WHITE PAPER

Evaluating Firm Fuel Options to Weather Challenging Conditions

By Mike Borgstadt

Power disruptions in Texas due to an extreme winter storm exposed the urgency of preparing generation facilities to operate on firm backup fuels when necessary. Operators have several options to consider as they explore the feasibility of inclusion in new facilities or updating existing plants

The electric industry has faced several challenges over the years. Over the past decade, the United States has been transitioning electric generation from a predominantly coal-fired fleet to a natural gas-fired and renewable portfolio. As illustrated in Figure 1, the U.S. is relying more heavily on gas-fired and renewable resources than ever. And the trend is expected to continue. This is certainly the case in the wind-rich areas of Texas and the Midwest, specifically the Southwest Power Pool (SPP).

As more coal-fired plants are retired, it's important to remember the advantages these facilities have enjoyed for providing reliable electricity: 1) a fuel source that had few competing uses and 2) a long-term, economical storage method for fuel. With the electric power industry now more reliant on natural gas, competing with all the other areas of the economy demanding natural gas, such as residential and commercial heating and industrial use, the demand for natural gas is at an all-time high. The power generation portfolio is becoming much more based on intermittent renewables and/or natural gas-fired resources that depend on just-in-time fuel deliveries. For the vast majority of the time, the natural gas production and delivery system can meet the needs of customers.

However, Winter Storm Uri in mid-February 2021 exposed the vulnerability of the electric system. The electric industry experienced a devastating event that will likely lead to industry changes. The demand and supply for natural gas was severely out of balance. This was caused when the Midwest and Texas experienced record-breaking cold weather that lasted for several days. The demand for electric generation soared — as did the demand for natural gas, for both power generation and heating.

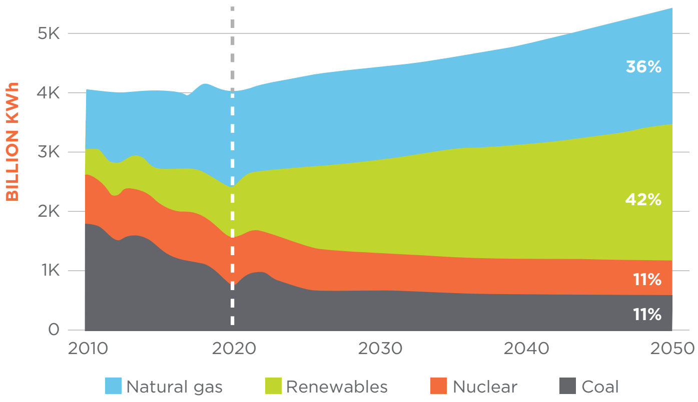

Figure 1:* *Historical and projected electricity generation. Source: U.S. Energy Information Administration, Annual Energy Outlook 2021 (AEO2021).

However, the system was not prepared to respond to such high demands in such extreme cold temperatures. Because of Texas' typically warmer climate, much of the natural gas production and delivery system wasn't designed for extreme cold weather operation. Therefore, demand not only was extremely high but supply and delivery were further squeezed. This led to a catastrophic event across Texas and SPP areas of the Great Plains with curtailment of electricity to many customers. At best, power generators received natural gas priced at 8 to 10 times normal pricing. At worst, natural gas was curtailed to many generators, which were unable to produce electricity when their customers needed it most. The result: prolonged rolling brownouts.

We've Been Here Before

Unfortunately, this scenario is not unprecedented in the U.S. Not all that long ago, in March 2014, the central Midwest (areas in the Midwest ISO and PJM Interconnection territories) experienced extreme cold weather as well. The system was stressed. Luckily there was sufficient thermal generation with firm fuel supplies — both coal-fired and oil-fired resources — that could be ramped up and supply electricity to meet the customers' needs. Through that process, PJM learned the value of firm fuel supplies and implemented market rules to incentivize firm capacity that would be available to meet high demand during cold weather events. PJM recognized that firm fuel and capacity would be required to make the transition from a coal-fired generating fleet to a more renewable and natural gas-fired portfolio, especially during winter months when there are competing uses further driving demand for natural gas.

In the aftermath of Winter Storm Uri, market rules seem likely to change in ERCOT, SPP, and other independent system operators and regional transmission organizations to support more firm fuel resources.

Firm Contracts Don't Mean Firm Fuel

Winter Storm Uri illustrated the difference between firm contracts and firm fuel. Many power generators have entered natural gas supply and delivery contracts for firm fuel. To reduce costs, many of these firm contracts are for a portion of the total output of the plant. But because the system isn't designed to operate in extreme cold weather, many producers and suppliers couldn't physically supply the gas. So firm fuel contracts don't guarantee fuel is going to show up at a plant in the most extreme cases. During "typical" high-demand scenarios, firm contacts prevent curtailment as others might be interrupted. But when the system cannot physically produce and deliver sufficient gas, regardless of contractual obligations, no plant is immune to a shortage of gas supply.

When Can Firm Be Firm

The market rules will evolve, requiring more firm capacity. Hydrogen is being billed as a fuel of the future. However, widespread use of hydrogen as an alternative fuel, let alone a primary fuel, does not appear feasible today for a variety of reasons. Energy storage could be an answer, but it would require multiday capacity without charging, an ability whose feasibility remains elusive. That leaves power generators with few options when it comes to providing firm capacity backed up with truly firm, on-site fuel that can span the duration needed for events like Winter Storm Uri. These options consist of fuel oil, liquefied natural gas (LNG) and propane. These options can look very different for an existing plant versus a new plant opportunity, as well as depending on the technologies installed.

For the purposes of this discussion, we're looking at firming simple-cycle, peaking resources consisting of either combustion turbines or reciprocating engines for 96 hours of operation.

Installing backup fuel options comes at a price. Converting an existing natural gas-fired unit to add fuel oil operation capability may be a non-starter. The economic benefit may be too small to overcome the cost of retrofitting the existing engines/combustion turbine, installing all the balance of plant equipment for fuel oil piping, and fuel delivery, unloading and storage equipment. However, when designing a new plant, fuel oil backup can be an excellent opportunity to provide reliable, on-site fuel. Whether existing or new, on-site storage of either LNG or propane may also provide excellent opportunities for firm fuel. All three of these options have benefits and trade-offs.

Backup Fuel Options For Combustion Turbines

There are many configurations of simple-cycle combustion turbines. For this example, we assumed two technologies: a 50-megawatt (MW) aeroderivative unit and a 200-MW frame unit.

Fuel Oil

Fuel oil is a proven backup for combustion turbine technologies, whether being used with frame or aeroderivative units. When operating on fuel oil, the turbines will require increased water consumption to maintain compliance with nitrogen oxide (NOx) emission limits. New power plants designed for fuel oil have combustion turbine specifications and equipment to operate as a dual-fuel unit, along with the ancillary piping, equipment and tanks.

Converting existing natural gas-fired units to dual-fuel capability presents increased challenges. Many of the plant components will need to be retrofitted or replaced, specifically the combustion turbine combustors.

Generally, the additional cost associated with a new unit having dual-fuel capability is approximately $70 to $90/kW. For an existing unit to be retrofitted, costs are approximately 25% greater. Additionally, existing units may not have as much water supply as would be required to operate using fuel oil.

Fuel oil is also typically more costly than natural gas, and it tracks closely with the price of crude oil. Historically it has been between $10 to $15 per million British thermal units (MMBtu). (Compare to pipeline natural gas, which hovers around $3/MMBtu during normal conditions.)

Propane

Propane has historically been evaluated as an opportunity fuel for use in combustion turbines. There's no consistency among the combustion turbine original equipment manufacturers (OEMs) on their ability to fire utilizing 100% propane fuel, let alone any operating experience. For the OEMs that may have the ability, specialized combustors are required, along with steam injection. Furthermore, if the unit is equipped to operate using propane, steam injection is required for either natural gas operation or propane operation. With this unproven fuel and steam injection requirement, utilizing propane as a firm backup fuel for simple-cycle combustion turbines currently does not appear feasible.

LNG

LNG provides an opportunity for on-site storage for both existing and new combustion turbines. The installation of a liquefaction plant on-site is cost-prohibitive (costing from $50 million to $100 million). However, installing a fuel unloading system for truck deliveries, storage tanks and vaporizer on-site is a potential option. The combination of these options would be approximately $15 million to $35 million for 50-MW and 200-MW combustion turbine units, respectively. However, LNG liquefaction facilities are quite region-specific, so depending on the location, long-haul truck deliveries may be required. Pipeline natural gas costs approximately $3/MMBtu. However, the cost adders associated with liquefaction, delivery and logistics will add approximately $7/MMBtu (including losses), bringing the total delivered cost of LNG to the plant to approximately $10/MMBtu.

Additionally, LNG experiences a boil-off: A percentage of the LNG is boiled off as gas. This gas can either be released to atmosphere, flared off or (if available) placed into a low-pressure natural gas system on-site. The boil-off equates to approximately 0.1% per day. Therefore, when storing fuel over the course of a year, the overall system would be expected to lose approximately one-third of its stored fuel. These losses could be pared by only storing fuel over the winter months.

Backup Fuel Options For Reciprocating Engines

For this example, we assumed 50-MW and 200-MW reciprocating engine plants were considering on-site fuel storage.

Fuel Oil

Fuel oil is a proven backup for reciprocating engine technologies. Since most reciprocating engine units already have selective catalytic reduction (SCR), NOx emissions are a relatively low concern, whether firing natural gas or fuel oil. New power plants designed for fuel oil have specific combustion specifications and equipment to operate as a dual-fuel unit, along with the ancillary piping, equipment and tanks. Furthermore, dual-fuel reciprocating engines require fuel oil — a 1% pilot fuel oil usage — even when operating on natural gas.

Converting existing natural gas-fired reciprocating engines to dual-fuel capability presents increased challenges, as many of the plant components will need to be retrofitted or replaced, specifically the engines themselves.

Generally, the additional costs associated for a new unit to attain dual-fuel capability is approximately $100 to $120/kW. For an existing unit to be retrofitted, costs are approximately 25% greater.

Propane

The use of propane in a reciprocating engine is feasible with the typical natural gas-fired equipment package. For propane operation, requirements would include truck loading, piping and storage. Unlike LNG, propane is widely utilized within rural residential heating applications, with an already established, widespread distribution system. This may provide a more streamlined delivery opportunity than LNG.

However, operating on propane does come with a performance hit. When utilizing propane, the engine takes a 25% derate (i.e., the plant is only capable of reaching 75% of full-load output on propane). At first glance, this appears to be a fatal flaw. When considering this as insurance against extreme conditions, however, any output is better than no output. Furthermore, many existing units operated at part load anyway during Winter Storm Uri to conserve fuel oil inventories due to lack of delivery availability.

The additional costs for propane operation for 50-MW and 200-MW reciprocating engine plants would be approximately $3 million to $10 million, respectively.

Propane is an expensive fuel, historically costing from $15 to $20/MMBtu for commercial and industrial uses.

LNG

LNG operation at a reciprocating engine plant looks very similar to that at a combustion turbine. However, reciprocating engines operate at much lower gas pressures than combustion turbines, possibly reducing some capital costs associated with the equipment. The costs associated with LNG for reciprocating engines would be approximately equal to those of a comparably sized combustion turbine, with similar delivered LNG prices.

Backup Fuel Options Summary

To condense this information, Figures 2 and 3 provide a summary of the capital costs and fuel costs associated with the backup fuel options previously described.

Potential Benefits

Dual-fuel capability is not new for natural gas-fired power plants. Areas of the country where natural gas deliveries are constrained often experience high natural gas prices in the winter. Many power generators in those areas have installed dual-fuel capabilities dating back many years. What's new is the increased interest in its benefits, and perhaps specifically the system's need for it to incorporate more renewable resources and maintain reliable generation and delivery of electricity to customers in the most extreme conditions.

PLANT TECHNOLOGY

	FRAME COMBUSTION TURBINE	AERODERIVATIVE COMBUSTION TURBINE	RECIPROCATING ENGINES (50 MW)	RECIPROCATING ENGINES (200 MW)
OUTPUT (MW)	200	50	50	200
DAYS OF STORAGE	4	4	4	4
CAPITAL COST ($M)				
LNG	35	16	16	34
Fuel oil	14	5	6	20
Propane	-	-	3	10

Figure 2: Summary of capital costs for dual-fuel operation.

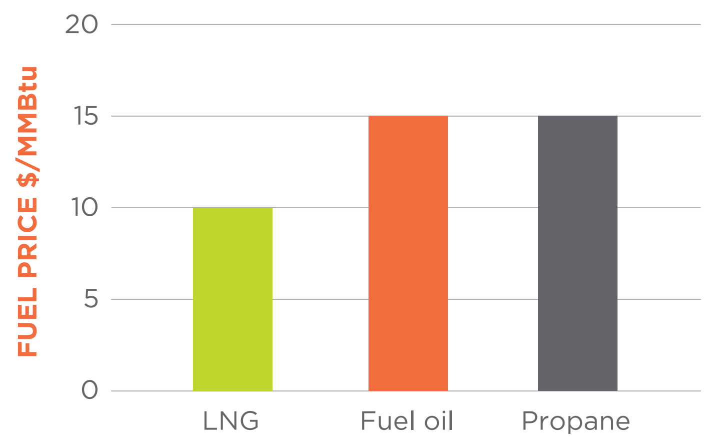

Figure 3: Summary of delivered price of backup fuels.

Market rules could change in Texas, MISO and SPP, requiring a certain percentage of those areas to have firm capacity resources, with a market mechanism for compensation. However, based on the current rules, the only compensation factor is through wholesale energy sales, particularly during periods of extremely high market prices.

In the wake of Winter Storm Uri, the price of power skyrocketed in both ERCOT and SPP. ERCOT hit $9,000/MWh for nearly four days straight. In that time, a 50-MW power plant operating 24 hours a day would have racked up over $40 million in energy revenue. Many utilities filed for bankruptcy protection, as they'll not be able to pay their bills. Obviously this will impact the payments to those power generators. But in theory, that one event would have more than paid for the investment into dual-fuel operation.

Rather than look at ERCOT, which has financial impacts to sort out, let's look at SPP, which appears to have financially weathered Winter Storm Uri a bit better. Figure 4 illustrates the Day-Ahead wholesale energy market price for the North Hub in SPP for the week of Feb. 14-20, 2021. As presented in the figure, SPP's energy prices skyrocketed that week and hovered between $1,500 and $4,000/MWh for approximately four days.

What economic benefit would a power plant have experienced for those four days? Utilizing these market prices and the backup fuel costs (assuming pipeline natural gas was either more costly or unavailable), we evaluated the financial impacts to determine the gross margins that the plant would have realized. Then we can compare those gross margins to the overall capital costs required for dual-fuel capability. (Note: We have excluded nonfuel O&M costs, as those would be incurred in any situation.)

Figure 5 presents the net margin for each technology for the three backup fuels we evaluated. The net margin was calculated by determining the gross margin less the capital costs. The gross margin was equal to the energy revenue less fuel costs incurred over the four-day event. As presented in the table, only the two 50-MW options operating with LNG would not have overcome the entire dual-fuel capital costs over the four days. That's right: This one event would have paid for all of the capital costs of the dual-fuel operation.

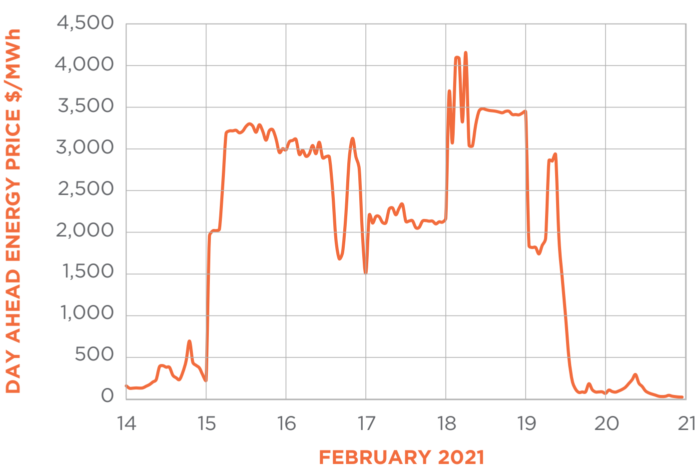

***Figure 4:** SPP power prices the week of Feb. 14, 2021.*

PLANT TECHNOLOGY

	FRAME COMBUSTION TURBINE	AERODERIVATIVE COMBUSTION TURBINE	RECIPROCATING ENGINES (50 MW)	RECIPROCATING ENGINES (200 MW)
OUTPUT (MW)	200	50	50	200
DAYS OF STORAGE	4	4	4	4
NET MARGIN ($M)				
LNG operation	17	(-3)	(-3)	18
Fuel oil	34	8	7	31
Propane	-	-	6	28

***Figure 5:** Summary of net margin (gross profits less capital costs for dual-fuel operation).*

Where Do We Go From Here?

Based on this quick evaluation, it is clear that this "once-in-a-lifetime" event — in reality, similar situations have occurred within the past decade — would have more than recovered the capital cost associated with dual-fuel backup. Of course, there are advantages and disadvantages to each of these alternatives. But clearly over the life of a plant, the cost of dual-fuel operation to guard against extreme weather is balanced by providing both reliability to the system and a potentially financially rewarding opportunity. For new plants, there's a clean slate to evaluate the options. For existing plants, the options may be a little narrower depending on the site, but nevertheless may warrant consideration.

There's no doubt the industry and markets will respond with firm capacity requirements in the wake of the catastrophic storm, fueled by a polar vortex, that unfortunately resulted in loss of life. The industry will adapt. And there appear to be several viable options to provide firm fuel supply for generators to provide a robust energy source for the grid.

About 1898 & Co.

1898 CO. PART OF BURNS & McDONNELL

1898 & Co. is a business, technology and cybersecurity consulting firm serving the industries that keep our world in motion. As part of Burns & McDonnell, our consultants leverage global experience in critical infrastructure assets to innovate practical solutions grounded in your operational realities. For more information, visit **1898andCo.com**.

835445-0224