Shaving emissions at LNG peak shaving facilities

Regions across the Northern Hemisphere have experienced an increasingly frequent number of extremely cold Winter weather episodes over the past four decades. During extreme cold spells, demand for natural gas can peak sharply above normal baselines and create demand for a reliable gas supply that can quickly be delivered into the distribution system to flatten (or shave) these peaks in demand.

Peak shaving with LNG is well-established as a means of providing an incremental supply of natural gas in order to meet energy needs on extremely cold days. The natural gas is liquefied and stored when prices are low during off-peak months. When more gas is needed – during peak demand periods – it is available. As a result, the need for spot market supply is reduced.

The US has approximately 70 active peak shaving facilities strategically located on the pipeline system in the Northeast, Upper Midwest, and Southeast. The majority were built between 1965 and 1975 and are reaching the end of their design life.

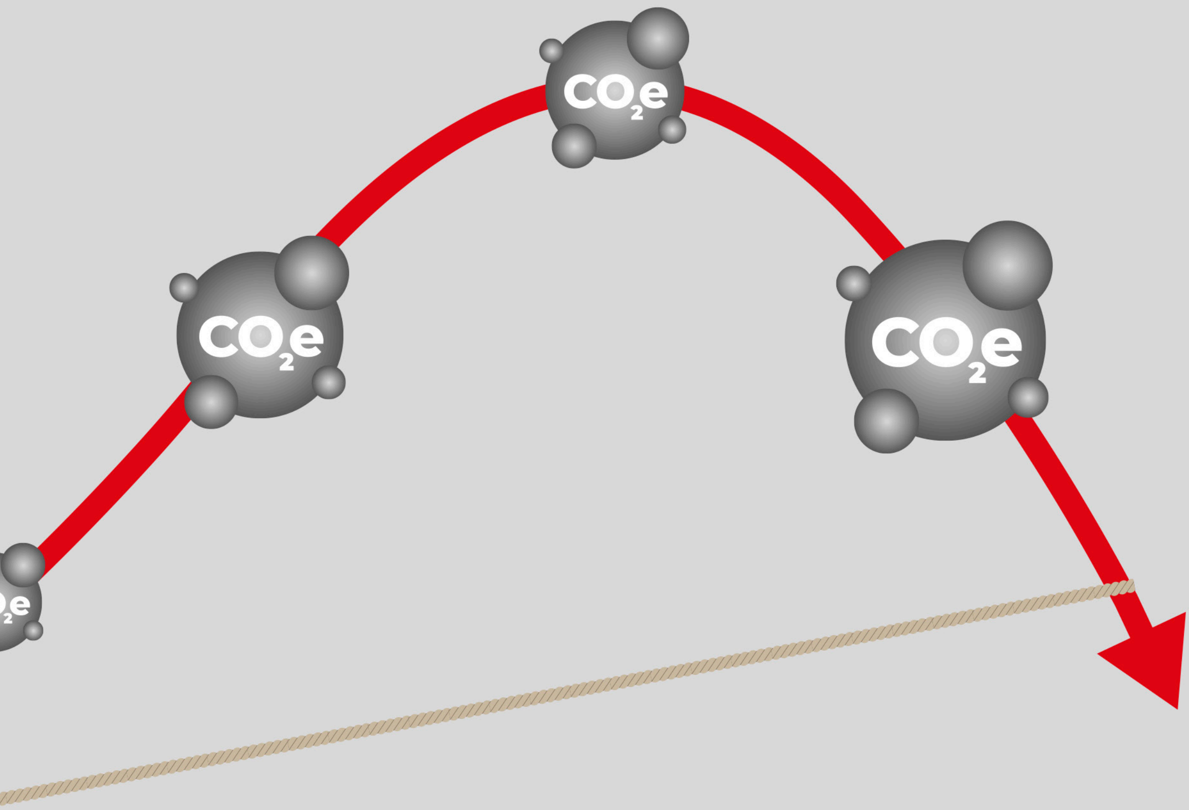
A typical LNG peak shaving facility design provides approximately 5 – 15 days of storage at the design maximum send-out rate, and liquefaction is usually sized to fill the installed storage capacity in approximately 200 days. Some facilities rely on third-party suppliers to replenish their LNG storage with tanker trucks, and most sites have truck loading and unloading facilities.

Challenges

Cost-effective emissions reduction technology solutions are urgently needed to achieve the net zero emissions required to address climate change.

Following a joint net zero upstream facilities study with McDermott, Schneider Electric, and io consulting,

Huw Thomas and Max Peile, io consulting, and Jeffery Baker and Sam Wojciechowski, CB&I, explore the possibility of net zero LNG peak shaving facilities.



CB&I (McDermott's storage business line) worked with io consulting to evaluate the feasibility of a net zero LNG peak shaving facility.[1] CB&I built the first LNG peak shaving facility in North America in 1965, and LNG peak shaving facility construction is a fast-growing segment of their business. The challenge was to develop a net zero LNG peak shaving facility concept, focusing on Scope 1 and Scope 2 emissions.[2]

The approach

The magnitude of carbon emissions for any given LNG peak shaving facility depends on the liquefier size, type of pre-treatment, send-out capacity, and the carbon emissions factor of the local power grid (measurement of how many grams of carbon dioxide [CO_2] are released to produce a kilowatt hour [kWh] of electricity). However, to establish the carbon emissions baseline for a typical modern LNG peak shaving facility, io consulting used an LNG peak shaving facility recently constructed by CB&I as the reference case. The 1.5 billion ft^3 gas storage facility, based on conventional peak shaving technology, emits approximately 20 000 tpy of carbon dioxide equivalent (CO_2e).

The largest contributors to the baseline annual emissions were found to be:

1. Heat generation (using gas fired heaters) for both pre-treatment of the natural gas stream and vaporisation of the LNG.

2. Waste gas disposal via the flare, consisting mostly of CO_2 that is removed from the natural gas prior to the liquefaction process.

3. Electrical power, including the liquefaction refrigerant compressors.

The io consulting team applied concept analysis methods and tools based on the Decision Quality Framework[3] to formulate a suite of feasible emission reduction alternatives, taking the facility configuration options and unit technologies into consideration. The options were then assessed based on their relative levelized cost of carbon abatement.[4]

The result

The analysis found that a 74% reduction in Scope 1 emissions alone can be achieved by selecting proven low emission technologies. In addition, through increases in operating efficiency and energy saving applications, a portion of Scope 2 emissions can be avoided, reducing the overall Scope 1 and Scope 2 LNG peak shaving facility emissions by 40%.

This emissions reduction potential is achievable within the battery limits of the facility, does not rely on external factors, and is within the control of the facility operator.

Key emissions reduction insights from the project

Carbon capture and re-injection avoids disposal via flare

To facilitate the liquefaction process, natural gas is pre-treated to remove impurities such as CO_2, hydrogen sulfide (H_2S), and water. The resulting waste stream containing CO_2 and H_2S (known as 'acid gas') is typically routed to flare for safe disposal to the atmosphere. Due to the high concentration of CO_2 in the waste stream, this disposal route requires 'assist gas' to ensure combustion at the flare tip. The result is the atmospheric release of both the CO_2 removed from the natural gas and the CO_2 generated from flaring the assist gas.

The lower emissions alternative solution is to store the captured CO_2 on site and to re-inject it into the natural gas send-out stream, avoiding the need to flare. Carbon storage and re-injection reduces the baseline emissions by 23% and retains carbon in the system. Carbon storage on site provides the option for trucking the carbon to a local sequestration site or to end users of carbon, rather than re-injecting the carbon into the system.

Maximising CO_2 capture can also be achieved through boil-off-gas (BOG) recovery. BOG is the natural gas lost during the process of storing LNG, and the filling and emptying of the tanks. Recovering BOG enables greater CO_2 recovery and re-injection since more CO_2 can be returned to the natural gas during send out. By capturing and re-liquefying all BOG, it is possible to re-inject up to 99% of the incoming CO_2, thereby reducing total emissions by a further 4%.

Ambient air vaporisers remove the need for gas fired heating

Vaporisation of the LNG from storage conditions to high-pressure pipeline temperature requires considerable thermal energy. LNG is typically pumped from the storage tank through a shell and tube heat exchanger where the LNG is heated indirectly using water propylene glycol (WPG). The WPG itself is heated by gas fired heaters.

Ambient air vaporisers (AAVs) are an alternative lower emissions solution to gas fired heating, saving approximately 10% of the total baseline emissions. AAVs are relatively uncomplicated heat exchangers which vaporise the LNG using heat absorbed from the ambient air.

Pre-cooling reduces the liquefaction process power requirement

Power consumed by the electric mixed refrigerant liquid (MRL) compressor motor contributes approximately 30% of total baseline emissions. Installing a pre-cooling refrigerant cycle is a proven means to increase both overall liquefaction energy and cost efficiencies.

Introducing pre-cooling to the LNG liquefaction process leads to a 10% improvement in liquefaction power consumption, compared to a common single stage MRL, which delivers a further 2.5% reduction in emissions.

On-demand flare removes the need for fuel gas purge and continuous pilot emissions

Flare stacks are an essential device to safely dispose of gas if another part of the facility has to be shut down suddenly. 'On-demand' flare ignition systems, in conjunction with advanced flare control and digital verification platforms, provide emergency depressurisation, while removing the need for fuel gas purge and continuous pilot emissions.

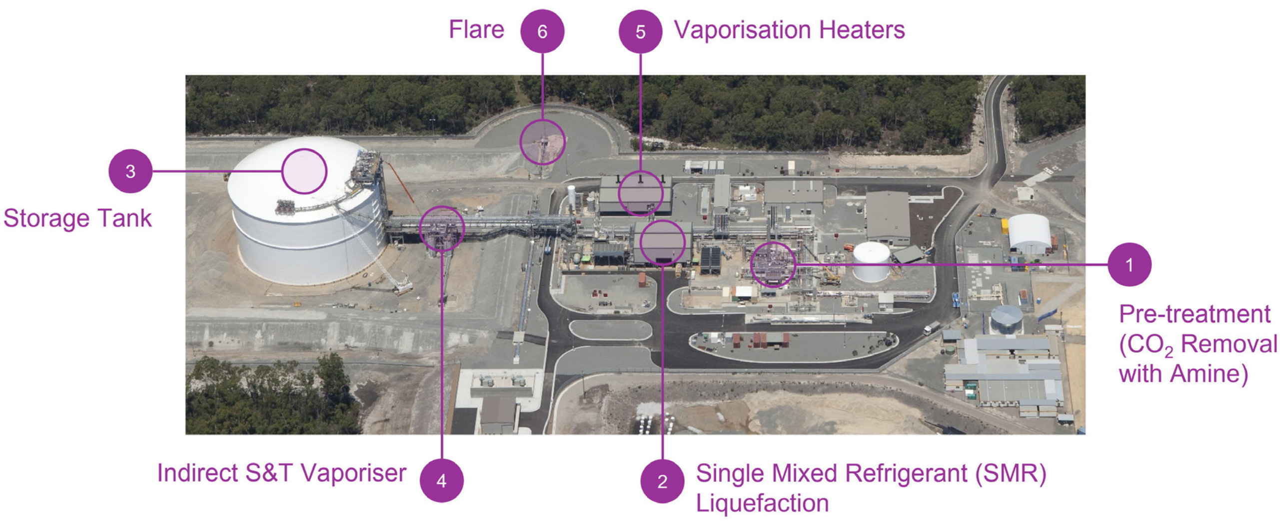


Figure 1. Major process components of an LNG peak shaving facility.

Achieving net zero

To achieve net zero, 100% of the Scope 1 and 2 emissions must be abated. The remaining balance of emissions from the reference case LNG peak shaving facility mainly comes from the pre-treatment fired heaters (16%) and fugitives (4%) under Scope 1, and the outstanding 80% is imported electrical power (Scope 2). Electrification and carbon offsetting are ways of tackling these harder-to-abate emissions to achieve absolute carbon neutrality.

Electrification

Power grids are increasingly decarbonising, and the electrification of facilities is an increasingly realistic prospect to reduced emissions. However, electrification is only advantageous if the grid's CO_2 emissions factor is low.

Due to the high efficiency of LNG peak shaving facilities' on-site fired heaters (85% heating efficiency), electrification is a viable emissions reduction option if the grid emissions factor is below 0.28 kg CO_2e/kWh. The grid emissions factor is determined based on the grid make-up, i.e. how much power is provided by coal, oil, gas, nuclear, wind, solar, etc.

This 0.28 kg CO_2e/kWh threshold is lower than the average grid emissions factors and requires significant renewables or green energy to achieve; only 11 US states currently have an average grid emissions factor below this threshold.

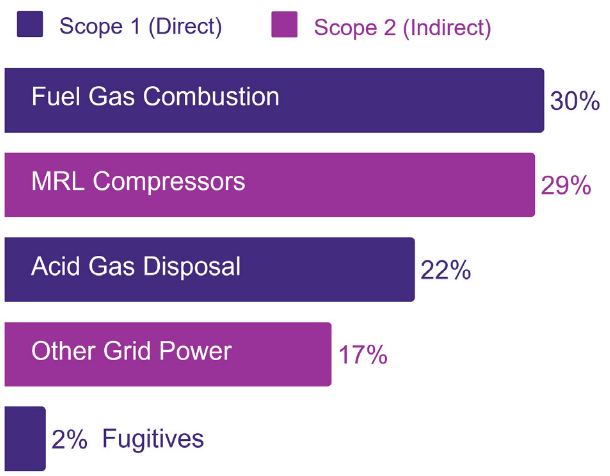


Figure 2. LNG peak shaving facility emissions (%).

Carbon offsetting

Carbon offset schemes enable individuals and companies to invest in environmental projects to achieve carbon neutrality. The projects are usually located in developing countries and most commonly are designed to reduce future emissions through reforestation, nature-based solutions, and the development of renewable power and other low-carbon sources.

Carbon offset schemes – along with carbon capture and storage, direct air capture, and other carbon reduction technologies – will form a critical pathway to limiting global warming, as switching to renewable energy alone will not produce enough carbon savings.

The voluntary carbon market is currently small and unregulated by governments, but demand for an established and well-functioning global carbon market is increasing with growing corporate net zero commitments.

The bigger picture

The natural gas and LNG sectors are increasingly pursuing actions to reduce their environmental impact. Lower emission technology solutions, such as those presented in this article for a typical peak shaving facility, can achieve meaningful and commercially viable emissions reduction outcomes.

The emissions reduction technologies outlined are proven, readily available, and can be applied to both new and existing facilities. Collectively, these solutions can achieve an estimated 30% reduction in CO_2 emissions for less than a 10% incremental CAPEX; a 40% emissions reduction is achievable without significant incremental cost.

Extrapolating from the reference case to the current stock of US peak shaving facilities offers a cumulative emissions reduction potential in the order of 400 000 – 500 000 tpy CO_2e. **LNG**

References

1. 'McDermott, Schneider Electric and io consulting join forces to develop net zero upstream facilities', *io consulting*, (2020), www.ioconsulting.com/news/mcdermott%2C-schneider-electric-and-io-consulting-join-forces-to-develop-net-zero-upstream-facilities
2. It is acknowledged that Scope 3 emissions should be considered for a net zero design and further work on this is being progressed separately; please refer to io consulting's recent article on 'reducing embedded carbon & EPC related emissions', www.ioconsulting.com/post/reducing-embedded-carbon-epc-related-emissions-in-oil-gas-facilities
3. 'Decision quality defined', *Strategic Decision Defined*, https://sdg.com/thought-leadership/decision-quality-defined/
4. FRIEDMANN, J., FAN, Z., OCHU, E., SHEERAZI, H., BYRUM, Z., and BHARDWAJ, A., 'Levelized Cost of Carbon Abatement: An Improved Cost-Assessment Methodology for a Net-Zero Emissions World', *Center on Global Energy Policy at Columbia University SIPA*, (2020), www.energypolicy.columbia.edu/research/report/levelized-cost-carbon-abatement-improved-cost-assessment-methodology-net-zero-emissions-world

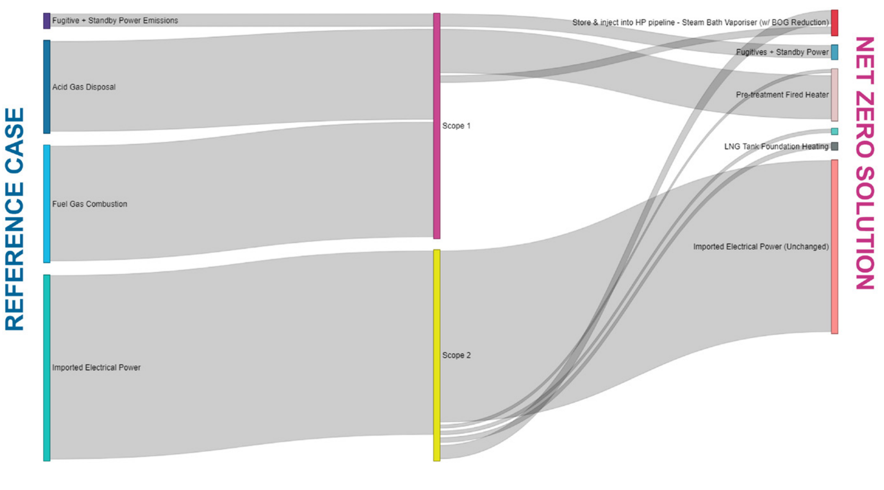


Figure 3. Emissions (t CO_2e/y) by source.