WHITE PAPER

Plotting the Optimal Approach for LNG Storage Selection

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The abundance of natural gas is creating opportunity to use liquefied natural gas (LNG) for peak shaving and to improve reliability. Evaluating plot space, siting options, and cost and schedule against project goals can help identify the right LNG storage container solution.

According to the Energy Information Administration (EIA), the U.S. is leveraging its more than 170 liquefied natural gas (LNG) facilities and is now the largest exporter of LNG in the world. While LNG production and exports are rising, the abundance of natural gas production is also creating opportunities for utilities and independent power producers (IPPs).

Facilities to store and use LNG on a local level are opening up ways for utilities and producers to better manage energy supply and peak shaving. While they are a potentially cost-effective approach to energy management, small-scale LNG projects deliver optimal results when operators carefully evaluate operating need against available real estate and storage requirements.

The Road to LNG

The natural gas shortage of the 1970s started the trend in the U.S. to use LNG as a supplement to manage energy supply. This trend led to many plants and facilities being built that would allow utilities and transmission pipelines direct access to natural gas to handle shortages.

Over the following decades, however, the original LNG peak shaving facilities were affected by both market changes and operations and maintenance cost-cutting that resulted in many assets' now-derelict condition.

Although domestic natural gas is now abundant and viewed as a more environmentally friendly fuel source, today's utilities and IPPs are faced with other challenges in how to reliably produce and deliver electricity to consumers:

- Change in the energy mix from coal to gas and renewables.
- High and seasonal demand for electricity generation.
- Pipeline delivery capacity constraints.
- Pipeline project permitting challenges.
- Weather-related events and impacts.

This new operating environment is motivating operators to actively evaluate how to use aging assets or construct new facilities that will tap into the power of LNG for effective energy management.

LNG Project Considerations

Composed almost entirely of methane, natural gas is a cleaner fossil fuel and simple hydrocarbon compound. When condensing to a liquid, natural gas is cooled to -260° F (-162° C) to form LNG, which is colorless, odorless and nontoxic. The process of cooling reduces the volume of LNG gas by a factor of more than 600, making it convenient and stable to store.

Whether upgrading an existing facility or exploring building on a new site, each project faces unique requirements and challenges. To develop a viable on-site LNG storage facility requires critical upfront evaluation of several factors to determine the right storage strategy:

- Analyze possible sites and soil conditions.
- Decide the LNG volume required.
- Determine thermal exclusion zone and boil-off gas strategy.
- Evaluate space, land and real estate requirements.
- Understand site access and maintenance considerations.
- Undertake vapor dispersion and containment analysis.

Determining project requirements and site development options at the outset helps guide decision-making to identify the preferred storage tank solution.

Powering LNG project success

While storage options play an important role on the path to LNG facility project execution, there are many other considerations and decisions that factor into project success:

- Community and stakeholder relations
- Environmental issues
- Facility design and permitting
- Land use and siting
- Natural gas quality
- Nitrogen supply
- Real estate acquisition
- Security and safety
- Site access

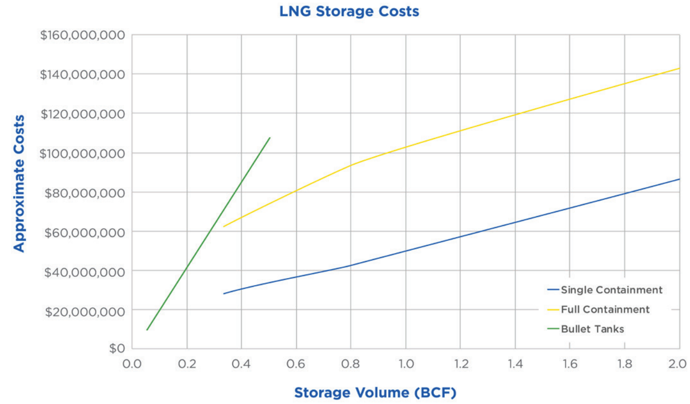

***Figure 1:** LNG storage costs for single containment, full containment and bullet tanks.*

Storage Tank Options

LNG storage tanks are specialized containers that come in a range of options, each with its advantages and challenges.

Flat Bottom Tanks

Flat bottom tanks are atmospheric tanks that are installed aboveground and offer maximum safety for site areas. The selection of a flat bottom tank option typically depends on the amount of real estate available for tank placement. Flat bottom tanks come in three types:

Full Containment Tank

Designed as a double tank, a full containment tank holds LNG at atmospheric pressure and is constructed so that both its inner and outer tanks can, independently, hold the LNG in the case of a breach. The inner tank of a full containment vessel will enclose the LNG under normal operating conditions. The outer tank is capable of containing the LNG and any venting of vapor in case of leakage.

Although it's the most expensive of the LNG storage tank options, a full containment tank requires the smallest thermal exclusion zone (the area surrounding a facility that might be impacted by radiant heat flux from a fire or vapor dispersion from a release of LNG) and, thus, requires the least real estate for installation. Full containment tanks are custom-designed and field-erected, requiring three years to build and prepare for use.

Single Containment Tank

Comprising an inner tank and outer container, a single containment tank holds LNG at atmospheric pressure and is designed to meet the low-temperature requirements for LNG storage. The outer tank retains and protects the inner tank insulation but is not designed to contain LNG in the event of leakage. This container type must have impoundment to contain any potential spill and requires a larger plot space compared to full containment.

Single containment tanks are field-erected and tend to be less expensive (Figure 1). They can take more than two years to construct ready for use. Approximate costs for the various LNG storage options shown below are for the storage system only and do not include secondary containment, pumps or any other supporting equipment.

Double Containment Tank

A double containment tank is similar in design to a single containment tank but is built inside a secondary LNG containment vessel. The secondary container is made of concrete and will contain breeched LNG liquid but will not control vapor release. The space between the primary and secondary containers must not be more than 20 feet, according to regulations.

The construction timeline for double containment tanks is similar to that for full containment tanks.

Bullet Tanks

By evenly distributing the content and, therefore, the stress load on the tank, a bullet tank creates an inherently strong structure to store LNG. Primarily used to store smaller volumes, a bullet tank offers pressurized LNG containment. It has a cryogenic steel inner shell surrounded by a steel outer shell. Bullet tanks come in predetermined sizes and are not customizable; they are delivered prebuilt and ready for installation.

Bullet tanks are suitable for a turnkey solution that is installed in a shorter amount of time. However, storage designs must include protection and containment measures, such as secondary impoundment and detailed dispersion analysis, for the full loss of LNG in the event of a spill.

Floating Storage

For utilities and IPPs with access to water, floating storage units for LNG are an option. As part of a strategy to achieve peak shaving, floating LNG facilities use a special tanker that is anchored offshore and typically feeds natural gas to shore via an underwater pipeline. The LNG storage is often detained inside the hull as an atmospheric tank option or in pontoons that can hold pressurized bullet tanks.

The specially designed tankers cost less to build than an onshore LNG regasification plant, but they have higher operating costs. They are also limited in the volume of LNG storage. This option, however, offers flexibility and may fit an IPP's business model by being able to move and serve different geographic areas along the coast as needed.

Storage Tank Evaluation Factors

Determining the right LNG storage solution is heavily influenced by available plot space, siting options, cost and schedule. Evaluating these criteria, along with container options, helps determine potential storage selections and limitations.

Plot Space

In determining the overall LNG facility layout, consideration should be given to the different tank types to establish the amount of real estate required for installation and operation.

With its outer concrete tank protection, a full containment tank needs less plot area than other options (Figure 2). Single containment tanks and bullet tanks require land for the outer dike or chosen secondary impoundment to contain LNG content if necessary. Likewise, single containment and bullet tanks will require an increase in the length of LNG piping to and from the container.

Siting

LNG plant siting requirements, which are intended to protect the safety of plant personnel and the surrounding public, are defined in the Pipeline and Hazardous Materials Safety Administration (PHMSA) Title 49 CFR Part 193 and the National Fire Protection Association (NFPA) Code 59A.

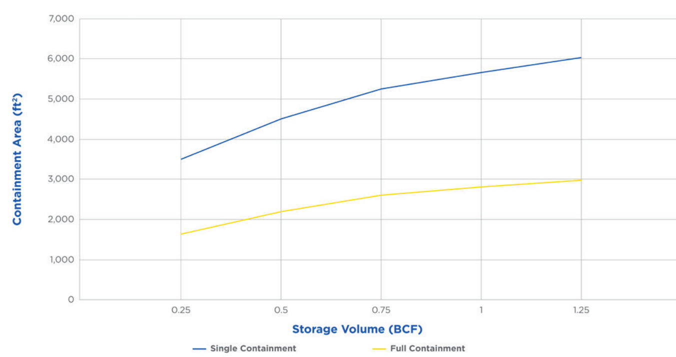

***Figure 2:** Full containment area volume needed.*

Analyzing hazards and minimizing the potential for LNG discharge, siting evaluation also must include thermal radiation levels and flammable vapor gas dispersion. This analysis helps to determine the needed exclusion zones for locating an LNG facility.

In addition to national and federal requirements, state, local and regional codes also must be evaluated. Calculations for radiation and vapor dispersion will default to the larger exclusion zone requirement and any other conservative siting approaches the project has adopted.

Single containment and bullet tanks will require a significantly larger site than a full containment tank would. The estimated acreage calculated to meet regulations will help determine the optimal LNG storage option.

Cost and Schedule

Once LNG storage options are narrowed down, cost and schedule estimates should be obtained and examined. Costs should include the tank, foundation, construction, hydrotesting, nitrogen purge and any required boundary or berm construction.

Estimating costs for engineering and construction of the facility and tanks can be calculated using the preliminary cost and schedule from tank suppliers. Full containment tanks will need the longest lead time while single containment tanks less time; bullet tanks are typically available the fastest.

Operators also must consider the range of LNG facility regulations and permitting requirements, which can affect the schedule significantly. Factoring in inspections and site permitting, along with storage tank lead times, helps avoid schedule surprises and budget impacts.

Conclusion

In this era of natural gas availability and low cost, the production and storage of LNG offers great potential for utilities and IPPs to manage electricity demand challenges. Likewise, LNG provides producers with a more environmentally friendly energy alternative to coal that can complement intermittent renewable energy generation.

Determining the right LNG facility development strategy, whether upgrading existing assets or undertaking a greenfield project, depends heavily on choosing the right storage solution. With several storage tank options available, project success relies on defining operating requirements at the outset and starting early to evaluate the most appropriate and cost-effective LNG storage solution.

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