Coal Repowering

a White Paper Series

Repowering Coal-Fired Power Plants for Natural Gas and Hydrogen-Fired Generation

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Abstract

In response to mounting pressure to retire coal-fueled generating assets, U.S. utilities have announced thousands of megawatts of coal plant retirements to take effect over the next 15 years [1]. While repowering coal plants to renewable resources, bulk storage, battery storage, and nuclear generation are important options to reduce carbon emissions, the transition to a low- or net-zero carbon industry is likely to require some natural gas-fired generation. To maximize decarbonization, the ideal natural gas-fired solution is likely to be a highly efficient natural gas combined-cycle plant with the capability to integrate over time an increasing percentage of blended hydrogen co-firing. Repowering a coal site for gas-fired generation with the potential for hydrogen co-firing offers several advantages, including the possibility of reusing existing site infrastructure, operating and environmental permits, equipment, facilities, and water access and storage.

For these reasons, many utilities and power producers seek strategies to evaluate the potential for repowering coal plants to efficient natural gas/hydrogen-fired facilities. This paper summarizes key issues to consider and understand when evaluating such a repowering project. It is part of a series of EPRI papers addressing various options for coal sites after decommissioning.

Contents

Introduction

As economic, regulatory, and carbon reduction goals evolve, the viability and desirability of operating coal-fueled generating assets continue to decline. Since 2000, at least 90 gigawatts (GW) of older, smaller, and less-efficient coal units have been retired in response to environmental and economic changes [1]. As power generators worldwide transition to low-carbon or carbon-free energy sources, pressure rises to decommission the remaining coal fleet. Global goals for managing climate change have placed intense policy pressure on the coal fleet while driving significant financial change, including an increasing difficulty in financing coal-related projects [2].

In the United States, utilities have announced thousands of megawatts of coal plant retirements, with anticipated closure dates within the next 15 years [1]. This round of plant retirements presents new challenges. The average nameplate capacity for this group of retiring coal plants is 420 MW, compared to an average of 152 MW for those retired in the past 15 years. Globally, including the United States, expected coal retirements over the next 15 years amount to nearly 290 GW [3]. Further, the World Economic Forum has noted that international coal plant retirements, preferably combined with conversion to cleaner energy, must be accelerated to meet International Panel on Climate Change (IPCC) goals by 2050 [4].

The plants slated for retirement now are more complex than the older plants, due to the presence of equipment such as air emission controls. Regulatory changes have resulted in stricter environmental air emissions and effluent limits, new regulated materials, and more public scrutiny on the closure process. These new challenges are adding cost and risk to the decommissioning process for larger plants.

While repowering coal plants to renewable resources, bulk storage, battery storage, and nuclear generation are important options to reduce carbon emissions, the transition to a low- or net-zero carbon industry is likely to require some natural gas-fired generation. To maximize decarbonization, the ideal natural gas-fired solution is likely to be a highly efficient natural gas combined-cycle plant, with the capability to integrate over time an increasing percentage of hydrogen co-firing.

Installing gas turbines, potentially in combined-cycle arrangements, on existing coal plant sites can leverage existing buildings, substations, and other critical infrastructure, although some major equipment, such as turbomachinery, may not be repurposed.

In the current scenario, converting existing challenges to opportunities can be addressed by systematically creating an inventory of the existing site infrastructure, characteristics, permits, and other attributes and correlating it with the needs of the evolving network and the proposed alternative—in this case natural gas/hydrogen-fired generation—with attention to maximizing useful service for both the utility and the local community.

Following are potential benefits of repowering an existing coal site:

- Operating coal plant sites have existing transmission infrastructure and interconnection permits.
- Many such sites have access to well-developed transportation infrastructure via road, rail, and waterways, as well as existing utility connections for buildings.
- The existing environmental permits for a coal facility may be modifiable for application to the new facility, possibly forestalling lengthy permitting processes that require multiple periods of public input.

- Larger facilities that already have a land use permit and certificate of occupancy, as well as buffer property to provide a visual and physical barrier from nearby neighbors, provide siting advantages that may allow the new system to be constructed and commissioned more quickly than siting the plant in a new location.
- Existing buildings, warehouses, and some other on-site equipment may offer opportunities to lower the cost of construction by repurposing those for the new functionality.
- Many current sites offer the advantage of access to a large daily water withdrawal and water discharge allowance. In the United States, the right to withdraw water is under more scrutiny. Modifying existing water withdrawal and discharge permits, rather than undergoing the permitting process at a new site, offers reputational and permitting advantages.

Utilities can develop long-term plans to support their corporate objectives for transitioning to low-carbon or carbon-free generation by developing a corporate strategy to thoroughly examine the assets, liabilities, obligations, and limitations of coal-powered facilities slated for decommissioning. Currently-available options include repowering or repurposing the site to a(n):

- Hydrogen production plant (most likely using electrolysis), with possible conversion to ammonia for higher-value shipment off-site for various industrial and power-production needs [5]
- Battery energy storage facility that stores energy from the grid, when electricity prices are low or renewable energy production exceeds demand, and discharges power to the grid when demand is high [6]
- Photovoltaic (PV) power generation facility that directly converts sunlight to electricity [7]
- Bulk energy-storage facility (most likely, thermal energy storage) that would store energy from the grid (when electricity prices are low) and discharge power to the grid when demand is high, while also leveraging existing turbomachinery [8]
- Concentrating solar power (CSP) facility that would create energy from solar thermal heat, potentially using the existing steam power island at the site to create power
- Natural gas-fueled (and potentially hydrogen-fueled) simple-cycle or combined-cycle power plant (the subject of this paper)
- Advanced nuclear generating station [9]
- A wind energy facility
- Hybrid plant using two or more low-carbon or carbon-free technologies, such as wind and solar, or solar and hydrogen

EPRI is exploring low- or zero-carbon repowering options for coal plants through a screening-level evaluation of the available infrastructure, permits, site characteristics, equipment, and water access typical of coal-fired generation that may be beneficial for repowering applications. The already completed papers in this series are referenced above.

This paper provides a high-level overview of the process of determining whether a coal-fired power plant slated for decommissioning is suitable for repowering as a natural gas/hydrogen-fired generation facility, vis-a-vis alternatives such as repowering to a PV plant, battery energy storage, or other options listed above. The paper covers the key issues to consider when evaluating the installation of a combined-cycle or simple-cycle system, including the following (see Figure 1):

- Identify existing infrastructure, including grid interconnection and transportation access that may be available
- Assess physical site characteristics, including available land and other attributes, to determine suitability for this option
- Consider potential reuse of structures and equipment
- Review opportunities to renew or modify existing permits applicable to natural gas/hydrogen-fired power generation
- Consider water availability and the capacity of stormwater management systems for this application

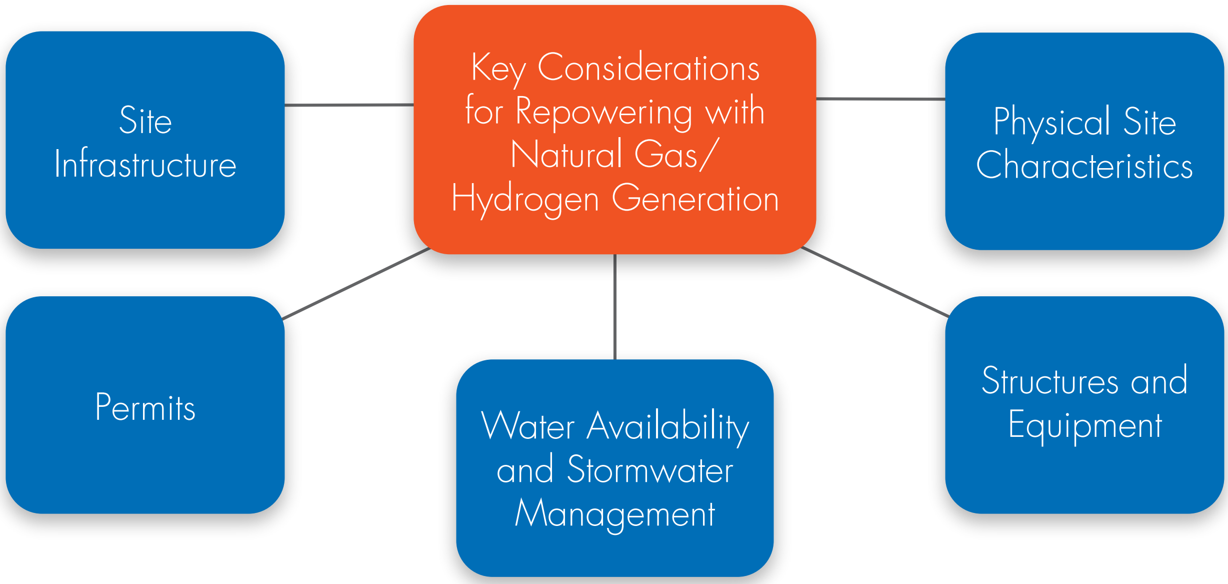

Figure 1. Key issues when evaluating coal plant sites for repowering with natural gas/hydrogen-fired generation

Siting of new natural gas- or hydrogen-fired generation at existing fossil-fueled plants is currently under way in the United States and around the world. Whether converting to natural gas alone or also including the potential to burn hydrogen, these projects provide value to the utility and to the local community [10–13].

Natural Gas- and Hydrogen-Fired Repowering Considerations

Repowering an existing coal plant to natural gas/hydrogen-fired technology covers a wide span of potential plant capabilities. The replacement plant could be as small as a 50-MW simple-cycle gas turbine or as large as a 1200-MW advanced combined-cycle facility. Between 2010 and 2019, in response to emissions standards, low natural gas prices, and the availability of more efficient natural gas turbine technology, U.S. utilities replaced 17 coal-fired power plants. The retired plants' rated capacity totaled 7.9 GW, with the replacement natural gas-fired combined cycle (NGCC) plants providing 15.3 GW of capacity [14].

General Considerations

Both simple-cycle and combined-cycle power plants are well-established technologies that can provide near-term reductions in criteria pollutant emissions and greenhouse gas (GHG) production from the generation plant [15,16]. In the United States, conversion to natural gas has been a major contributor to reducing power sector carbon dioxide (CO_2) emissions by over 30% since 2005 [17]. Worldwide, the International Energy Agency estimates that conversion from coal to natural gas could reduce total worldwide energy-related CO_2 production by 4%, or 1.3 billion tons (1.2 gigatonnes) per year [18].

Replacing coal facilities with relatively low capacity simple-cycle gas turbine units can support a carbon transition and help utilities balance supply and demand, while a larger fraction of electricity generation is provided by intermittent generation such as large solar and wind power installations. Combined-cycle and simple-cycle units have quicker

start times, faster ramp rates, and better turndown than coal plants, which is advantageous for supporting intermittent generation. Recent developments in turbine technology and balance-of-plant systems have significantly improved these plants' ability to provide ancillary benefits. As a result, gas turbine or combined-cycle plants can take the place of coal power plants for baseload generation in a way that intermittent technologies cannot.

Air Quality Impacts

Repowering to natural gas/hydrogen-fired generation reduces overall emissions of criteria pollutants and GHGs. As a result, although gas-fired generation remains fossil fueled, it supports long-term decarbonization by serving as a bridge through the transition from a heavily fossil-based generation system to a low- or zero-carbon future. Gas-fired combined-cycle generation produces about one-half the CO_2 of coal combustion per MWh generated, due in part to the higher efficiency of modern combined-cycle generation. The majority of GHG production in natural gas combustion is CO_2, although incomplete combustion and other factors may yield carbon monoxide (CO), methane (CH_4), and volatile organic compounds (VOC) [19].

Table 1 summarizes the relative emissions from coal and natural gas generation. With the emphasis on reducing power generation's carbon footprint, the potential reductions of other pollutants may be overlooked. Nitrogen oxides (NO_x) production for gas-fueled generation is more than 70% lower than for coal per MWh generated (see Table 1). With selective catalytic reduction (SCR), NO_x production can be further reduced. Natural gas contains very little sulfur; the odorant mercaptan, added to natural gas for safety, adds much of the sulfur in natural gas. As a result, SO_2 production is extremely low for gas turbines. CO is also produced at lower levels than with coal and may be reduced further through oxidation catalyst treatment. Particulate matter (PM) production, a major component of coal plant emissions, is a relatively minor issue with natural gas combustion.

Hydrogen Combustion

Table 1. Relative Emissions of Major Pollutants, by Fuel (Source: EPA [20])

Fuel	Coal		Natural Gas		Reduction
	lb/MWh	kg/MWh	lb/MWh	kg/MWh	%
NO_x	1.40	0.64	0.39	0.18	72%
SO_2	1.96	0.89	0.02	0.01	99%
CO_{2e}[1]	2182	992	898	408	59%

Fueling the new plant partly or entirely by hydrogen has two direct impacts on emissions. GHG emissions are eliminated in proportion to the use of hydrogen as fuel, because hydrogen does not contain carbon atoms. Because there is no carbon in the fuel, combustion does not yield CO, CH_4, or CO_2 emissions. NO_x emissions may be an issue. When measured in accordance with current regulations (on a dry parts per million by volume [ppmv] basis, with combustion air at 15% oxygen), NO_x emission

[1] CO_{2e} describes the combined impact of different greenhouse gases, expressed in terms of the equivalent amount of CO_2 that would yield an equivalent amount of global warming. In this table, taken from EPA data, CO_2 equivalent is defined as the sum of CO_2, CH_4 and N_2O emissions, adjusted by applying global warming potential values from the fourth assessment by the Intergovernmental Panel on Climate Change.

values are greater than with natural gas combustion. However, considered on a mass per unit heat input, NO_x emissions with hydrogen are very similar to those with natural gas. Post-combustion controls (primarily SCR) are available and likely to be needed for 100% hydrogen-fueled plants. Designers are developing modifications to control fuel flow, fuel-air mixing, and other factors to yield flame temperatures that reduce NO_x production, and manufacturers are already installing such systems [21,22]. Another alternative involves blending hydrogen with ammonia, which has a lower flame temperature than natural gas [23].

Hydrogen-Ready Design

New natural gas-fired powerplants can be designed as "hydrogen ready" for future conversion to partial or 100% hydrogen fuel. At present, advanced gas turbines are capable of burning a mix of 30–50% hydrogen (by volume); by 2030, all major equipment vendors plan to achieve 100% hydrogen capability [24,25]. Planning for hydrogen firing affects plant layout to allow incorporation of a fuel mixing skid, calls for modifications to certain other plant components, and impacts the sizing and materials selection for fuel piping. Each of these design considerations can be taken into account during the planning phases for repowering a coal-fired plant.

Site Infrastructure

A key benefit of repowering a coal-fired power plant site is the opportunity to reduce costs by reusing existing site infrastructure. In general, a suitability evaluation of a site includes a complete inventory and analysis addressing age, condition, value, suitability for supporting natural gas/hydrogen power generation, and estimated adaptation costs of incorporating the new system. The evaluation may also consider demolition and/or removal costs for infrastructure elements that will not be used. This section describes infrastructure reusability issues relevant to repowering to natural gas/hydrogen generation.

Overall, the key elements to consider when planning a conversion to a natural gas/hydrogen-fired generation at a coal plant are:

- Proximity to interstate and intrastate natural gas pipelines—a critical factor
- On-site electric transmission facilities able to accommodate the needs and performance factors of the new generation technologies
- Availability of land suitable for the new construction, including transportation access
- The condition of any existing equipment that might be useable for the repowered plant
- Air permits and emissions status for the existing plant
- For a combined-cycle installation:
  - Applicability of existing water and water permits
  - Applicability of existing National Pollutant Discharge Elimination System (NPDES) permit

Grid Interconnection

Existing high-voltage power connection infrastructure, land-use rights, and off-taker agreements (especially electrical) in place at the coal plant can facilitate grid interconnection of the repowered plant. Coal plants that have conducted interconnection studies will have a site permitting evaluation on record. Reusing existing structures and interconnection equipment avoids new construction and equipment expense, while avoiding the time to secure authorizations from the authorities having jurisdiction (AHJs). The available carrying capacity of transmission and distribution (T&D) lines near the site can impact overall costs.

When repowered for gas turbine or combined-cycle operation, the T&D lines and interconnections may need to be assessed and reconfigured to accommodate the requirements of new equipment or to allow for the new plant layout. It is not likely that the plant would require significant transmission-line upgrades, although some updates to substations may be needed. A clear understanding of the current and likely future generation mix in the local region is important to project the potential operation of the new facility and its function within future grid operations. The sidebar lists key steps to plan and implement any needed changes to the utility grid connection.

Transportation Access and Utilities

Transportation requirements apply through the construction period and the operating life of the new facility. To the extent that any part of the fuel will be hydrogen, one of the most critical transportation issues is moving the fuel on-site.

Fuel shipping and storage. When planning for a natural gas/hydrogen-fired plant, it is important to prioritize logistics for fuel transport to the site and fuel storage. Whether the fuel is natural gas, hydrogen, or a blend of the two, the following may be considered:

- Access to local pipelines for natural gas and the possible availability of blended hydrogen/natural gas delivered by pipeline
- Access to rail or barge services for hydrogen (or ammonia) fuel delivery
- Access to potential storage facilities, such as salt domes or existing gas storage facilities

Access to backup fuel may also be considered. Determining access to natural gas pipelines is significantly more complex than the issue appears on the surface. If the site is reliant on interruptible gas, the plant's supply may not be available when extreme cold weather events occur. Most utilities plan for backup fuel oil to cover such events, if firm gas transportation is not available.

Utility Interconnection Process

Overall, evaluating and planning to reuse existing interconnections for a new natural gas/hydrogen-fired simple-cycle or combined cycle generation plant may include the following steps:

1) Preliminary review and report

2) Scoping meeting

3) Interconnection studies
   - a) Impact study
     - i) Thermal and voltage analysis of circuits
     - ii) Power flow and load flow analysis
     - iii) Stability analysis
     - iv) Harmonic analysis
     - v) Risk-of-islanding analysis
   - b) System protection
     - i) ANSI/IEEE 1547 devices
     - ii) Device short-circuit study
     - iii) Arc-flash hazard analysis
     - iv) Coordination study: relay settings and fuse curves (time-current curves)
   - c) Utility facility study with upgrades, costs, and timelines
   - d) Interconnection agreements
     - i) Planning, design, and approvals
     - ii) Construction
     - iii) Interconnection approval
     - iv) Testing and commissioning
     - v) Energization (permission to operate)

Plant Construction. When repowering a coal plant, minimizing the impact of the transition between the coal plant's shutdown and repowered operations offers several benefits. Because the grid relies on the coal plant output, when that generation is unavailable, alternative power sources need to be brought online to avoid undue strain on the grid. Currently-available equipment may be available in modular components, minimizing construction time, space needed for installation, and on-site disruptions.

For simple-cycle and combined-cycle installations:

- Certain key equipment (e.g., turbines, generators, and transformers) requires heavy haul to the site. Available transportation needs to be considered, including assessment of on-site roads and surfaces for these loads.
- Special attention may be needed for transportation and installation of hydrogen or ammonia storage.

For combined-cycle systems:

- For heat recovery steam generators (HRSGs), the delivery method is closely tied to modularity. On-site construction savings with additional modularity tend to be offset by the delivered equipment cost. In-shop module construction tends to provide higher quality control and lower costs.
- Depending on local construction costs, modular pipe racks may be installed.
- Steam turbine-generator units are designed for rail shipment in modular components, such as the high-pressure/medium-pressure expansion turbine portion, the low-pressure turbine element, and the generator.

Plant Operation. Over the new generating plant's operating lifetime, new components need to be transported to the plant and installed to replace equipment or to increase the plant's capability. In addition, maintenance and safety crews and equipment require ongoing access, while any retired equipment requires transportation off-site. Therefore, adequate transportation access is needed throughout the facility's lifespan.

- The existing plant is likely to have rail access in place; coordination of new operations with the gas/hydrogen-fired plant is highly desirable. Ideally, the plant has a dedicated rail-unloading spur for new equipment deliveries or for fuel deliveries.
- A separate construction gate for new plant equipment deliveries may also be helpful, rather than using the one established for coal deliveries and coal plant operations.

Utilities. Existing utilities, such as water, gas, and sewer, that serve the needs of plant equipment and personnel are useful during the natural gas/hydrogen plant's construction and operation. Availability of these utilities may minimize or avoid entirely the need to truck water, portable generators, trailers, and restrooms to the site. Typically, the construction contract will already include a requirement to supply such facilities for construction crew and managers and to provide any required permits.

Waste Removal. Compared to the decommissioning coal plant, a natural gas/hydrogen-fired plant is likely to produce minimal solid waste. The only solid waste disposal is solids collected from water clarification and filtering. These are nontoxic and may be reusable for fill material or feedstock for construction components such as brick. During construction, some waste water may be produced from pressure testing and pipe flushing. Cleaning wastewater from turbine water washes may contain heavy metals, which may not be dischargeable under the NPDES permit.

Physical Site Characteristics

This section summarizes the physical coal-fired power plant site characteristics that may be beneficial for development of a new natural gas/hydrogen-fueled facility.

Land Characteristics

For repowering a coal site to natural gas/hydrogen-fueled generation, the following site features are beneficial:

Size. Adequate space to construct and implement new equipment alongside the existing operating coal plant is advantageous.

Flat terrain. Primarily flat terrain enables minimal technical modification. Grading costs can be expected to be relatively low compared to overall capital costs for a gas/hydrogen-fired plant.

Local dust production. Coal operations are accompanied by substantial dust. In contrast, gas turbine operations are sensitive to dust in the air. Preferred sites are not proximate to agricultural or industrial uses that produce dust as part of normal operations.

Land requirements vary according to the scale of the plant and the type of technology selected—gas turbines or combined-cycle equipment. A large power block calls for approximately 10 acres (0.04 km^2) of land; taking into account land needed for laydown and construction parking, an area of roughly 40 acres (0.16 km^2) is desirable. Gaining access to significant land area enables facility construction with less disruption to ongoing coal generation and may provide opportunities for future expansion.

A 2013 National Renewable Energy Laboratory and EPRI study estimated total land available at U.S. pulverized coal plants, including adjacent land within a 2-mile (3-km) radius. The potential land area ranges from about 400 acres (1.62 km^2) to nearly 7000 acres (28.3 km^2), with an average of about 3900 acres (15.8 km^2) [26]. This provides a large area for installation of new generation equipment. Given these metrics, even a substantial natural gas/hydrogen-fueled plant requires only a fraction of a typical coal plant's available land.

Closed CCR Management Units

Power block equipment for a gas/hydrogen-fired plant requires a deep foundation or bedrock construction, which is not suitable for construction on coal combustion residual (CCR) landfills. The landfill may be useable for construction parking and light laydown. However, certain types of construction and maintenance vehicles are restricted on landfills due to weight.

To the extent that such ancillary uses are sited on CCR landfill, the design of those areas during installation needs to be compatible with the landfill cap to ensure the cap's integrity with minimal cap disturbance. Vehicle restrictions on landfills may also affect operation and maintenance (O&M) practices.

Structures and Equipment

Overview

According to a 2020 study conducted in Poland, reusing physical plant infrastructure such as auxiliary buildings, electrical equipment, turbogenerators, cooling water systems, cooling towers, and pumphouses, could allow a utility to continue use of up to 40% of its initial investment [27]. Reuse potential varies significantly depending on the type of repowering.

Structures

Reusing existing structures can speed construction, decrease costs, and reduce environmental impacts. Depending on the plant size and location, a mix of permanent on-site and remote staff support O&M. Plant operators, site technicians, and other maintenance staff could likely continue to use one or more existing administrative buildings and/or trailers. Plant staff can also use communications systems, such as phone and internet access. Warehouses or other buildings on coal-fired power plant sites could be used to store plant spare parts and other replacement components and materials, house maintenance vehicles, and store tools. Reutilizing these spaces with new functions avoids the cost of demolition and the need to build new buildings. Existing fences can continue to deter trespassing, vandalism, and unwelcome wildlife.

If the existing generator building is to be demolished, preserving some building functions may not be possible, as structures housing administration, communications, and other functions are often attached to the main generator building. In that event, buildings associated with other equipment at the coal plant may prove useful, such as those built to serve retrofit flue gas desulfurization (FGD) or SCR installations.

Structures built to handle water intake and discharges to the river, lake, or ocean used as water supply may be useful. These structures are built into the water and so can provide significant benefits, compared with the cost of building new structures and obtaining U.S. Army Corps of Engineers permits and U.S. EPA Clean Water Act (CWA) 401 and 404 permits.

Equipment

Reuse of existing equipment, including turbomachinery, for a combined-cycle installation may be possible when repowering a decommissioned coal plant. If reuse of the existing steam turbine-generator, boiler, condenser, and cooling water source is possible, one study estimates that capital cost savings could be substantial, potentially as much as $200–400/kW [28]. This study is now somewhat dated, given improvements in gas turbine technology and new plant efficiencies. Because existing coal-fired boilers are older and do not match well with modern combined-cycle steam requirements, existing steam generation equipment is probably not reusable.

Turbine-generator reuse has been done. For example, Cooperative Energy's Morrow station in Mississippi is repowering with a reused turbine-generator, which is expected to begin service in 2023 [29]. Turbine-generator reuse is uncommon for the following reasons:

- Most steam turbines at existing coal plants are older equipment and also have not been as well maintained, due to planned retirements.
- Most modern coal plants have large supercritical steam turbines, and these do not fit well into combined-cycle plants.
- Coal plant steam turbine cycles are more complex, with feedwater heating, and would require modifications.

Other plant equipment may be more readily adapted to the new use. If the coal plant uses once-through cooling, water intakes may be reusable, although likely to be oversized for a combined-cycle repowering. New intake screens and supply pumps are likely to be needed, and may be essential if the existing plant uses cooling towers. Depending on their condition and the combined-cycle system's design steam requirements, the existing water treatment systems for the boiler may have reuse potential. In addition—depending on their condition—service water, fire water, and demineralized water tanks may be reused. If the plant has cooling towers, the towers and their water treatment systems may be reused, if they are in good condition.

A new natural gas/hydrogen-fired generation system at a coal-fired facility could reuse existing site substations for grid interconnection. The new gas turbine or combined-cycle plant may have multiple generators, which need to be properly matched to existing transmission interconnection facilities. Depending on the scale of the new plant, the size and configuration of the substation may require modifications. Incoming power flows needed for startup can be anticipated to be in the range of 2–10 MW, which are lower than that for a coal plant, and auxiliary power requirements are about 1.5–3% of rated power. Consideration may be given to potential future power needs, such as carbon capture (for gas-fired operation) and on-site hydrogen production (for hydrogen co-firing).

If any substation modifications are needed, the design engineer needs to conduct the following civil/structural substation-related analyses and calculations:

- Land survey and site grading analysis
- Geotechnical investigation and foundation calculations
- Structural steel calculations
- Bus bar physical separation calculations
- Miscellaneous (e.g., substation design calculations)

If a digital control system (DCS) is planned for the new gas turbine or combined-cycle facility, this most likely requires new equipment, as the existing coal plant's DCS is probably not adaptable to the new facility.

Water Availability

Coal-fired power plants consume significant amounts of water, so they incorporate substantial process and cooling water equipment. They usually store water on-site or have ready access to water, in addition to off-flow facilities such as water retention ponds.

Although most repowering projects can be expected to have access to water, arid conditions constrain water supply in the western United States and increasingly in other areas. In these cases, grey water, air-cooled condensers, or hybrid cooling systems may be employed. Air-cooled condensers may also be appropriate in areas where salt water corrosion from cooling water evaporation and drift may be an issue.

Relative to coal plants, combined-cycle plants have lower process water intensity. In a combined-cycle plant, 60–70% of the electricity output originates from the gas turbine portion of the plant. Because the steam cycle portion of a combined-cycle plant is only about 30–40% the size of the steam cycle for a similar-scale coal plant, the boiler water treatment requirement is less. In addition, many operating coal plants have wet FGD systems (not needed for gas/hydrogen plants), which are water intensive.

Similarly, cooling water requirements are lower for combined-cycle plants than for coal plants. As for process water, because the steam cycle is a smaller proportion of the total power production, the condenser cooling water requirement is about 30–40% less for a combined-cycle system than for coal. The original coal plant may have either once-through cooling or a closed-loop cooling system with cooling towers for heat removal. Under the U.S. EPA Clean Water Act, Rule 316A, new plants are required to use cooling towers. Because cooling towers use evaporative cooling, they consume more water than once-through cooling, in which the water is returned to the source. However, when combined with the relatively high process water needs of coal plants, total consumption for a combined-cycle plant is usually lower. In light of this, existing permits for water intake could be leveraged to provide that supply.

Water treatment at a combined-cycle plant can be expected to be similar, in general, to that of the original coal plant. Incoming water may require primary treatment such as filtration and clarification. Process water for the boiler may need purification treatment, such as reverse osmosis or demineralization, and cooling tower blowdown water may require dechlorination. Wastewater may require some chemical treatment.

Permits and Contracts

A major benefit of siting a new natural gas/hydrogen-fired generation facility at a coal-fired power plant is the possibility of renewing or modifying existing permits, rather than applying for new permits. This can potentially eliminate some lengthy permitting processes, or reduce the time required for re-approval. Larger facilities that already have a land use permit, certificate of occupancy, and buffer property offer siting advantages that can allow a new natural gas/hydrogen-fueled plant to be constructed and commissioned relatively quickly. Key factors observed during a recent EPRI examination of environmental permitting for battery storage may be applicable [30]:

- Certain projects built alongside existing infrastructure, such as power plants and substations, usually do not need to complete a full Environmental Impact Statement.
- Similarly, land-disruption permitting under federal air and water quality regulations may not apply to new components installed at existing facilities.

Codes, standards, and permitting requirements are evolving rapidly. Construction and operation permits depend on national, state, and local requirements, and codes and standards vary by site, host, owner, utility, and contract. There may be permit requirements for associated equipment (e.g., if a small generator is included in the design for short-term backup power). Other general types of applicable permits that may already exist at a coal-fired power plant include:

- Transportation infrastructure and utility connection permits
- Environmental permits, including noise
- Daily water withdrawal and discharge allowance permits

In sum, a variety of permits may be required for repowering to a natural gas/hydrogen-fired generation plant, though some exemptions may be available and some permits may carry over from the existing plant. Plant owner/operators need to perform due diligence to identify and comply with applicable permitting requirements.

Permit categories for a gas turbine or combined cycle plant may also include:

- Stakeholder and community approval
- Land use approval (use permit)
- Temporary use permit
- Stormwater and groundwater discharge permits for construction and industrial activities
- Notice of construction or alteration
- Endangered species review
- National Environmental Policy Act (NEPA) review
- National Pollutant Discharge Elimination System (NPDES) permit
- Water appropriation
- Easement, lease, or right-of-way
- Siting permit, including visual impact of tall and/or large structures
- Construction of plant or transmission lines
- Fire protection system approval
- Worker safety protection system approval
- New source review construction permit
- Air emissions
- Hazardous waste
- Water quality
- Access or driveway permit (construction entrance)
- Crossing permit (transmission)
- Oversize loads permit
- Archeological and historical
- Building permits
- Certificate of occupancy
- Potable water extension/connection
- Pretreatment permit/sewer connection
- Potable well permit

In the event any components of the new installation, including parking areas and other supporting elements, are sited on a capped landfill, additional factors may influence permitting requirements, including:

- Piling/ballasting compatible with site requirements
- Geotechnical considerations
- Water management (stormwater control, treatment)
- Potential soil and groundwater contamination
- Cap (impact)
- Soil penetrations
- Vegetation height and root depth
- Erosion control
- Mowing requirements
- Site maintenance activities

In addition, off-taker agreements may need to be updated or renewed. If there is an existing contract for the electricity generated by the coal-fired facility, the coal plant retirement schedule may already have addressed the issue. Overall, the utility needs to perform due diligence to ensure ongoing concurrence with the modified plant operation.

Conclusion

This paper covers natural gas/hydrogen-fired generation in EPRI's white paper series on considerations when repowering a coal plant planned for decommissioning. While repowering for natural gas/hydrogen-fired generation may be complex and require careful planning, it presents significant opportunities to leverage existing site infrastructure, equipment, permits, and other attributes. It also provides a means to reduce environmental impacts and improve community perceptions, while supporting the transition to clean energy.

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