kW	**REDACTED**	**REDACTED**	**REDACTED**
Heat Rate	Btu/kWh	**REDACTED**	NA - Fuel cost is fixed	**REDACTED**
Asset Life	years	**REDACTED**	**REDACTED**	**REDACTED**
Total Overnight Plant Cost	$/kW	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Fixed O&M	$/kW-yr	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Variable O&M	$/MWh	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Post-COD Capital Expenditures	$/kW-yr	**REDACTED**	**REDACTED**	**REDACTED**
	$x1000	**REDACTED**	**REDACTED**	**REDACTED**
Downtime for Planned Outages	wk/yr	**REDACTED**	**REDACTED**	**REDACTED**
Forced Outage Rate	%	**REDACTED**	**REDACTED**	**REDACTED**
Degradation Factor (Lifetime) - Maximum Output	%	**REDACTED**	**REDACTED**	**REDACTED**
Degradation Factor (Lifetime) - Heat Rate	%	**REDACTED**	**REDACTED**	**REDACTED**
O&M Escalation Rate	%/yr	**REDACTED**	**REDACTED**	**REDACTED**
Startup Fuel Required	MMBtu	**REDACTED**	NA	NA

Notes
1. Output rating for Supercritical CO_2 Cycle with CCS is for 2 units