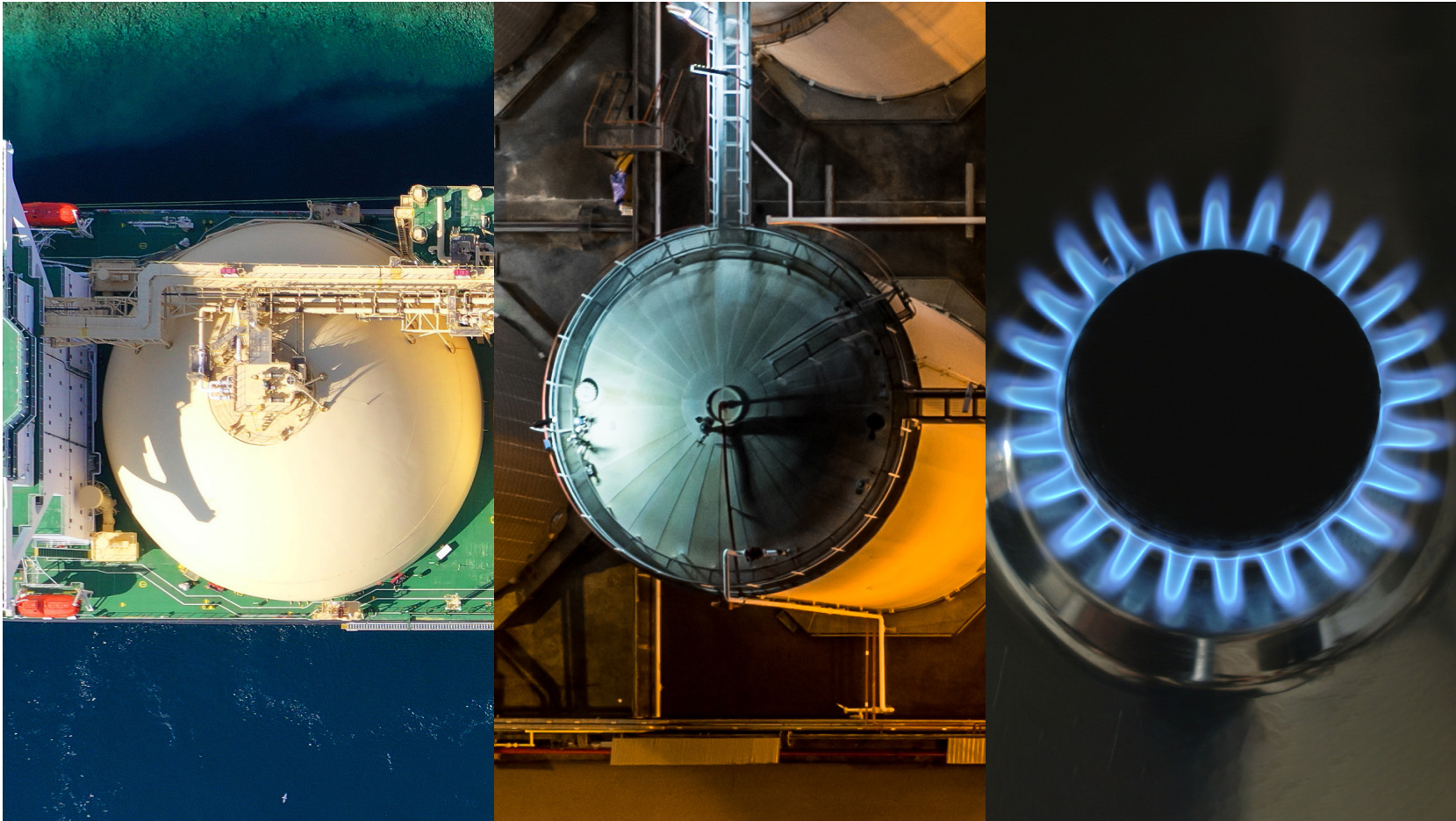




LNG: Fueling the Future

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As our clients navigate the transition from a carbon-based economy to an electron and molecule-based economy, finding the right energy mix for near-term needs and long-term change is essential. **Liquefied natural gas (LNG) plays a vital role** as the world strives to accelerate our journey toward a low carbon future.

Mario Azar
Chairman and CEO
Black & Veatch

The Future of LNG

Increased investment in renewables, nuclear, and other new energy solutions has created an extremely competitive landscape as the world moves toward zero emission and sustainable energy sources. However, during this period of transition, we still need to provide cost-effective energy sources. Liquefied Natural Gas (LNG) is leading the charge as the transition fuel for a low-carbon future and meeting increased demand for reliable, baseload fuels around the globe.

Natural gas in its liquid state (known as LNG) can be efficiently and economically shipped around the world. For decades, global LNG trade has moved natural gas from wellheads to the demand centers, through facilities that supercool the gas to very low temperature to convert it into a liquid that is then stored in cryogenic tanks. Specially designed carriers with insulated

tanks then ship it to destinations anywhere around the globe where the liquefaction process is reversed through vaporizing – called regasification – converting the LNG into usable natural gas.

Whether it's used for power generation, transportation, or industrial applications, LNG remains a cleaner-burning fossil fuel that: improves energy efficiency, reduces emissions, has a lower cost of carbon capture, and enables renewable energy integration. In this eBook we examine the role LNG will play in the future of the global energy landscape and the technology developments that enable it, and how it must scale beyond its current production capacity to meet incremental decarbonization goals in the near and long term.





LNG and the Global Energy Landscape

Geopolitics and LNG Markets

Geopolitical events impact the flow of energy around the globe. Periods of volatility, like we've seen in recent years, cause disruptions in the energy market and lead to volatile, reactive pricing. These periods of instability prompt the world to look for common threads to offset disruptions and diversify energy sources. As a globally traded commodity that is also a flexible and reliable source of energy, LNG is a stabilizing component of an evolving energy market that is prioritizing decarbonization.

As the world pursues net-zero and zero emission energy, it's important to balance this with the need to sustain the safety, security, and convenience that is the bedrock of our economies and communities. Countries with a single dependency on natural gas require alternative solutions for accessing available fuel to prevent interruptions in service to the homes and businesses that

rely on it. But how do you access natural gas from sources other than traditional pipeline transmission?

To offtake LNG in any capacity smart investment decisions must be made about the type of LNG infrastructure needed to support energy resilience. And these decisions must prioritize proven technologies that enhance the portability and mobility of natural gas.

Unlocking available gas supply is a key to economic independence

LNG provides an added layer of energy security to countries seeking diplomatic means to diversify their energy portfolio.

According to Kpler, The EU and the UK imported

121 Mt
(million tons) of LNG in 2022,

a nearly 60% increase compared to 2021 as Europe rushed to fill the supply gap left by reduced pipeline deliveries from Russia.***

***Source: <https://www.naturalgasintel.com/despite-spring-lull-competition-for-lng-could-heat-up-between-asia-europe-as-year-unfolds/>



Growing Demand for LNG in Asia Pacific

Much of the world's supply of natural gas is located far from the countries that need it most. This means transporting the gas from natural reserves to the end users' poses a significant logistical challenge that makes the fuel more susceptible to price volatility. With this understanding, three infrastructure options exist to effectively convey natural gas: point-to-point pipeline development, LNG infrastructure development, as well as the transfer of power through grid systems.

energy portfolio because of the inherent complexity that comes with modernizing backbone energy infrastructure such as: wind and solar project developments, large-scale nuclear, regional inter-country grid networks, and hydropower projects.

Learn how Asia is leveraging LNG and renewables in our **Decarbonization Pathways - Natural Gas: An Energy Transition Fuel for Asia Pacific eBook**.

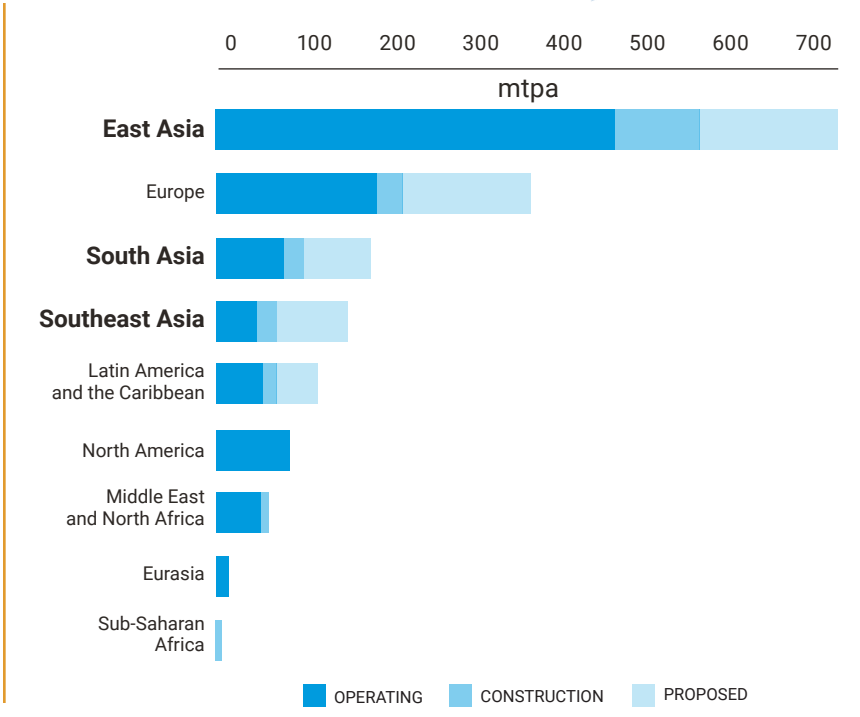
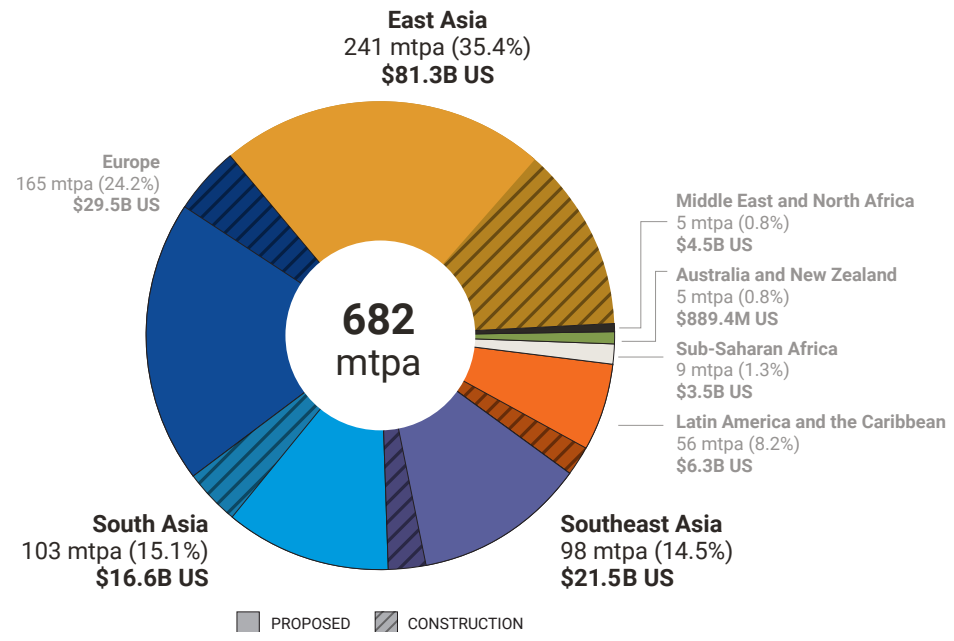


As Asia races to expand its variable renewable energy generation, more integration of generation, transmission, and distribution technologies will be required to balance electric grids, enhance energy security and reach decarbonization goals.

As populations grow, economies expand, living standards rise, and nations consider the effectiveness of natural gas as part of their energy transition plans, demand for LNG will not subside in Asia. According to Global Energy Monitor, Asia is home to 65% of the world's new LNG import terminals under development*. Japan and Korea have long relied on LNG while in more recent years Bangladesh, China, India, Indonesia, the Philippines, Thailand, and Vietnam have all become LNG importers. Asia needs large-scale power generation solutions that replace coal to keep pace with demand growth. This rising demand must be balanced with the region's decarbonization goals. So, building gas-fired power generation is a necessary component of the near-term

*Source: Global Energy Monitor – Asia LNG Update December 2022

LNG IMPORT CAPACITY BY DEVELOPMENT BY REGION*





Global Competition Between Energy Sources

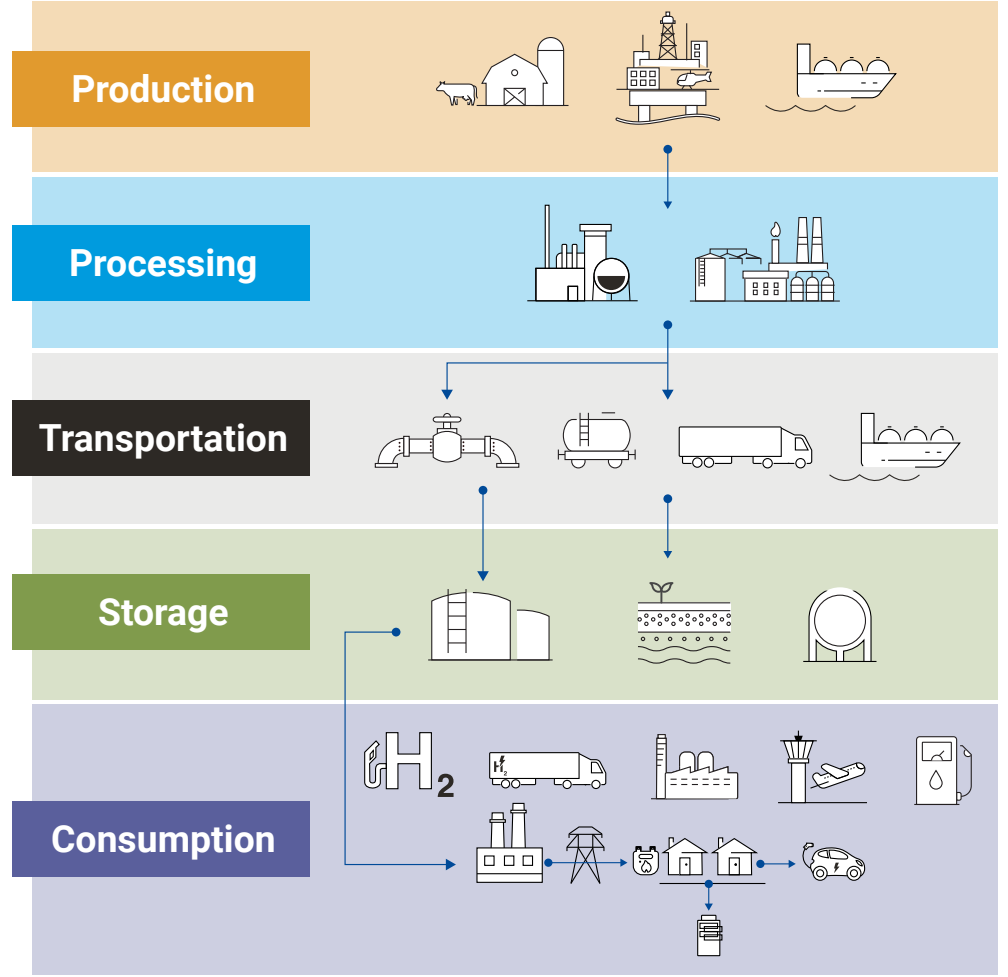
LNG is steadily propelling the world down the path towards replacing carbon-intensive energy sources with renewables and other low-carbon power generation technologies. The increasing demand for decarbonizing the world’s energy markets is being driven by the influence of environmental, social, and governance (ESG) policies that have proven to be beneficial to businesses and communities through decreased liability and increased profitability. More commonly referred to as “triple bottom line” benefits for people, the planet, and profits. Recently, governments in developed economies have taken a more active role in accelerating investment in the decarbonization of the energy sector by providing financial incentives and regulatory frameworks that encourage the deployment of low-carbon or no-carbon solutions. Whether it’s subsidies, emission reduction target setting, regulation, or research and development incentives, governments in the United States and across Europe are laying out strong incentive programs to steer investments toward these technologies. Investor preferences also play a role in determining where investment flows. Some investors prioritize low-carbon technologies that have the potential to generate high returns, while others may prioritize investments that align with ESG goals.

Black & Veatch brings a full view across every stage of the gas value chain.

Our consultants, engineers and EPC contractor teams work with financiers and developers from conception stage right through to operations and maintenance helping our clients move further, faster.

Overall, the need for LNG in the global energy portfolio is one aspect of a larger transition towards more sustainable and low-carbon energy systems. LNG will continue to play a role in the energy mix to provide reliable baseload service while other low or no-carbon power generation technologies continue to develop and become more competitive with improved economies of scale. However, companies that can utilize new and variable renewable energy sources paired with LNG will realize an even greater benefit as they meet the energy transition head-on to reap both environmental and economic benefits.

Gas Value Chain

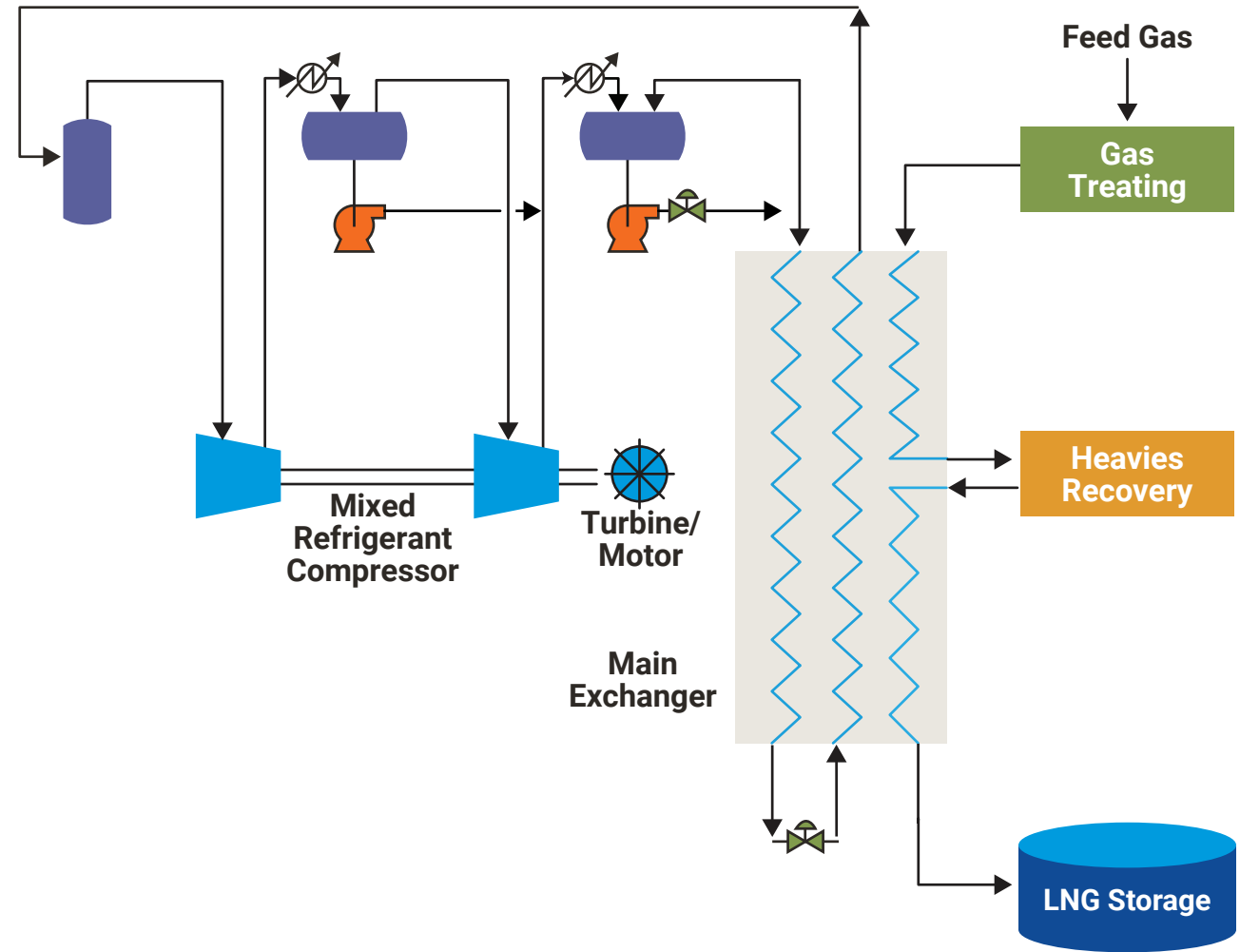




Evolving LNG Technology

Ensuring a secure, reliable supply of LNG depends on the processing technologies that are required to efficiently convert the gas to a liquid, then back to a gas for many of its uses. Among the available processing technologies PRICO®, a proven liquefaction technology offered by Black & Veatch, is ideal for producing LNG that can be used for peak shaving, medium and heavy-duty vehicles, industrial fueling, baseload power, and offshore applications. Its simplified operation and flexible configuration make it scalable for use in small, mid, and large-scale facilities, and enables innovative project solutions for offshore and nearshore LNG facilities. New approaches to technology and execution, like floating LNG and modularization, have already proven successful in bringing a competitive project to stranded gas in locations not conducive to a traditional large-scale facility. Meeting the rising demand for LNG around the world means developing more small and mid-scale LNG assets in regions where large-scale projects are not economically viable or technically feasible.

PRICO® LNG Technology



Applied across a broad range of plants

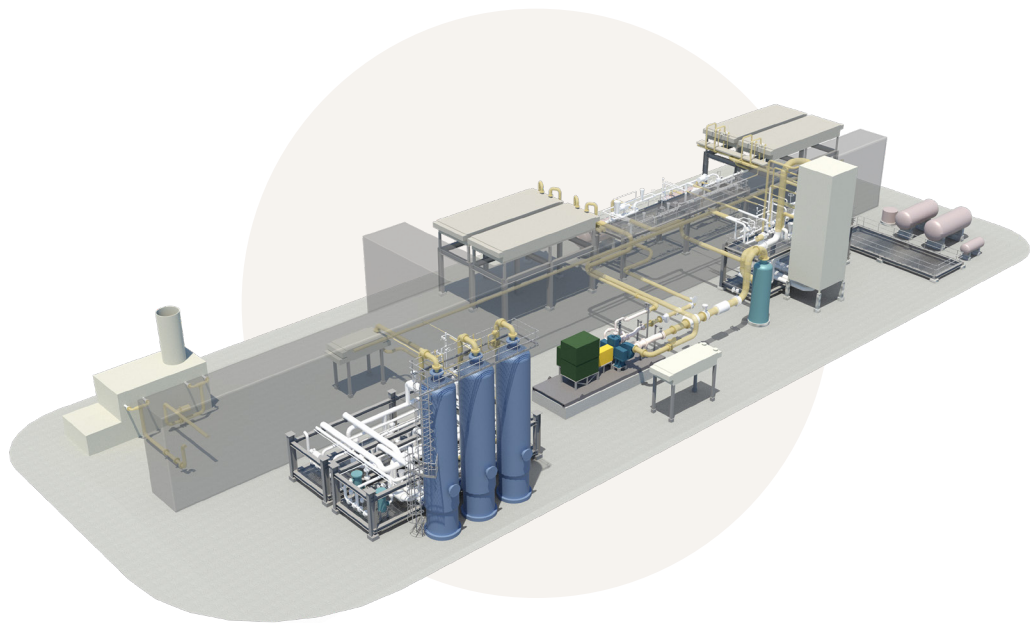
34 liquefaction plants in operation

60+ years of LNG production

>150M tonnes of LNG produced

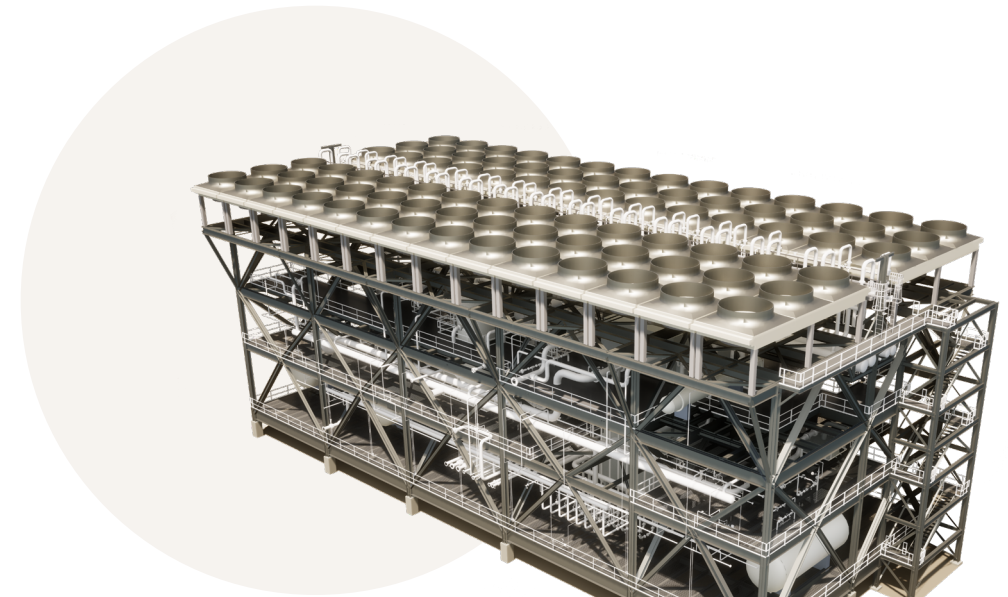
20 plants in development





Small-scale LNG facilities (Less than 0.5 MTPA)

Small-scale LNG assets are best suited for remote off-grid areas that don't have, or can't support, the infrastructure for pipelines. These facilities are a "sweet spot" for fast-to-market results, with remote installation capabilities and truckable modules and skids. Governments around the world offer incentives for the development of small-scale LNG facilities to promote cleaner and more sustainable energy sources.



Mid-scale LNG Facilities (0.5 to 2 MTPA per train)

Mid-scale, modular LNG trains can offer a more attractive option versus large-scale stick-built projects by offering more flexibility in production capacity and lower risk execution, which is an advantage with increasingly dynamic markets and shifting customer needs. The simplicity of mid-scale LNG solutions begin with a modular, repeatable, and compact design. The modules are constructed in a controlled environment, then brought to the project site for a quick, lower-risk installation, providing ease of operations and maintenance, as well as maximize economy of scale. With pre-configured designs, you can monetize smaller gas volumes at a reduced cost. The execution strategy using multiple modular mid-scale trains has been used to build LNG export facilities with more than 10 MTPA total capacity. Additionally, you can plan for the now and be ready for the future, by deploying parallel trains to match the optimal capacity for each production facility.





As the world demand for LNG rises, FLNG will continue to improve the global supply through liquefaction of natural gas in remote areas.

To date, 9 FLNG projects have entered construction, 6 have achieved commercial operations, and many more proposed facilities look to take Final Investment Decision.

Golar Hilli Episeyo

Floating LNG Facilities (FLNG)

Over the last decade, FLNG has emerged as a key piece of the LNG liquefaction market. Many developers have turned to FLNG, even before the recent global spike in demand for LNG, because it offers:

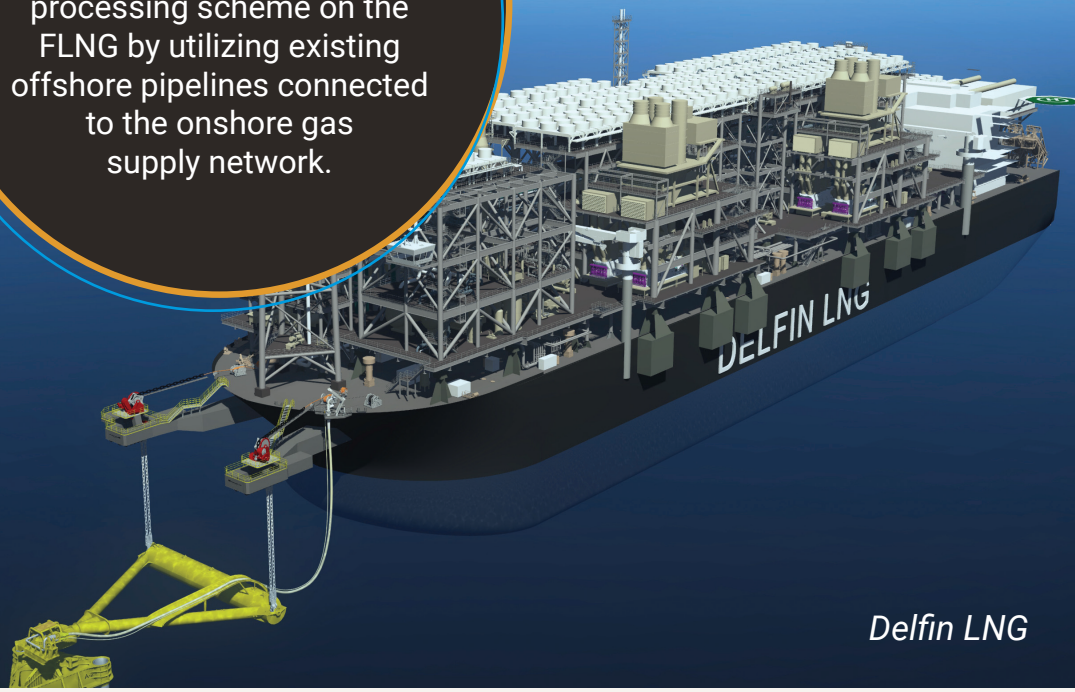
- 1 **Speed to market.**
- 2 **Capitally efficient and innovative solutions for monetizing offshore gas reserves.**
- 3 **Ability to develop nearshore facilities to export pipeline gas.**
- 4 **Increased construction efficiency and quality while risks are mitigated through modular design and construction in shipyards.**
- 5 **Compact design enables smaller environmental footprints than an onshore facility.**

Floating solutions maximizing mid-scale train capacity enabled by PRICO® while minimizing onsite work with modular execution and integrated hull storage, results in the most capital efficient projects on the market.

Nearshore FLNG removes many of the infrastructure, labor, and environmental barriers of developing onshore facilities which offers significant cost and schedule advantages over the traditional execution approach.



Delfin LNG's proposed project in the Gulf of Mexico provides an example of the simplified processing scheme on the FLNG by utilizing existing offshore pipelines connected to the onshore gas supply network.



Delfin LNG



FLNG Projects to Achieve Commercial Operation

Project Name	Owner	MTPA LNG	Raw Gas / Pipeline Gas
Prelude	Shell	3.6	Raw Gas
PFLNG Satu	Petronas	1.2	Raw Gas
PFLNG Dua	Petronas	1.5	Raw Gas
Tango FLNG*	Exmar	0.6	Pipeline Gas
Hilli Episeyo FLNG*	Golar	2.8	Pipeline Gas
Coral Sul FLNG	ENI	3.4	Raw Gas

FLNG Projects Under Construction

Project Name	Owner	MTPA LNG	Raw Gas / Pipeline Gas	Projected Delivery
Gimi FLNG*	Golar	2.8	Pipeline Gas	2023
ZLNG*	Petronas	2.2	Pipeline Gas	2027
Wison Congo	ENI	2.4	Raw Gas	2025

*Black & Veatch is providing technology, equipment, and engineering



Western LNG's Ksi Lisims LNG project is looking to use green energy sources in Western Canada to power their FLNG facilities and significantly reduce their carbon footprint for their FLNG facility.



Near-shore LNG Facilities

While LNG is a carbon-based fuel, it still presents a lower carbon intensity than other fossil fuels. This means it has an important role to play on our path to a net-zero global economy. Developing near-shore LNG is an important part of expanding our ability to produce and export gas as part of an “all of the above” plan to reduce greenhouse gas emissions.

Built near major ports, shipping lanes, or on coastlines, near-shore LNG facilities allow for efficient liquefaction, fast transportation and storage with less complexity than offshore floating projects and significantly smaller footprint than traditional onshore plants.

Additionally, the modular approach to construction helps to safely commercialize fields and accelerate lower emissions by supporting the transition of fuels through increased access to LNG. There are a few proposed projects that are looking to significantly reduce their carbon footprint by using renewable energy sources from the onshore power grid to power near-shore LNG facilities.

This blended solution is appealing because it has a knock-on effect of further reducing the carbon emissions within the LNG value chain. This blending of renewables within the LNG production and distribution industry serves to further decarbonize the gas supply chain to meet lifecycle emissions reduction goals.



Cedar LNG is exploring the e-LNG approach to provide not only a cost competitive facility, but one of the lowest carbon emitting natural gas liquefaction facilities in the world.

The 3 MTPA nearshore FLNG unit will employ motors to drive the refrigeration compressors and other smaller services with electricity sourced from the hydropower-supplied grid.

Electric Drive LNG (e-LNG)

As companies across markets set aggressive decarbonization goals and sustainability commitments to align with changing regulations and consumer demands for energy and fuel that have low or no carbon emissions, the LNG industry is investing in innovative tools and technology that will reduce their carbon footprint.

Electric drive LNG (e-LNG) has emerged as a potential solution to lower carbon emissions in liquefaction plants and, in some cases, cut costs. e-LNG, already commonly used in small- and medium-scale plants, uses electric motors to drive refrigerant compression rather than combustion gas turbines. e-LNG offers increasingly attractive—and in some areas, crucial—adaptability because its use of electricity allows it to be run by fossil fuels or renewables. This flexibility has led to its popularity in a volatile energy market, where the costs and availability of renewable and fossil-fueled electricity are constantly changing.



Signed into law in November 2021, the \$1.2-trillion, bipartisan Infrastructure Investment and Jobs Act (IIJA) earmarks **\$73 billion for grid upgrades**, including the buildout of thousands of miles of new, resilient transmission lines to help expand renewable energy ostensibly meant to mitigate climate change. That single biggest federal investment in power transmission in U.S. history comes at a time of runaway expansion of renewables.

Then in August, the “Inflation Reduction Act” became the single biggest climate investment commitment in U.S. history, with **\$369 billion over 10 years devoted to climate and clean energy provisions**.



Excerpt from BV's 2022-2023 Strategic Directions Electric Report



Electric Drive LNG (e-LNG) *continued*

However, as LNG asset owners, operators, and investors increasingly eye this technology for their plants, they must understand it is not a one-size-fits-all solution. Significant development of clean energy and grid infrastructure will be required if e-LNG is to become the new industry standard.

[Black & Veatch + Canary Media Report Energy Transition Snapshot 2022](#) highlights the need to help modernize the electric grid through new processes and partnerships that move away from traditional, project-focused energy development plans to more systemwide and collaborative approaches that can rapidly drive greater scale.

By pairing LNG with renewable grid energy as a source of power and employing carbon capture in gas processing and at industrial end users, the carbon emissions from the natural gas value chain can compete with other green fuel sources. E-LNG is a helpful tool as operators and utilities look to modernize the grid to produce fewer emissions and create more sustainable infrastructure.



Adapting LNG for a Decarbonized World

Understanding that LNG is a “bridge fuel” as we cross into a decarbonized economy raises the question “What will become of all this infrastructure in the long run?” LNG has the flexibility to integrate more renewables by modifying and adapting LNG infrastructure for the emerging role hydrogen/ammonia can play in the global energy industry. Known for its role in fertilizer production, ammonia is gaining attention as a stable energy carrier for hydrogen whose volumetric energy density makes storage and transport technically and economically challenging. Ammonia is more energy dense than liquid hydrogen and is also easily liquified for storage and shipment in the same fashion as LNG.

In addition, planning for and complementing LNG infrastructure with carbon capture, utilization, and storage (CCUS) capabilities, as well as powering upstream processes with renewable energy, are other ways gas developers can reduce overall carbon emissions from supplying natural gas. LNG facilities designed and built with that energy transition in mind have the potential for additional revenue streams by using the latest technology and creating additional energy commodities such as biogas, hydrogen, and ammonia.

Download our **Hybrid LNG & Ammonia Infrastructure: Key to a Green Economy eBook** to see how we help clients at every stage of the process de-risk investments and scale solutions that meet budget constraints, expectations for return on investments and navigate complex regulations.





Advantages of Modular Construction

To achieve cost savings and schedule improvements, the LNG industry has been on a path to minimize bespoke facility designs in favor of standardized offerings integrated with modular construction. While it is nearly impossible to apply standard designs to entire facilities in different areas of the world with different feed gas conditions, various pre-engineered components within those designs can be pieced together to meet the needs of a specific project. By utilizing past and current project experience, along with the development of philosophies consistent across projects, standardization can be realized to a great extent in some cases.

A main driver leading to the adoption of such practices has been FLNG projects, as they have followed the shipyard industry standard of modularizing construction. Onshore small and mid-scale facilities have followed suit, allowing for construction to happen in a modular yard and then assembled onsite to finalize construction. Adopting a modular approach provides flexibility in compressor driver selection, cooling medium, and capacity from 1 – 2 MTPA per train, which allows for schedule efficiency through minimized interfaces and reduced onsite installation time and manpower.





Conclusion

As countries around the world seek cleaner and more sustainable sources of energy, LNG is an attractive transition solution due to its lower carbon footprint, versatility, and reliability.

With the ability to unlock reserves and replenish gas supply for countries in need, the future of LNG looks promising with ongoing technological developments, including the development of modular construction and increased adoption of floating facilities, which offer significant advantages over traditional large-scale projects.

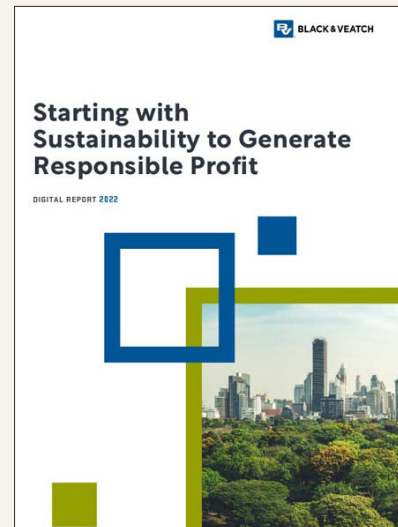
The scalability, flexibility, and mobility of modular LNG plants make them ideal for small and mid-scale liquefaction projects and remote locations. As demand for natural gas continues to increase, we can expect to see continued innovation in LNG technology, positioning it as a major contributor to the world's energy portfolio and progress on our path to net-zero emissions.

[Learn more about our LNG Solutions](#)





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Want to design sustainability and energy resilience into your facility?

Contact Us 



Our mission is to build a world of difference through innovation in sustainable infrastructure. We help organizations integrate a range of technologies to cost-effectively achieve resilience, sustainability, and growth.

