August 21, 2023

CGS REPURPOSING STUDY

SALT RIVER PROJECT

Prepared by: Kiewit Engineering Group Inc.

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EXECUTIVE SUMMARY

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The electric power industry is transitioning from fossil fuel generation to low-carbon resources for power supply. As part of this transition, the Salt River Project (SRP) announced that it will close the Coronado Generating Station (CGS) no later than 2032. CGS supplies approximately 800MW of reliable baseload generation to SRP's customers and provides economic support as a major employer to the surrounding community. SRP engaged Kiewit to identify and evaluate low-carbon technologies as potential generating resources for repurposing. The feasibility of repurposing the facility with nuclear is also being studied under a separate effort led by the Gateway for the Acceleration of Nuclear (GAIN), a DOE initiative, and as such, is outside of the scope of this study.

Because it is not yet clear what type of resource SRP will need when CGS is retired, the purpose of this study is not to select or recommend a technology for implementation. Instead, its purpose is to assess the suitability of the CGS site for repurposing and to provide insights for SRP to consider in resource planning.

PROCESS

Kiewit developed a list of over thirty (30) technologies for consideration. The technologies were screened according to their ability to meet SRP's criteria for reliable, cost-effective and low to no-carbon generation. During the screening process, it became clear that some technologies have a maturity or development advantage over others. For example, some can be brought online immediately following the closure of CGS, "Phase 1". Other technologies are not sufficiently mature and would leave a gap between the plant's closure and when they could come online. Kiewit classified technologies that are considered proven technologies with a path for an online date of Spring 2033 as "Phase 1 Technologies". Those that lack the technical maturity, supply chain capacity or critical infrastructure to support an anticipated resource commitment decision in 2028 to support an online date in the Spring of 2033 were classified as "Phase 2 Technologies".

Solar PV, Wind, Biomass, and Li-Ion battery storage were deemed to have sufficient maturity, reliability, and supply chain development to be classified as Phase 1 Technologies and received an additional evaluation in this study. A Long Duration Energy Storage (LDES) option was also included. This is in anticipation of projects in development that may demonstrate sufficient maturity in time for a 2028 resource commitment decision.

PHASE 1 TECHNOLOGIES

As described above, five (5) Phase 1 technologies were identified and received additional consideration:

- Wind
- PV Solar
- Biomass
- Li-ion Batteries (SDES)
- Adiabatic – Compressed Air Energy Storage (A-CAES) (LDES)

Technology cost estimating is especially complex in the power generation industry. As part of a technology selection process, utilities may compare installed costs ($/KW), levelized costs of energy ($/MWh), and with the advent of intermittent resources, the effective load carrying capacity of a resource. Technologies which are in early development stages present additional complexity due to the lack of project volume and operating experience. Even mature resources are subject to uncertainty surrounding a variety of factors including volatile commodity prices, potential import tariffs, and most importantly a lack of detailed design and project capacity information.

For the purposes of this study, an order of magnitude cost comparison was performed to show the cost of technologies relative to each other as depicted in tables A.2 and B.1. It is assumed that SRP would conduct a detailed cost analysis as part of any technology selection.

CONCLUSIONS

1. The Coronado Generating Station's interconnection facilities, land and other resources make it a favorable site for the development of future generating resources once the coal generation is retired.
2. Of the over 30 technology options reviewed, because of varying degrees of development and maturity, only a limited number have demonstrated technical readiness to support a 2028 resource commitment decision that would support a Spring 2033 online date.
3. The composition and performance characteristics of SRP's resource mix and resource needs will ultimately determine the capacity (size) of any replacement resources.
4. Biomass is the only Phase 1 resource with operating characteristics comparable to those of CGS. However, challenges with obtaining fuel may limit the size and scale of a potential biomass facility.
5. Wind and solar have a lower energy density than thermal resources and, depending on the size of a facility, may require additional land beyond what SRP currently owns in the area.
6. Intermittent resources, such as wind and solar, and limited-duration resources, such as battery storage, require multiple megawatts (overbuild) to replace 1 MW of thermal generation.
7. Long duration energy storage is under development and expected to be sufficiently mature to be considered in 2028, in particular A-CAES

RECOMMENDATIONS

The following activities are recommended actions to help SRP prepare to decide on repurposing the CGS site. The assumed objective is to have a high confidence level that the technology selection(s) will meet SRP resource needs, is commercially viable and has demonstrated performance and reliability.

1. **Implement a Phased Approach to Repurposing** – The CGS site is well suited to host multiple technologies. Additionally, the reuse of the existing infrastructure could reduce costs for subsequent generation projects. SRP should develop a phased approach that capitalizes on the infrastructure in the near term while preserving the option for more advanced technology integration in the future.
2. **Define Resource Needs** – Because the closure of CGS is still almost a decade away, it is not yet clear what SRP's resource needs will be when CGS is retired. As such, SRP should work to understand how Phase 1 resources satisfy SRP's needs under a wide range of planning scenarios.
3. **Identify Critical Path & Milestones** – Indicative project schedules that include front-end development activities needed to support a 2028 resource commitment decision and a Spring 2033 online date should be prepared and maintained. SRP should continue to monitor the development of emerging technologies, including those selected for further consideration in this study.
4. **Commence Due Diligence & Pre-tasks** – Commencing front-end tasks and due diligence activities for Phase 1 resources will allow SRP more time to preserve development options that allow more time to confirm its future resource needs. Such activities may include:
   a. For A-CAES, studies to develop a refined-cost estimate for underground storage of compressed air.
   b. All options will require additional geotechnical surveys and a more developed topographic map to support more accurate site layouts and better foundation cost estimates.

   c. For biomass, confirmation of sufficient fuel supply, location of sources, and cost of transport to CGS will be needed.

   d. For all options, SRP Power Delivery will need to determine what switchyard modifications / additions are required to accommodate the new resources.

5. **Evaluate Resource Development Risks** - SRP should continue to monitor development of Phase 1 technologies, regulations and incentives supporting their development and impact on supporting supply chains. This includes whether technologies have been demonstrated in sufficient size (MW) and the number of projects to justify being considered for deployment by SRP when a resource commitment decision is made.

6. **Plan for Phase 2 Resources** - Develop and implement a plan to evaluate and prioritize Phase 2 resource opportunities.

SECTION 1

Introduction

SECTION 1
INTRODUCTION

The Coronado Generating Station (CGS) is a two-unit, coal-fired electric power generating facility near St. Johns, Arizona. The facility consists of two (2) coal-fired units. Unit 1 entered service in 1979 and Unit 2 in 1980. The units have nameplate capacities of 382 MW and 380 MW, respectively. The facility is owned and operated by Salt River Project (SRP) and has access to nearly 10,000 acres of surrounding land. Power is delivered to the Phoenix metropolitan area via a 500kV transmission system.

In January 2020, SRP announced that it will close CGS no later than 2032. Kiewit was retained to identify and evaluate potential future replacement resources that could allow SRP to repurpose the site with up to 800 MW of clean (low to no-carbon), reliable and affordable power to its customers in the Phoenix metropolitan area.

The study scope included technology identification, screening, scoring and development of high-level cost estimates. See Section 3 for a more detailed description of the scope and study findings.

Advanced nuclear technologies are outside of the scope of this study. The feasibility of repurposing with nuclear is being studied under a separate effort led by the Gateway for the Acceleration of Nuclear (GAIN), a DOE initiative.

SECTION 2

Project Site

SECTION 2

PROJECT SITE

The Coronado Generating Station (CGS) is in Apache County, AZ. It is located six (6) miles northeast of St. Johns and east of US Highway 191. The station is approximately thirteen (13) miles west of the New Mexico state line. The area surrounding the CGS power block is generally level, while the remainder of the site consists of rolling terrain, with some ravines. The site consists of approximately 9,600 acres and is located east of U.S. Highway 191. SRP owns additional land west of the main site, near US-180 and Arizona State Route (SR) SR-61 and SR-180A. but those parcels were not contiguous with the main site and/or too remote from the CGS switchyard and transmission line to be considered further. Portions of this area are a "checkerboard" of ownerships, alternating between lands owned by the U.S. Bureau of Land Management, the State of Arizona, and private parties. Nearby areas appear to be used for ranching or agriculture, with limited irrigation.

Figure 2A. Coronado Generating Station is in Apache County six miles northeast of St. Johns, Arizona.

Kiewit relied on information in the public domain as well as that provided by SRP to assess the suitability of the Coronado site to host low to no-carbon technologies as potential options for repurposing the site. This information, and that from an in-person site visit, was used to support the comparative cost analysis.

2.1 SITE IMPROVEMENTS

In addition to Units 1 and 2, the site also hosts other improvements associated with a coal plant. These include a rail loop, coal pile, switchyard, ash disposal areas south of the power block, air quality control system equipment and various dedicated ponds for groundwater storage, stormwater retention, evaporation and a water reservoir for recovery and containment of process waste, access roads, power lines and interconnecting switchyard. The section of land containing the existing ash disposal pond was not considered for the deployment of renewable generating resources.

2.2 SITE CONDITIONS

The site is in a high desert area. The area surrounding the CGS power block is generally level, while the remainder of the site consists of rolling terrain with some ravines.

2.3 AIR PERMITTING AND EMISSION CONTROLS

CGS Units 1 and 2 are equipped with electrostatic precipitators (ESP) and wet scrubbers to control fly ash and SO_2, respectively. Unit 2 has selective catalytic reduction (SCR) for NOx control. The units are also equipped with low NOx burners and mercury control equipment.

Apache County is not listed on the U.S. Environmental Protection Agency (EPA) website as Nonattainment for any criteria pollutants.

2.4 WATER SUPPLY AND DISCHARGE

Raw water is provided by a system of wells located both on the site and in areas west of the site and St. Johns. Reservoirs for storage of groundwater are on site. Water treatment is part of the power block equipment and could possibly be retained for future use after the retirement of the coal units.

Heat rejection is via wet cooling towers, one per unit. Wastewater disposal is via an evaporation pond in the southern area of the site and a wastewater reservoir on the plant site. Other discharging facilities include a cooling tower blowdown reservoir and coal yard retention ponds northeast of the power block.

2.5 OTHER ENVIRONMENTAL CONSIDERATIONS

The section of land containing the existing ash disposal pond was not considered for the deployment of renewable generating resources.

2.6 FUEL

CGS is fueled by sub-bituminous coal from Powder River Basin mines in Wyoming and Montana. It is delivered by BNSF Railroad in unit trains via a 70-mile rail spur from a mainline located north of CGS and just south of Interstate 40 (I-40).

Natural gas is not currently available at CGS. The shortest potential route from the interstate natural gas pipelines near I-40 to the CGS site would be approximately 90 miles along the BNSF right-of-way. Other paths are approximately 110 to 130 miles and would present challenges from both economic and siting perspectives.

Costs to construct such a pipeline and tie into an existing system are expected to be high. A pipeline project would also require the construction of metering, compression and regulating stations. The plant's location introduces additional siting and installation complexity due to the expected difficulty in obtaining needed right-of-way (ROW). The route would likely cross federal, state, and tribal lands with their accompanying permitting requirements.

Similarly, resource options that include co-firing with hydrogen would require either a hydrogen pipeline, on-site storage and/or on-site production. Each of these options would add considerably to the development cost, time, and complexity.

Biomass could be delivered from forested areas such as the Apache-Sitgreaves National Forest south of Springerville and Eagar, AZ, or various national forests west of Show Low or in the Flagstaff area. The Novo-BioPower plant located in nearby Snowflake currently draws on remains from logging and thinning operations. It is unclear how much fuel would be available for a potential CGS biomass resource without impacting the Novo-BioPower plant.

2.7 TRANSMISSION

Power is delivered to SRP's service territory onto two double-conductor 500kV transmission lines via the CGS switchyard. SRP has rights to nearly 800MW of transmission capacity, which could support multiple repurposing options. Reuse of the transmission infrastructure could minimize project construction costs as compared with costs associated with a new, greenfield, interconnection.

2.8 TRANSPORTATION

Primary access to the site is via I-40, which is approximately 47 miles to the north, and US-180 from Holbrook, AZ to St. Johns and US-191 to the site. US-180 and US-191 are 2-lane highways suitable for tractor-trailers. This means that truck deliveries of equipment are possible.

Rail access is via BNSF Railroad as described above. However, whether the rail line could be used for the delivery of heavy equipment has not been explored with BNSF. No railroad sidings that might be suitable for unloading heavy equipment were identified between CGS and the BNSF main line south of I-40 or en route to Springerville. Kiewit observed a railroad track at CGS that might be suitable for unloading heavy equipment, but its condition was not assessed for this study.

St. Johns has a general aviation airport next to an industrial park with a runway large enough to accommodate corporate jets. The nearest airports with commercial air service are Flagstaff (138 miles), Grant County, NM (147 miles), Albuquerque (161 miles) and Phoenix Sky Harbor (169 miles).

There is no water transportation (barge) in this high desert area.

2.9 POPULATION

The 2020 US Census indicates populations for the towns nearest to CGS as St. Johns, 6 miles south, with a population of 3,417; Springerville, 36 miles south, with a population of 2,208; Eagar, 42 miles south, with a population of 4,457; and Show Low, 50 miles southwest, with a population of 11,730. CGS is in Apache County, one of fifteen Arizona counties and has a population of approximately 66,000. Except for Show Low, population in these areas is reported as slowly declining.

Per the CGS plant management, of the approximately 150-person CGS workforce, 43 percent reside in St. Johns, 17 percent in Eagar, 14 percent in Show Low, 11 percent in Snowflake and the rest reside in surrounding Navajo and Apache County communities.

2.10 ZONING

SRP is not subject to use permits or zoning approvals for electrical facilities because SRP is a governmental entity providing electric power services and is entitled to the immunities and exemptions granted to municipalities and political subdivisions of the state of Arizona. Any non-exempt user of the CGS property would be subject to local land use restrictions.

An Arizona DEQ draft fact sheet states that “according to a letter from Apache County Planning and Zoning Department, CGS property is zoned “Agricultural General” in which utilities are permitted.” This zoning classification covers much of the county. The Apache County Zoning Ordinance (as amended through December 3, 2019), Section 403.C lists “utilities, and other essential services” as an approved public and quasi-public use for that zoning classification.

2.11 LAND USE PLAN

Apache County has a Comprehensive Plan adopted in 2019. It is advisory in nature and not a regulatory document. No specific statements relating to the future of CGS were observed. The Land Use portion of the document contains a policy goal (Goal 8, p. 23) to increase the amount of commercially and industrially developable land.

SECTION 3

Technology Identification
and Screening

SECTION 3

TECHNOLOGY IDENTIFICATION AND SCREENING

3.1 TECHNOLOGY IDENTIFICATION

Kiewit developed a list of over thirty (30) low to no-carbon technologies. The list drew on information from Kiewit's databases, knowledge of the industry, input from SRP, and additional research by Kiewit. The objective of this step was to create as comprehensive a list as possible and explore every available option.

Only technologies with lower carbon emission profiles than what is currently produced by CGS were considered. The initial technologies list was a mix of existing and emerging technologies and included gas turbines, solar PV, energy storage systems and carbon capture technologies. Both traditional and innovative approaches to power generation were considered, such as repowering existing steam turbines and the use of hydrogen fuel cells. A range of energy storage systems such as batteries, flywheels, and thermal energy storage were included to address the need to provide system capacity and manage the intermittent nature of renewable energy resources. A synchronous condenser was considered for transmission system inertia, voltage or power factor support but was eliminated due to not providing generation to the SRP system.

As mentioned previously, advanced nuclear technologies are outside of the scope of this study. The feasibility of repurposing with nuclear is being studied under a separate effort led by the Gateway for the Acceleration of Nuclear (GAIN), a DOE initiative.

3.2 TECHNOLOGY SCREENING

The next step in the screening process was to filter out those technologies which did not meet the minimum study requirements. Ten technologies were removed from further evaluation for reasons such as a lack of suitability for the site, the existence of better, lower-cost alternatives (e.g., Solar PV in lieu of Concentrated Thermal), inability to achieve utility-scale, or being too early in the development cycle. The technology options considered for screening are listed in Appendix A. *(See Table A.1: Technology Options Initially Considered.)*

After the initial filtering, Kiewit and SRP collaborated to develop the technical screening criteria depicted below. Maturity and reliability were recognized as key requirements and prioritized to help SRP identify which resources could reasonably be deployed immediately following the closure of CGS. SRP refers to the period immediately following the plant's retirement as "Phase 1" and is generally described as Spring 2033.

The screening process assumed that to qualify for Phase 1 development, a resource should be available no later than 2028 (preferably earlier), and have the following characteristics to leave enough time for permitting, engineering, procurement, and construction:

- Be proven at a utility scale (maturity)
- Have a well-developed manufacturing process
- Have a reliable supply chain

"Phase 2" technologies were those technologies that were identified as lacking the maturity, supply chain or critical infrastructure to be online by Spring 2033.

The evaluation process included scoring each technology based on its performance against the scoring criteria. (*See Table A.2: Evaluation Approach for a more detailed explanation of each criterion*.)

The assessment of each technology was performed based on the scoring criteria identified below:

1. Estimated technology maturity in 2028
2. Power industry experience as of 2022
3. Power industry interest as of 2022
4. Land required
5. Water consumption
6. Carbon reduction relative to the existing CGS facility
7. Cost
8. Ability to leverage the existing electrical interconnection
9. Generation capability – contribution to capacity, time of day, intermittent, continuous, flexible

Each technology was rated a 1, 2 or 3 on each of the above scoring criterion. Table A.2 provides a detailed explanation of the rating system.

3.3 SUMMARY OF RESULTS

Table 3.1 lists each technology's classification as Phase 1, Phase 2, or Not Evaluated Further, and an explanation of each classification.

Table 3.1: Technology Screening Narratives

TECHNOLOGY	BASIS
TECHNOLOGIES SELECTED FOR PHASE 1	
Solar – Utility Scale PV	Solar PV demonstrates sufficient technology and supply chain maturity. Its lack of energy density results in high land use, but this was not an exclusionary characteristic for this study.
Wind	Wind demonstrates sufficient technology and supply chain maturity. It is less energy dense than Solar PV but may be compatible with alternative uses such as grazing. High land use was not an exclusionary characteristic for this study.
Biomass - Thermal Generation Plant (air-cooled)	Biomass has been demonstrated at a utility scale. Additionally, SRP has a special interest in this resource's ability to support its forest health initiatives.
Lithium-ion batteries (Short Duration Storage)	The integration of utility scale Lithium-Ion batteries is driving technology and supply chain maturity. The demand for reliable storage and competition with the transportation sector has increased demand for batteries and may require careful monitoring of manufacturing and supply chains. However, these issues were not exclusionary for this study.
Adiabatic Compressed Air Energy Storage, w/waste heat recovery (A-CAES) (Long Duration Energy Storage)	This technology has been successfully demonstrated at 2 MWs, and there are multiple projects >200MW in development. Successful demonstration at a utility scale by 2026 will qualify this technology for Phase 1 consideration.
TECHNOLOGIES SELECTED FOR PHASE 2	
Combined cycle, hydrogen-fired, dry cooling	Combustion turbine (CT) Original Equipment Manufacturers (OEM) have announced plans for CT models capable of burning 100% hydrogen (by volume) by 2030. Several CT models can burn 30% hydrogen (by volume) today. Hydrogen (H2) has one-third the heating value per standard cubic foot (SCF) compared to natural gas. Therefore, very large volumetric quantities of H2, compared to natural gas, will be required to avoid significant derates in net generating capability when burning high percentages of hydrogen. All technologies that require pipeline or onsite underground storage are classified

TECHNOLOGY	BASIS
	as Phase 2 due to the complexity and duration of pipeline and underground storage development.
Simple cycle, hydrogen-fired	Classified as Phase 2 for the same reasons discussed above.
Reciprocating Internal Combustion Engines (RICE) with renewable fuel	Reciprocating Internal Combustion Engines (RICE) can operate on a variety of gaseous or liquid fuels, but the vast majority (over 85%) of utility scale reciprocating engine generator sets are fueled by natural gas. A minority can use ultra-low sulfur diesel (USLD), which is typically much more expensive than natural gas. Utility scale plants generally vary from 50 to 200 MW in size, and the largest engine typically deployed in such plants is in the 18 MW range (Wartsila 18V50SG and DF). All technologies that require pipelines or onsite underground storage are classified as Phase 2 due to the complexity and duration of pipeline and underground storage development. This technology does not require underground storage, but if fueled with natural gas, it requires a pipeline.
Adding carbon capture to CGS Units 1 and/or 2	Amine technology is maturing in other industries but is still developing in the utility scale electric generation sector. Membrane technology is not as developed nor has as high a CO_2 capture efficiency as amine technology. Alternatives to amine-based technologies (oxy-combustion, flameless pressurized oxy-combustion, cryogenic, solid sorbent and possibly membrane) may be ready for consideration in 2028, but the high installed costs and issues with disposal of CO2 make these impractical alternatives. Like the H2 options, the practicality of disposing of CO_2 produced on this site (because of the absence a of CO_2 pipelines) is challenging. All technologies that require pipeline or onsite underground storage are classified as Phase 2 due to the complexity and duration of pipeline and underground storage development.
Modify existing CGS units to fire hydrogen	The hydrogen supply and storage issues noted previously apply here as well. This alternative was retained as a Phase 2 option with a recommendation to monitor technology and fuel supply maturation, either from onsite production or via pipeline/rail to the site.
Allam-Fetvedt cycle	This technology is promising but lacks sufficient maturity and a fuel (natural gas) source to be considered for Phase 1. All technologies which require pipeline or onsite underground storage are classified as Phase 2 due to the complexity and duration of pipeline and underground storage development.
Combined cycle, gas-fired, wet cooling	Although not carbon-free, natural gas combustion options have lower CO_2 intensity than the current coal generation and could be considered as a bridge resource to hydrogen. However, the EPA recently proposed new GHG standards and guidelines which could pose development challenges and operational limits for fossil fuel-fired power plants. Additionally, natural gas is not currently available at the CGS site, and as stated previously, all technologies which require new pipelines or onsite underground storage are classified as Phase 2 due to the complexity and duration of pipeline and underground storage development.
Combined cycle, gas-fired, dry cooling	See Combined Cycle, gas-fired above
Gravity energy storage (vertical, new towers)	This technology has not been sufficiently demonstrated at a utility scale. Is being retained as a potential Phase 2 option if/when the technology matures.
Flow Batteries	The lack of current maturity and cost competitiveness resulted in retaining this option for Phase 2 as the technology matures.

TECHNOLOGY	BASIS
TES - Molten salt energy storage (Thermal Energy Storage)	The lack of current maturity for non-Concentrated Solar Power applications resulted in retaining this option for Phase 2 as the technology matures.
TES – Concrete (Thermal Energy Storage)	The lack of current maturity Resulted in retaining this option for Phase 2 as the technology matures.
Liquid Air Energy Storage (LAES)	The lack of current maturity was a factor in retaining this for Phase 2. In addition, based on Kiewit's experience, it is expected to be a high-cost option.
CO_2 energy storage	The lack of sufficient demonstration at utility scale to provide cost certainty resulted in retaining this technology for Phase 2 as the technology matures.
Hydrogen production on-site with fuel cell power generation	Many uncertainties exist regarding production and storage of hydrogen on-site at this scale. Additionally, this technology would require a high level of effort (and associated cost) to bring hydrogen pipelines to CGS. As a result, this technology was retained for Phase 2 as the technology matures and for a future potential for improved hydrogen availability, (either from onsite production or via pipeline/rail, to the site) and improved viability/economics.
Hydrogen on-site production and storage (electrolyzation process)	Hydrogen production alone does not produce power by itself. Therefore, this option was eliminated for the hydrogen reasons noted above. It was retained for Phase 2 as the technology matures and for a future potential for improved hydrogen availability, (either from onsite production or via pipeline/rail to the site) and improved viability/economics.
Hydrogen on-site production and storage (ammonia process)	Hydrogen can be produced on-site but the cost of above-ground storage for large quantities can be prohibitive. Hydrogen can be delivered to CGS by rail in the form of anhydrous ammonia. However, conversion of ammonia back to hydrogen requires considerable energy. In addition, the use of hydrogen crackers to do so is still considered an emerging technology. Using ammonia as a sole fuel for power generation is being developed, mainly for the Asia market.
TECHNOLGIES NOT EVALUATED FURTHER	
Solar - Concentrated Thermal	There is a relatively low power industry experience and interest when comparing Concentrated Thermal to PV solar. Additionally, it has much higher cost and, although it has sufficient maturity, PV solar offers a more cos-effective alternative.
Integrated Gasification Combined Cycle (IGCC; coal gasification)	This is a highly complex technology with limited applications in power generation. Existing facilities experienced significant cost overruns during construction, schedule delays, and ongoing O&M challenges.
Waste-to-Energy w/Decarbonization Technology (Trash Incinerator)	Air emissions from combustion of solid waste/trash are high in carbon, requiring a decarbonization technology to help reduce emissions. Both processes are high cost and complex. The availability of a sufficient fuel supply is also a concern.
Modify Existing Unit(s) to Fire Biomass	Extensive modifications to the existing facility would be required. A new, smaller biomass unit offers a more cost-effective alternative.

TECHNOLOGY	BASIS
Convert Existing Unit(s) to Synchronous Condenser *(Does not generate power; helps grid reliability w/inverter-based resources)*	The technology is not a power producing or energy storage technology and was therefore not evaluated further.
Kinetic Energy Storage: Flywheel	This technology was eliminated due to lack of scale (too small for utility applications).
Gravity Energy Storage (gradual gradients / hill type topography)	CGS topography is not considered suitable for deployment at this site. In addition, the maturity level is not where it needs to be for consideration as a Phase 1 technology.
Pumped Storage Hydro	This is a mature and proven technology, but CGS site topography is not considered suitable for deployment at this site.
Iron Air Energy Storage ("Rust Battery", days of storage)	There are concerns about whether this technology will be sufficiently developed for an SRP resource commitment decision by 2028 and be online by Spring 2033. A recent announcement on a 10 MW project in 2 years supports that view. There is a significant development gap between 10 MW to 400 MW and scaling up will take time.
CAES (Compressed Air Energy Storage, w/o waste heat recovery)	This has industry experience. However, adiabatic CAES, or A-CAES, was considered a better option due to higher round-trip efficiency.

3.4 TECHNOLOGY SELECTION FOR FURTHER STUDY

The technologies selected for further evaluation and cost estimating in a Phase 1 process are listed below:

1. Wind
2. PV Solar
3. Biomass
4. Li-ion Batteries (Short Duration Energy Storage, SDES)
5. Adiabatic-Compressed Air Energy Storage (A-CAES) (Long Duration energy Storage, LDES)

A more detailed summary of the screening can be found in Appendix B, (*Table B.1: Results technology screening criteria)*, which also identifies technologies recommended as potential Phase 2 candidates

SECTION 4

Technology Cost Estimates

SECTION 4

TECHNOLOGY COST ESTIMATES

Technology cost estimating is especially complex in the power generation industry. As part of a technology selection process, utilities may compare installed costs ($/KW), levelized costs of energy ($/MWh), and with the advent of intermittent resources, the effective load carrying capacity of a resource. Technologies which are in early development stages present additional complexity due to the lack of project volume and operating experience. Even mature resources are subject to uncertainty surrounding a variety of factors including volatile commodity prices, potential import tariffs, and most importantly a lack of detailed design and project capacity information.

For the purposes of this study, an order of magnitude cost comparison was performed to show the cost of technologies relative to each other as depicted in Tables A.2 and B.1. It is assumed that SRP would conduct a detailed cost analysis as part of any technology selection.

Advanced nuclear technologies are outside of the scope of this study. The feasibility of repurposing with nuclear is being studied under a separate effort led by the Gateway for the Acceleration of Nuclear (GAIN), a DOE initiative.

SECTION 5

Conclusions and Recommendations

SECTION 5

CONCLUSIONS AND RECOMMENDATIONS

5.1 OVERVIEW

The electric power industry is experiencing dramatic transformation and innovation due to pressures to shift to dispatchable, carbon-free generating resources. Development of new generating and storage technologies are under way that have the potential to facilitate this transformation, but many of these technologies are in the early stages of development and have yet to prove their commercial viability and long-term reliability. Other technologies that are mature or are more fully developed, with lower carbon emissions than coal-fired generation, have significant fuel supply limitations for the CGS site (e.g., natural gas).

At national and regional levels, conventional dispatchable generating resources (coal, natural gas, nuclear) are leaving the system faster than they are being replaced, with implications for electric utilities' ability to meet the load during extreme or even normal weather conditions (see the North American Electric Reliability Corporation (NERC) 2022 Long Term Reliability Assessment, issued December 2022) [1]. In the Western Interconnection, all three sub-regions (CA/MX, Western Power Pool, and Southwest Reserve Sharing Group (SRSG)) have increasing demand and resource mix variability, which is accommodated on the transmission network by delivering power from regions that have excess supply to areas where demand exceeds supply. More extreme summer temperatures can reduce the amount of supply available for transfer and reduce the transmission network's ability to transfer the excess power [NERC 2022 LTRA, p. 6]. Kiewit expects that SRP, located within the SRSG sub-region and experiencing significant load growth, is exposed to these developments as are other utilities in the SRSG and Western Interconnection. Adding generation on a developed site, with infrastructure that allows power delivery directly to SRP's service territory, is a prudent part of the response to these developments.

In addition to the conditions described above, the push towards electrification, load growth in SRP's service territory, and the retirement of coal assets all indicate the need for additional low carbon generating resources. The costs and challenges associated with siting new resources can be lessened by leveraging an existing site's access to transmission. As a result, it will be important for SRP to assess the opportunity offered by the CGS site as it considers future resource needs, and what 2028 resource commitments are required to meet post-CGS resource requirements.

5.2 CONCLUSIONS

After completing the study, Kiewit provided SRP with the following conclusions:

1. The Coronado Generating Station's interconnection facilities, land and other resources make it a favorable site for the development of future generating resources once the coal generation is retired.
2. Of the over 30 technology options reviewed, because of varying degrees of development and maturity, only a limited number have demonstrated technical readiness to support a 2028 resource commitment decision that would support a Spring 2033 online date.

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[1] *North American Electric Reliability Corporation (NERC) 2022 Long Term Reliability Assessment, issued December 2022 https://www.nerc.com/pa/RAPA/ra/Reliability%20Assessments%20DL/NERC_LTRA_2022.pdf*

3. The composition and performance characteristics of SRP's resource mix and resource need will ultimately determine the capacity (size) of any replacement resource.
4. Biomass is the only Phase 1 resource with operating characteristics comparable to those of CGS. However, challenges with obtaining fuel limits the size and scale of a potential biomass facility.
5. Wind and solar have a lower energy density than thermal resources and, depending on the size of a facility, may require additional land beyond what SRP currently owns in the area.
6. Intermittent resources such as wind and solar and limited-duration resources such as battery storage require multiple megawatts (overbuild) to replace 1 MW of thermal generation.

5.3 RECOMMENDATIONS

The following activities are recommended actions to help SRP prepare to decide on repurposing the CGS site. The proposed objective to have a high confidence level that the technology selection(s) will meet SRP resource needs, is commercially viable and has demonstrated performance and reliability.

1. **Implement a Phased Approach to Repurposing** – The CGS site is well suited to host multiple technologies. Additionally, the reuse of the existing infrastructure could reduce costs for subsequent generation projects. SRP should develop a phased approach that capitalizes on the infrastructure in the near term while preserving the option for more advanced technology integration in the future.
2. **Define Resource Needs** – Because the closure of CGS is still almost a decade away, it is not yet clear what SRP's resource needs will be when CGS is retired. As such, SRP should work to understand how Phase 1 resources satisfy SRP's needs under a wide range of planning scenarios.
3. **Identify Critical Path & Milestones** – Indicative project schedules that include front-end development activities needed to support a 2028 resource commitment decision and a Spring 2033 online date should be prepared and maintained. Continue to monitor the development of emerging technologies, including those selected for further consideration in this study.
4. **Commence Due Diligence & Pre-tasks** – Commencing front-end tasks and due diligence activities for Phase 1 resources will allow SRP more time to preserve development options that allow more time to confirm its future resource needs. Such activities may include:
    a. For A-CAES, studies to develop a refined cost estimate for underground storage of compressed air.
    b. All options will require additional geotechnical surveys and a more developed topographic map to support more accurate site layouts and better foundation cost estimates.
    c. For biomass, confirmation of sufficient fuel supply, location of sources, and cost of transport to CGS will be needed.
    d. For all options, SRP Power Delivery will need to determine what switchyard modifications / additions are required to accommodate the new resources.
5. **Evaluate Resource Development Risks** - SRP should continue to monitor development of Phase 1 technologies, regulations and incentives supporting their development and impact on supporting supply chains. This includes whether technologies have been demonstrated in sufficient size (MW) and number of projects to justify being considered for deployment by SRP when a resource commitment decision is made.
6. **Plan for Phase 2 Resources** - Develop and implement a plan to evaluate and prioritize Phase 2 resource opportunities.

APPENDICES

APPENDIX A

Identified Technology Options
and Evaluation Approach

APPENDIX A

IDENTIFIED TECHNOLOGY OPTIONS AND EVALUATION APPROACH

Table A.1: Technology Options Initially Considered

TYPE	TECHNOLOGY
New Renewable and/or Low Carbon	Solar–Utility Scale PV Solar–Concentrated Thermal Wind
Conventional	Simple cycle, hydrogen-fired Reciprocating internal combustion engines (RICE) with renewable fuels Pumped hydro Combined cycle, gas-fired, wet cooling Combined cycle, gas-fired, dry cooling Combined cycle, hydrogen-fired, dry cooled
Other Fossil	Combined Cycle, Allam-Fetvedt cycle, supercritical CO_2 Integrated Gasification Combined Cycle (IGCC) Biomass–Thermal (wet or dry cooled) Waste-to-Energy (WTE) with decarbonization technology (trash incinerator)
Modify Existing CGS Units (1, 2 or both)	Retrofit with decarbonization technology Convert to synchronous condenser Modify to fire biomass Modify to fire hydrogen CC repower with hydrogen-capable CTs, new HRSGs and existing steam turbine
ENERGY STORAGE:	
Short Duration Energy Storage (SDES) (4-6 hours)	BESS (Lithium Ion) Kinetic (flywheel)
Long Duration Energy Storage (LDES) (8–10+ hours)	BESS (Flow battery) Gravity energy storage (vertical, new towers) Gravity (gradual gradients, hill type topography) Iron air (rust battery) Compressed air energy storage (CAES) Liquid air energy storage (LAES) CO_2 energy storage Thermal energy storage (TES)–concrete Thermal energy storage (TES)–molten salt Hydrogen–on-site production and storage (PEM electrolyzer) Hydrogen–on-site production & storage (ammonia) Hydrogen–on-site production and storage + fuel cell power generation

Table A.2: Evaluation Approach

CRITERIA	DEFINITION	RATING
Estimated Technology Maturity in 2028	This is an evaluation by Kiewit based on technology today and expectations on commercial deployment. The assessment is based on what projects are being performed now, the current Technical Readiness Level (TRL) and their size.	**1** – Traditional technology, industry standard / Many examples of utility-scale installations **2** – At least one utility-scale installation by 2028 **3** – No utility-scale installations by 2028, but some smaller scale installations by 2028
Power industry experience as of 2022	This is an assessment of the number of projects (both utility scale and pilots) that have been performed as of 2022.	**1** – Traditional technology for power industry / Many examples in power industry **2** – At least one example in the power industry **3** – Mostly used outside of the power industry / No significant experience in any industry
Power industry interest as of 2022	This is an assessment of how many Original Equipment Manufacturers (OEM's), utilities, and other industries are interested in building and developing this technology.	**1** – Common, lots of development **2** – Becoming more used **3** – Not used often
Land required	This is an assessment of how much land is required.	**1** – <2.5 acres per MW **2** – 2.5-5 acres per MW **3** – >5 acres per MW
Water consumption	This is an assessment of how much water is required for operation. 300 gal/MWh is just over the approximate makeup water requirement of a wet-cooled natural gas combined-cycle power plant based on SRP experience.	**1** – Little to no water required **2** – <300 gal/MWh **3** – >300 gal/MWh
Carbon Emissions	This is an assessment of whether the technology is carbon neutral or low carbon (based on the spectrum of zero carbon emissions, carbon neutral, and carbon producer).	**1** – Produces no carbon **2** – Mitigate the combustion through sequestration or other means **3** – Carbon emitter
Cost	This is an assessment of technology overnight capital cost compared to other technologies listed. This rough order of magnitude assessment is based on public industry information.	**1** – <$1,500/kW **2** – $1,500-5,000/kW **3** – >$5,000/kW
Ability to leverage existing interconnect	The interconnect and transmission line are valuable resources, so this is an important assessment. Kiewit did an assessment to determine how often the technology would be able to fully utilize the existing electrical interconnection capacity (800 MW).	**1** - The maximum interconnection capacity could be utilized **2** - The maximum interconnection capacity could be utilized for roughly half the time **3** – The maximum interconnection capacity is utilized for less than 1/3 of the time day

CRITERIA	DEFINITION	RATING
Generation Capability	The type of generation that can be supplied by the technology to serve the grid.	**CONT** – Continuous generation, best used in a base load condition **FLEX** – Can be used to operate as needed by the grid **INT** – Available intermittently as favorable conditions allow **DAY** – Only available during the day **NONE** – Not used for power production but for some other purpose, either grid stabilization or commodity production.

APPENDIX B

Technology Screening

APPENDIX B

TECHNOLOGY SCREENING

Table B.1: Results technology screening criteria

TECHNOLOGY OPTIONS	EST. TECHNOLOGY MATURITY IN 2028	POWER INDUSTRY EXPERIENCE (2022)	POWER INDUSTRY INTEREST (2022)	LAND REQUIRED	WATER CONSUMPTION	CARBON EMMISSIONS	COST	CONTRIBUTION TO MAXIMIZING ELECT. INTERCONNECTION	GENERATION CAPABILITY	SELECTED FOR PHASE 1, 2, OR NOT CONSIDERED FOR FURTHER EVALUATION	BASIS
POWER GENERATION											
Solar - Utility Scale PV	1	1	1	3	1	1	1	3	DAY/INT	1	Demonstrates sufficient technology and supply chain maturity.
Wind	1	1	1	3	1	1	1	3	INT	1	Demonstrates sufficient technology and supply chain maturity.
Biomass - Thermal Generation Plant (air-cooled)	1	1	1	1	3	2	2	3	CONT	1	Biomass has been demonstrated at utility scale. Integration of this resource would require fuel supply and transportation analysis to deliver an adequate fuel supply.
CT Combined Cycle, Hydrogen Fired (air cooled) *(Requires H2 On-Site Fuel Production from Energy Storage category)*	3	3	1	1	2	1	3	1	CONT	2	Lack of confidence for availability of H2 pipelines to CGS site or practicality of producing and storing H2 on site at 800 MW scale. **Retain option for Phase 2 as technology matures and should hydrogen availability (from onsite production or via pipeline/rail to the site) be viable/economical.**
CT Simple Cycle, Hydrogen Fired (air cooled) *(Requires H2 On-Site Fuel Production from Energy Storage category)*	2	3	1	1	3	1	3	2	FLEX	2	Lack of confidence for the availability of H2 pipelines to CGS site or practicality of producing and storing H2 on site at 800 MW scale. **Retain option for Phase 2 as technology matures and should**

TECHNOLOGY OPTIONS	EST. TECHNOLOGY MATURITY IN 2028	POWER INDUSTRY EXPERIENCE (2022)	POWER INDUSTRY INTEREST (2022)	LAND REQUIRED	WATER CONSUMPTION	CARBON EMMISSIONS	COST	CONTRIBUTION TO MAXIMIZING ELECT. INTERCONNECTION	GENERATION CAPABILITY	SELECTED FOR PHASE 1, 2, OR NOT CONSIDERED FOR FURTHER EVALUATION	BASIS
											hydrogen availability (from onsite production or via pipeline/rail, to the site) be viable/economical.
Reciprocating Internal Combustion Engines (RICE) w/ Renewable Fuel	1	2	1	1	2	2	2	3	FLEX	2	Lack of confidence for availability of fuel supply to CGS site. **Retain option for Phase 2 should fuel become economically available.**
Retrofit Existing Unit(s) w/Decarbonization Technology	2	3	3	1	3	2	3	1	CONT	2	Lack of confidence for availability of CO2 pipelines from CGS site or practicality of storing CO2 onsite or within an acceptable distance. **Retain option for Phase 2 should a way to sequester CO2 onsite or transport elsewhere become economically available.**
Modify Existing Unit(s) to Fire Hydrogen *(Requires H2 On-Site Fuel Production from Energy Storage category)*	3	3	2	1	2	1	3	1	CONT	2	Lack of confidence for availability of H2 pipelines to CGS site. **Retain option for Phase 2 as technology matures and should hydrogen availability (from onsite production or via pipeline/rail to the site) be viable/economical.**
Repower Existing Unit(s): New Hydrogen CT/HRSG + Existing ST Cycle	3	3	3	1	2	1	3	1	CONT	2	If new hydrogen fired CTs/HRSGs were to be installed at CGS, a new air-cooled steam turbine cycle would be a better alternative. New air-cooled steam cycle would not rely on existing systems that may be approaching end of useful life,

TECHNOLOGY OPTIONS	EST. TECHNOLOGY MATURITY IN 2028	POWER INDUSTRY EXPERIENCE (2022)	POWER INDUSTRY INTEREST (2022)	LAND REQUIRED	WATER CONSUMPTION	CARBON EMISSIONS	COST	CONTRIBUTION TO MAXIMIZING ELECT. INTERCONNECTION	GENERATION CAPABILITY	SELECTED FOR PHASE 1, 2, OR NOT CONSIDERED FOR FURTHER EVALUATION	BASIS
											thereby increasing reliability and reduce water consumption. **Retain option for Phase 2 as technology matures and should hydrogen availability (from onsite production or via pipeline/rail to the site) be viable/economical.**
CT Combined Cycle, Natural Gas Fired (water-cooled) *w/Allam Cycle (CO2 as working fluid vs. water/steam)*	1	3	2	1	2	2	2	1	CONT	2	Allam (CO2) cycle offers several advantages over a traditional (water/steam) cycle in a combined cycle plant including improved performance and reduced water consumption. SRP previously studied installation of a new fuel supply line and determined it to not be a cost-effective option for CGS. **Retain option for Phase 2 as a bridge to hydrogen or should fuel supply to the site and CO2 sequestration be viable/economical.**
CT Combined Cycle, Natural Gas Fired (air-cooled)	1	1	2	1	2	3	1	1	CONT	2	SRP has previously studied the installation of a new fuel supply pipeline and determined it to not be a cost-effective option for CGS. **Retain option for Phase 2 as a bridge to hydrogen or should fuel supply to the site and CO2 sequestration be viable/economical.**

TECHNOLOGY OPTIONS	EST. TECHNOLOGY MATURITY IN 2028	POWER INDUSTRY EXPERIENCE (2022)	POWER INDUSTRY INTEREST (2022)	LAND REQUIRED	WATER CONSUMPTION	CARBON EMISSIONS	COST	CONTRIBUTION TO MAXIMIZING ELECT. INTERCONNECTION	GENERATION CAPABILITY	SELECTED FOR PHASE 1, 2, OR NOT CONSIDERED FOR FURTHER EVALUATION	BASIS
CT Combined Cycle, Natural Gas Fired (water-cooled)	1	1	2	1	2	3	1	1	CONT	2	SRP previously studied the installation of a new fuel supply pipeline and determined it to not be a cost-effective option for CGS. **Retain option for Phase 2 as a bridge to hydrogen or should fuel supply to the site and CO2 sequestration be viable/economical.**
Solar - Concentrated Thermal	1	2	3	3	2	1	3	1	CONT	Not evaluated further	Recommend utility scale solar PV over concentrated thermal due to lower capital cost (order of magnitude $6500/kW for CSP vs. $1600/kW for PV solar).
Integrated Gasification Combined Cycle (IGCC; coal gasification)	1	2	3	3	3	1	3	1	CONT	Not evaluated further	Highly complex technology with limited installations in power generation applications. Based on industry feedback, existing facilities have experienced significant cost overruns, schedule delays, and on-going O&M challenges.

TECHNOLOGY OPTIONS	EST. TECHNOLOGY MATURITY IN 2028	POWER INDUSTRY EXPERIENCE (2022)	POWER INDUSTRY INTEREST (2022)	LAND REQUIRED	WATER CONSUMPTION	CARBON EMISSIONS	COST	CONTRIBUTION TO MAXIMIZING ELECT. INTERCONNECTION	GENERATION CAPABILITY	SELECTED FOR PHASE 1, 2, OR NOT CONSIDERED FOR FURTHER EVALUATION	BASIS
Waste-to-Energy w/Decarbonization Technology (Trash Incinerator)	1	1	3	2	3	1	3	1	CONT	Not evaluated further	Air emissions resulting from combustion of refuse (solid waste / trash) are high in carbon. A decarbonization technology must be used in conjunction with a waste-to-energy facility to help reduce emissions. Both processes involve the use of very high cost and technically complex facilities that require a significant amount of water. Volume of available fuel is a concern.
Modify Existing Unit(s) to Fire Biomass	1	1	2	2	3	2	2	1	CONT	Not evaluated further	Converting existing boiler to fire biomass is expected to require extensive modifications to the steam cycle and other BOP infrastructure. Sufficient fuel supply is a concern. A more cost-effective alternative would be to install a new biomass unit.
Convert Existing Unit(s) to Synchronous Condenser *(Does not generate power; helps grid reliability w/inverter-based resources)*	1	2	2	1	1	N/A	1	1	NONE	Not evaluated further	May offer valuable ancillary services not within the scope of this study. Not a power producing or an energy storage technology.
ENERGY STORAGE											
SDES (4 – 6 Hours)											
Lithium ion	1	2	1	1	1	N/A	2	3	FLEX	1	Demonstrates adequate technology and supply chain maturity. Competition with other industries (transportation) for batteries is a concern.

TECHNOLOGY OPTIONS	EST. TECHNOLOGY MATURITY IN 2028	POWER INDUSTRY EXPERIENCE (2022)	POWER INDUSTRY INTEREST (2022)	LAND REQUIRED	WATER CONSUMPTION	CARBON EMISSIONS	COST	CONTRIBUTION TO MAXIMIZING ELECT. INTERCONNECTION	GENERATION CAPABILITY	SELECTED FOR PHASE 1, 2, OR NOT CONSIDERED FOR FURTHER EVALUATION	BASIS
Kinetic Energy Storage: Flywheel	1	2	3	2	1	N/A	2	3	FLEX	Not evaluated further	Power output of flywheel technologies is too small making this an impractical option for utility scale applications.
LDES (Long Duration Energy Storage; 8 – 10+ Hours)											
A-CAES (Adiabatic Compressed Air Energy Storage, w/waste heat recovery)	2	3	2	1	2	N/A	2	2	CONT	1	Demonstrated at >2MW scale with multiple projects in development >200MW – expected to demonstrate maturity.
Flow Battery	2	1	1	1	2	N/A	2	2	FLEX	2	Lack of current maturity. **Retain option for Phase 2 as technology matures.**
Gravity Energy Storage (vertical, new towers)	3	3	2	2	1	N/A	2	3	FLEX	2	Lack of current maturity. **Retain option for Phase 2 as technology matures.**
LAES (Liquid Air Energy Storage)	1	2	1	1	2	N/A	3	2	CONT	2	High cost. **Retain option for Phase 2 as technology matures.**
TES - Concrete (Thermal Energy Storage)	2	3	2	1	2	N/A	2	2	CONT	2	Lack of current maturity. **Retain option for Phase 2 as technology matures.**
TES - Molten salt energy storage (Thermal Energy Storage)	3	3	2	1	2	N/A	2	2	CONT	2	Lack of current maturity. **Retain option for Phase 2 as technology matures.**
CO2 Energy Storage	2	2	2	1	1	N/A	2	2	FLEX	2	Lack of current maturity. **Retain option for Phase 2 as technology matures.**

TECHNOLOGY OPTIONS	EST. TECHNOLOGY MATURITY IN 2028	POWER INDUSTRY EXPERIENCE (2022)	POWER INDUSTRY INTEREST (2022)	LAND REQUIRED	WATER CONSUMPTION	CARBON EMISSIONS	COST	CONTRIBUTION TO MAXIMIZING ELECT. INTERCONNECTION	GENERATION CAPABILITY	SELECTED FOR PHASE 1, 2, OR NOT CONSIDERED FOR FURTHER EVALUATION	BASIS
Hydrogen - On-Site Fuel Production & Storage (Electrolyzer Process) *(Does not generate power; produces fuel for use in other technologies)*	3	3	3	2	2	N/A	3	2	NONE	2	Lack of confidence for availability of H2 pipelines to CGS site or practicality of producing and storing H2 on site at 800 MW scale. **Retain option for Phase 2 as hydrogen synthesis technology matures and shows improvements with round trip efficiencies, should a transportation method become economically available.**
Hydrogen - On-Site Fuel Production & Storage (Ammonia Process) *(Does not generate power; produces fuel for use in other technologies)*	3	3	2	2	2	N/A	3	2	NONE	2	If hydrogen is to be produced on-site at CGS, an electrolyzer process is preferred vs. an ammonia process. Ammonia is currently delivered in limited quantities to the site via rail or truck. Ammonia transportation / storage costs and the potential for delivery risks makes this a less favorable option. **Retain option for Phase 2 as hydrogen and ammonia synthesis technologies mature, show improvement with round trip efficiencies, and/or should a transportation and storage method become economically available.**

TECHNOLOGY OPTIONS	EST. TECHNOLOGY MATURITY IN 2028	POWER INDUSTRY EXPERIENCE (2022)	POWER INDUSTRY INTEREST (2022)	LAND REQUIRED	WATER CONSUMPTION	CARBON EMISSIONS	COST	CONTRIBUTION TO MAXIMIZING ELECT. INTERCONNECTION	GENERATION CAPABILITY	SELECTED FOR PHASE 1, 2, OR NOT CONSIDERED FOR FURTHER EVALUATION	BASIS
Hydrogen - On-Site Production & Storage + Fuel Cell Power Generation	1	2	3	2	2	N/A	3	2	FLEX	2	Lack of confidence for availability of H2 pipelines to CGS site or practicality of producing and storing H2 on site at 800 MW scale. **Retain option for Phase 2 as technology matures and should hydrogen availability, (from onsite production or via pipeline/rail to the site) be viable/economical.**
Gravity Energy Storage (gradual gradients / hill type topography)	2	3	2	3	1	N/A	3	2	FLEX	Not evaluated further	Topography of SRP-owned property is not suitable for this technology.
Pumped Hydro	1	1	1	3	2	N/A	3	1	FLEX	Not evaluated further	Topography of SRP-owned property is not suitable for this technology.
Iron Air Energy Storage ("Rust Battery", days of storage)	3	3	1	1	2	N/A	3	1	CONT	Not evaluated further	Lack of current maturity.
CAES (Compressed Air Energy Storage, w/o waste heat recovery)	1	2	2	1	1	N/A	2	2	FLEX	Not evaluated further	Lower efficiency than new A-CAES designs, need natural gas to provide heat input for gas expansion.