INFRASTRUCTURE

MINING & METALS

NUCLEAR, SECURITY & ENVIRONMENTAL

OIL, GAS & CHEMICALS

Cheniere Energy Sabine Pass LNG – World's First Import/Export Facility

2017

Cheniere Energy Sabine Pass LNG –
World's First Import/Export Facility

P. Pillai, S. Buoncristiano
Bechtel Corporation

J. Pfeffer, E. Lehotsky
Cheniere Energy

E. Romero, M. Culligan
Conoco Phillips Company

Gastech
Conference & Exhibition
CHIBA | TOKYO | 4 - 7 APRIL 2017

GASTECH 2017

Tokyo, Japan
4-7 April, 2014
ABSTRACT

Cheniere Energy Partners is developing, constructing, and operating a liquefaction project at the Sabine Pass LNG terminal (the "SPL Project") adjacent to the existing regasification facilities for up to six trains, with expected aggregate nominal production capacity of approximately 27.0 mtpa of LNG. Train 1 achieved substantial completion in May 2016, Train 2 achieved substantial completion in September 2016, Train 3 is commissioning and Trains 4 and 5 are currently under construction. All regulatory approvals have been received to construct and operate Train 6.

The Cheniere Liquefaction trains are being built and commissioned by Bechtel using ConocoPhillips Optimized Cascade® process technology. The plants utilize aeroderivative drivers that use evaporative coolers for power augmentation to run the refrigeration compressors with a state-of-the-art Heavies Removal Unit (HRU) designed to efficiently manage the swings in the feed gas composition while ensuring stable LNG production.

This paper sheds light on the economics, technology/design features, execution facets, and operational flexibility of the Cheniere Project, which integrates the existing marine, interconnecting pipelines, and storage facilities with new LNG liquefaction trains.

This paper will also provide some details on the startup and commissioning aspects of the first two trains, culminating in a successfully executed plant performance test and handover of the first stage of the project to Cheniere Operations.

A well planned and phased execution strategy maximizing replication across the LNG trains while continually integrating lessons learned throughout the project execution phase, coupled with close coordination among Cheniere, Bechtel, and Conoco Phillips personnel, have been instrumental in the continued success on the project.

1.0 INTRODUCTION

There has been a significant increase in the U.S. natural gas production since the discovery and exploration of shale gas reserves in North America. The domestic energy industry is deploying fewer resources to produce more natural gas than ever before, highlighting the dramatic productivity gains that have underpinned the U.S. unconventional energy boom of the last decade. The U.S. Energy Information Administration (EIA) estimates marketed U.S. natural gas production of 28.88 trillion cubic feet in 2015, a level that would mark a new high and the fifth consecutive year that U.S. natural gas production has eclipsed historical records (Figure 1).

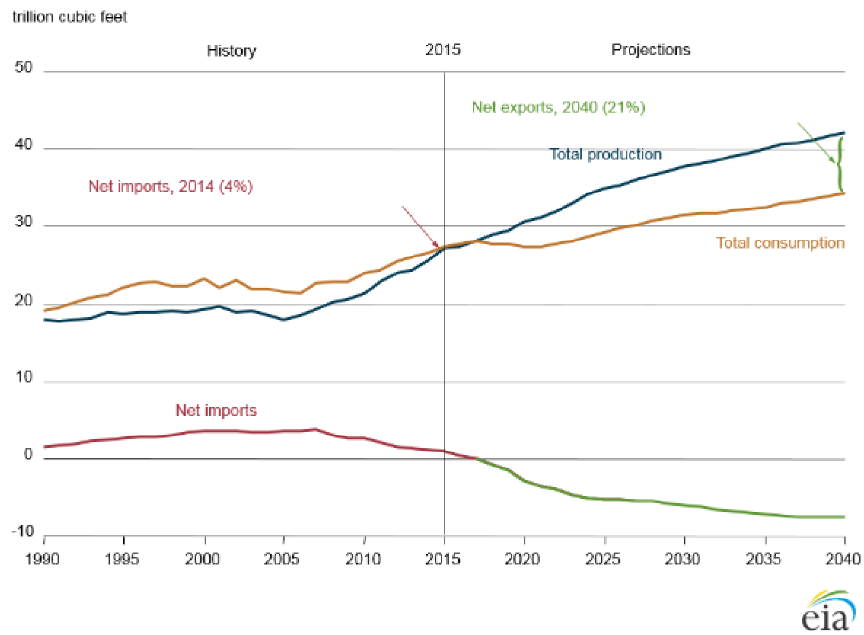

Figure 1 - Net Increase in U.S. Natural Gas Production

The advances in the production of shale gas dramatically increased the amount of gas that could be recovered at a relatively low cost. This presented an opportunity for the U.S. to export gas to other countries with much higher natural gas market prices and at a time when the demand for LNG is expected to be growing faster than the demand for natural gas overall (Figure 2). The first 'lower 48' US export project was sanctioned in August 2012 – Sabine Pass trains 1 and 2. Cheniere having successfully operated a world class 4 bcfd LNG import and regasification terminal at Sabine Pass made a strategic decision to capitalize on the paradigm shift in natural gas market conditions while utilizing their existing assets from the LNG import terminal, to add natural gas Liquefaction capacity to their existing terminal. SPL Liquefaction trains utilize the existing five LNG tanks and the marine facilities that were originally built and operated as an import terminal.

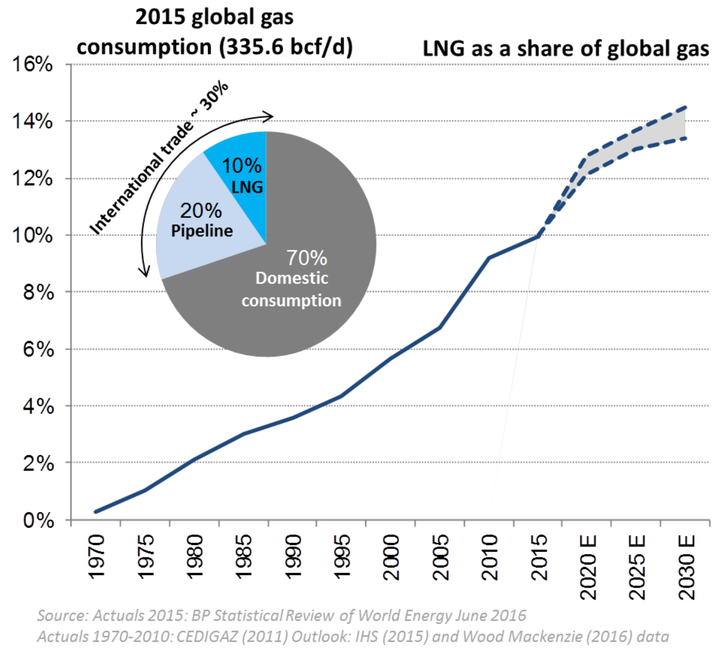

Figure 2 - Global LNG Demand

Since Cheniere sanctioned Sabine Pass trains 1 and 2, as of November 2016 another five LNG export projects have been sanctioned for a total of around 64 mtpa in export capacity currently online and under construction. Cheniere represents about 50% of that capacity with five trains online and under construction at Sabine Pass and another two trains under construction at Corpus Christi. At Sabine Pass, liquefaction capacity is being developed, constructed and commissioned in a staged manner for up to six trains – two of which are online, one is commissioning, two are under construction, and one is fully permitted and awaiting sanction -- with expected aggregate nominal production of approximately 27.0 mtpa of LNG (Figure 3). The addition of the liquefaction trains has transformed the SPLNG terminal into a bi-directional facility capable of liquefying domestic natural gas for export, in addition to regasifying imported foreign-sourced LNG.

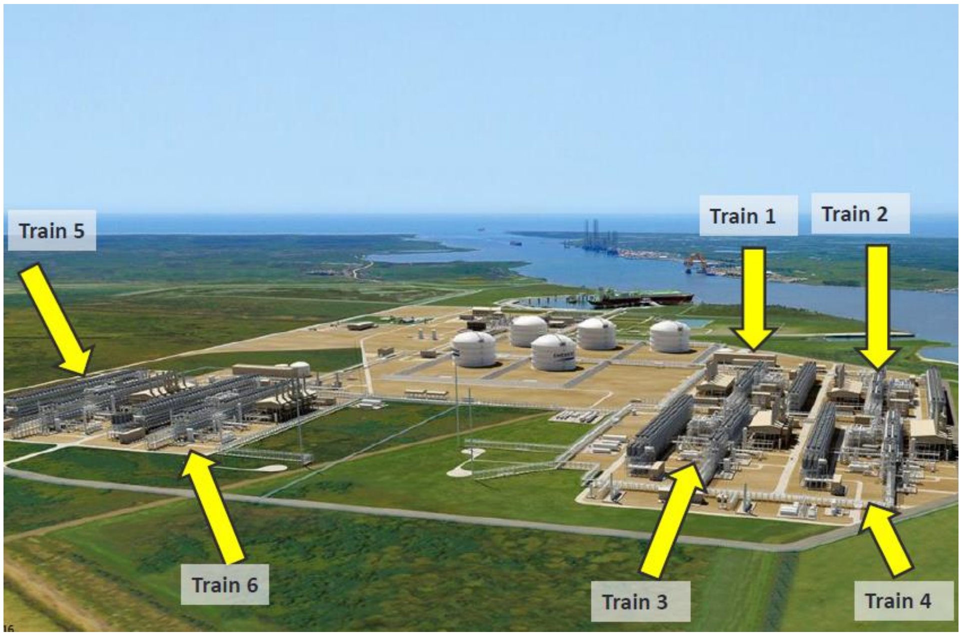

Figure 3 - Artist Rendition of Sabine Pass Liquefaction

Once all of the sanctioned US projects are online, the US will be the 3rd largest LNG exporting country (Figure 4). More US LNG liquefaction trains are likely to be sanctioned in the coming years as LNG demand continues to grow and additional competitively priced LNG is required to meet the expected demand growth.

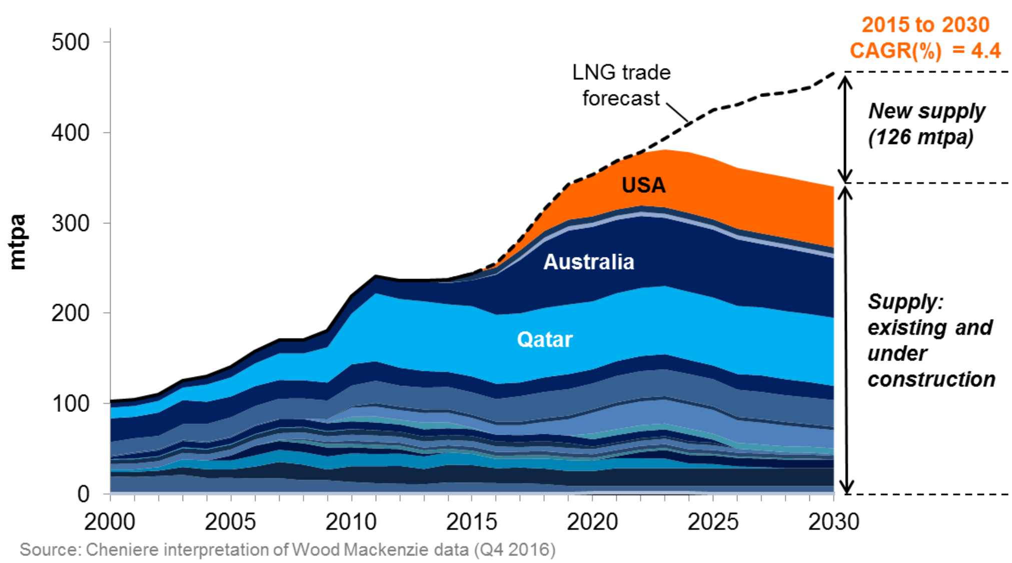

Figure 4 - LNG Trade Forecast

2.0 PROJECT ENABLERS

The U.S. oil and gas industry has been undergoing a renaissance driven by the combination of advances in deep horizontal drilling and hydraulic fracturing. Cheniere was able to seize the opportunity rising from the dramatic increases in U.S. gas production and has effectively capitalized on it by changing their business model to add LNG export within a very short time frame.

2.1 Time to Market - US LNG Export

Cheniere's vision and ability to be a first mover in US shale gas to LNG export market have been instrumental in the huge success of Sabine Pass LNG. Cheniere started developing the LNG terminal business in 1999 and was one of the first companies to set up large-scale LNG import and regasification terminals in the US to satisfy domestic gas demand. Bechtel built and expanded the Sabine Pass LNG receiving terminal between 2005 to 2009. There was a precipitous drop in natural gas prices in 2009 fueled in part by the "shale revolution."

This provided Cheniere the opportunity to modify their LNG import business model by initiating the Sabine Pass LNG export project in June 2010 to add liquefaction capabilities. Understanding that the U.S. natural gas market had flipped quickly and somewhat unexpectedly due to the shale gas revolution, Cheniere surmised that it could happen again. Therefore it was important that the liquefaction facilities had to be on line quickly to take advantage of the market opportunity. But also the facility should remain capable of importing and regasifying LNG to support the terminal use agreements already in effect with its customers.

As a result of the timely decision-making, SPL was the first LNG export terminal to receive FERC approval and begin pre-filing in August 2010. The DOE granted the order authorizing SPL to export LNG in September 2010. Being a first mover with a short time to market, Cheniere was able to generate significant interest from capital markets and LNG buyers, which, coupled with quick and sound decision-making, facilitated a challenging project timeline and efficient project execution to completion.

2.2 Regulatory Approvals - FERC

The US Federal Energy Regulatory Commission ("FERC") is the lead federal agency that has exclusive authority to approve or deny an application for the siting, construction, expansion, or operation of an LNG terminal. The following general steps were followed by Cheniere for FERC approval from project inception:

- FERC pre-filing - provided federal agencies and public stakeholders to comment on project impact prior to filing
- Draft Resource Reports - prepared to aid in the preparation of an environmental assessment (EA)/environmental impact statement (EIS) to fulfill obligations to the National Environmental Policy Act (NEPA) and inform stakeholders of potential beneficial and adverse project impacts (includes general project information, water use, impact on fish/vegetation/wildlife, socioeconomics, geological resources, soils, land use, air and noise quality, PCB contamination)
- Public meetings and postings - to solicit stakeholders concern on the resource reports, identify issues, and address mitigations
- FERC commission order - to proceed with conditions to be met prior to construction

Besides FERC, additional environmental permits were sought and obtained from Louisiana Department of Environmental Quality, US Army Corps of Engineers, Coastal Zone Management clearance, US Fish and Wildlife, Air Emissions Permit, Historic Preservation permit, several other local, state, and federal organizations, and finally the US Department of Energy permits for exporting LNG to both Free Trade countries and non-Free Trade countries.

2.3 Selection of EPC Contractor and LNG Liquefaction Process

Cheniere developed the Sabine Pass LNG import terminal in two phases, with Phase 2 commencing operations in 2009. Bechtel built the terminal and was well aware of the challenges, including site preparation and labor mobilization that would be required to undertake the much larger liquefaction project. Building on the strong collaborative history with Bechtel and leveraging Bechtel's design experience and execution track record on multiple LNG projects being constructed around the world, Cheniere chose Bechtel in 2010 to initiate a pre-feed study on the Sabine Pass LNG export facility. Given the volatility in world LNG and natural gas prices, Cheniere knew the liquefaction process had to be able to be efficiently run at low turndown rates, and started up quickly after being idled to take advantage of short term market trends. Bechtel's experience deploying the ConocoPhillips Optimized Cascade® process - a well proven technology that has already been built many times by Bechtel - thus became a perfect fit.

Cheniere's decision to sole source Bechtel as its lump-sum turnkey contractor from the start of the project development phase and working with Bechtel in a collective manner during project execution to start-up has resulted in significant savings in schedule and effort throughout the project cycle. Bechtel's seamless execution of the project from the study phase of concept through engineering, procurement, and construction into startup with a continuity maintained in team expertise throughout the project life has greatly benefited the project.

2.4 Experience/Lessons Learned/Replication

There was a lot of experience across the board, starting with Cheniere recruiting an owner's team with hundreds of years total experience in building and operating LNG facilities, and then hiring two very qualified LNG players in the market (Bechtel and ConocoPhillips). Across the project timeline and through its various phases, these world-class teams were present in execution and management of the project. Bechtel's best-in-industry engineering, procurement, construction, startup planning, and execution capability worked with ConocoPhillips Optimized Cascade® process technology design team to deliver the project well ahead of schedule. As an owner itself, ConocoPhillips also supplied operations expertise that truly helped Bechtel and Cheniere during startup and early operations.

The design on SPL was started using a well proven template for liquefaction that was site-specific with key decisions made very early on. In addition to the design template, there were lessons learned from other LNG projects being implemented that were absorbed to enhance the design of SPL trains.

The Bechtel/ConocoPhillips/Cheniere team employed a continuous learn and implement approach during the staged project execution to ensure timely project completion and trouble-free plant operation. Lessons learned from the LNG receiving terminal were cascaded to the SPL Project while subsequent lessons learned during the initial liquefaction train design and implementation were absorbed into a well-managed replication program to be utilized in successive trains, including Cheniere's Corpus Christi liquefaction project.

2.5 Site Location

The Sabine Pass site can readily accommodate up to six liquefaction trains with a combined LNG production capacity of 27 MTPA; the production capacity of each LNG train is being designed for approximately 4.5 mtpa. The 1000+ acre Sabine Pass site is strategically situated to provide LNG export services given its large acreage position, proximity to unconventional gas plays in Louisiana and Texas, its interconnections with multiple interstate and intrastate pipeline systems, and its premier marine access less than 4 miles from the Gulf Coast (Figure 5). The pipeline connection network feeding the LNG Facility is shown in Figure 6.

Figure 5 - U.S. Gulf Coast Location of Sabine Pass Terminal

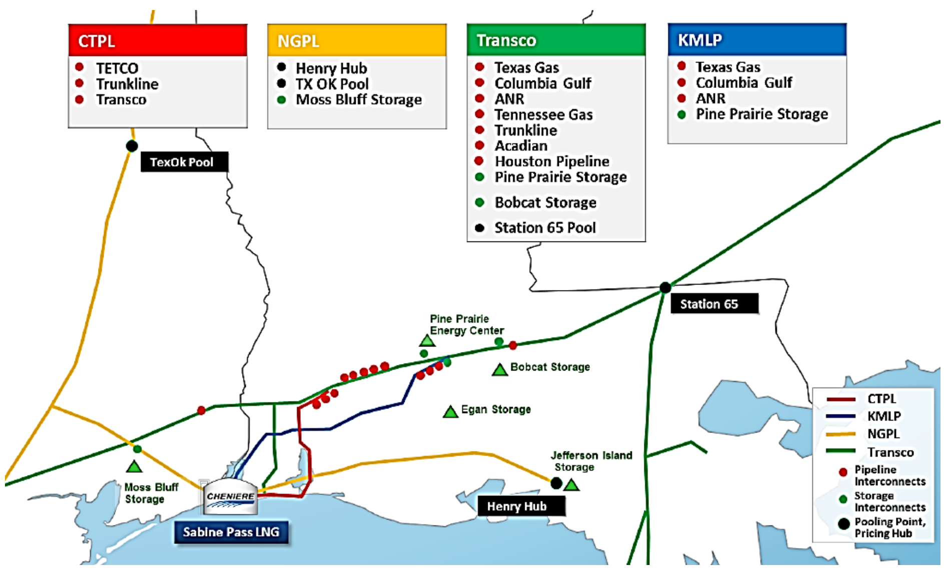

Figure 6 - Pipeline Connection Network

Easy access to a qualified Gulf Coast labor pool, extensive support from the local community, and strong labor relations, together with well-established road and marine access for materials have also facilitated the efficient execution of the project.

2.6 Expansion Economics

The Sabine Pass Liquefaction project added liquefaction trains to an already existing LNG terminal while utilizing the existing LNG tanks, jetty, gas pipeline, and other facilities. The construction costs of the liquefaction capacity were, therefore, competitive due to expansion economics since the Sabine Pass LNG terminal already has many of the facilities required for an export terminal. Sabine Pass Liquefaction could access the existing infrastructure, including five storage tanks and two berths at the Sabine Pass terminal, as well as Cheniere's 94-mile Creole Trail Pipeline, which was reconfigured to reverse the flow of natural gas, making it a bi-directional pipeline. Building multiple LNG trains on the same site provided additional economies of scale and efficiency that can be derived from a well thought out replication work process.

After Cheniere issued a Notice to Proceed in August 2012, Trains 1 and 2 achieved substantial completion in May 2016 and September 2016, respectively. Construction commenced on Trains 3 and 4 in May 2013 and on Train 5 in June 2015. All regulatory approvals have been received to construct and operate Train 6, and FID is expected to be reached upon obtaining commercial contracts and financing sufficient to support construction.

2.7 Committed LNG Contracts

For the first five LNG trains, 19.75 of the 22.5 mtpa nominal production capacity (approximately 88%) has been contracted to third party, foundation customers on a long-term FOB basis under sale and purchase agreements (SPAs). Foundation customers include Shell, Gas Natural Fenosa, KOGAS, GAIL, Total, and Centrica. Any excess capacity not sold under long-term SPAs to foundation customers is available for Cheniere Marketing.

2.8 LNG Pricing and Gas Supply

The Cheniere business model differs from other U.S. LNG projects in that in addition to processing natural gas into LNG (tolling model), Cheniere will procure the natural gas supply used for feedstock. Once the natural gas is liquefied, the customer takes delivery at the tailgate of the terminal. As a result, Cheniere is expected to become one of the largest buyers of natural gas in the U.S. once all of the trains are operational. Cheniere have built a world class operation to advantageously acquire feedstock for the terminal. Cheniere's gas procurement business has secured long-term transportation capacity on many pipelines to ensure reliable gas deliverability and diverse access to multiple producing basins. Cheniere have also entered into several supply arrangements to purchase natural gas from suppliers at prices discounted to applicable market indices.

Cheniere's Sabine Pass LNG (SPL) facility in Cameron Parish, Louisiana is ideally suited to capitalize on the abundance of natural gas in the United States which has been created due to the development of unconventional reserves. SPL has the ability to access supplies from every supply source located in the continental United States east of the Rocky Mountains. SPL has been working with natural gas producers and infrastructure companies to purchase long term natural gas supply and ensure that the needed infrastructure is in place to transport the supply to the terminal. Currently SPL has purchased approximately 50% of its baseload natural gas needs for Trains 1-5 for the next few years and is fully contracted with transportation capacity to meet the full requirements of the terminal.

2.9 LNG Market - Competitive Advantage

Early on, Cheniere differentiated itself in the LNG market by offering global LNG buyers more attractive features and contract terms, including:

(1) An alternative pricing mechanism basing LNG prices on a natural gas index as opposed to a traditional crude-based index . Cheniere's sales are based on a price comprising a fixed-price component and a fee linked to Henry Hub for that quantity of LNG actually delivered
(2) Destination flexibility allowing customers to determine delivery points as opposed to the traditionally restricted delivery locations.

(3) Volume flexibility by allowing the buyer, in most cases, to elect to cancel/suspend LNG deliveries with the buyer only paying the fixed-price component, provided required notice is given.
(4) Cheniere is procuring natural gas and selling LNG to customers at the tailgate of the plant versus offering a tolling model whereby the customer has to procure its own feedstock and is just paying for the liquefaction process.

Figure 7 shows estimated breakeven LNG pricing ranges across different regions.

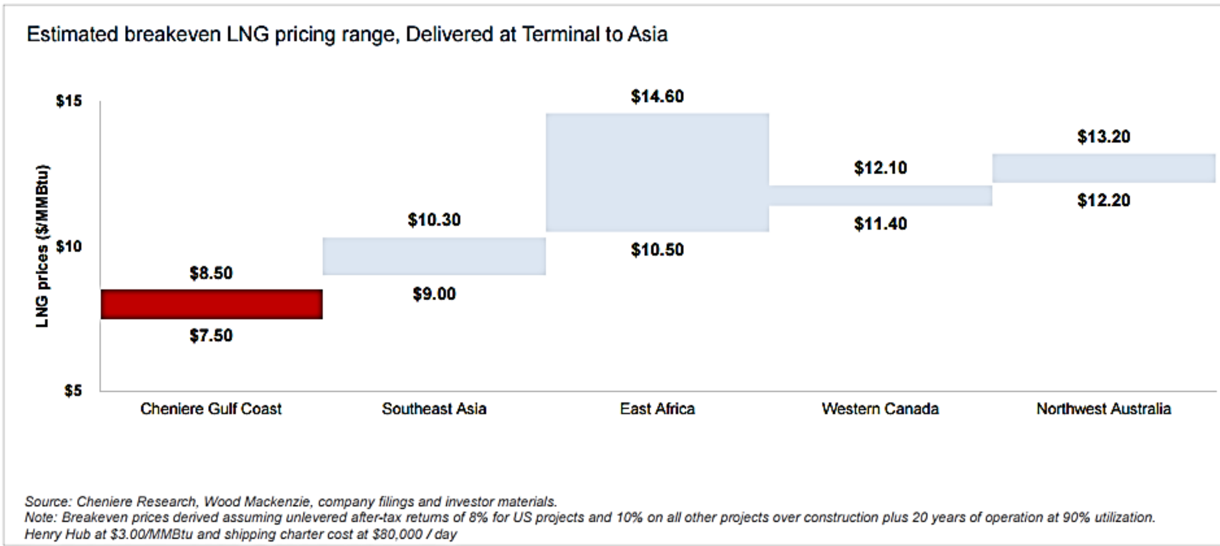

Figure 7 - LNG Breakeven Pricing

3.0 PROJECT SCHEDULE AND EXECUTION

3.1 Engineering and Procurement

Bechtel commenced a pre-FEED study for SPL liquefaction trains in 2010, followed by the FEED phase and development of an open book LSTK price in 2011. On completion of the FEED, Cheniere awarded Bechtel the EPC contract in December 2011 and, after all permits were finally obtained, issued full Notice to Proceed (NTP) in August 2012 to design and build Sabine Pass liquefaction Trains 1 and 2. NTP for liquefaction Trains 3 and 4 followed in May 2013, and Train 5 in June 2015.
EPC schedule development commenced at the conclusion of FEED, well in advance of the EPC contract. The engineering phase for Trains 1 & 2 lasted about 18 months. A strict duplication philosophy allowed efficient replication of deliverables into the subsequent trains. The engineering schedule was influenced by many factors, including the construction work plan and long-lead equipment delivery. LNG trains were commissioned generally at six-month intervals (Train 2 commissioned six months after Train 1), using a core-team approach with experienced craft, professional leadership, and project expertise transferring from one train to the successive train in a timely manner as the project team expanded and contracted to meet required needs.

Engineering execution was performed from Houston with support from satellite offices; procurement centralized in Houston based on common suppliers across all trains, and self-performance of pipe fabrication with CIMTAS, supplemented by local fabricators, U.S. steel and several large pieces of equipment from U.S. For Trains 1 thru 4 alone (data is not yet final for Train 5) over $2.3. billion dollars were invested in U.S. manufacturing (Figure 8).

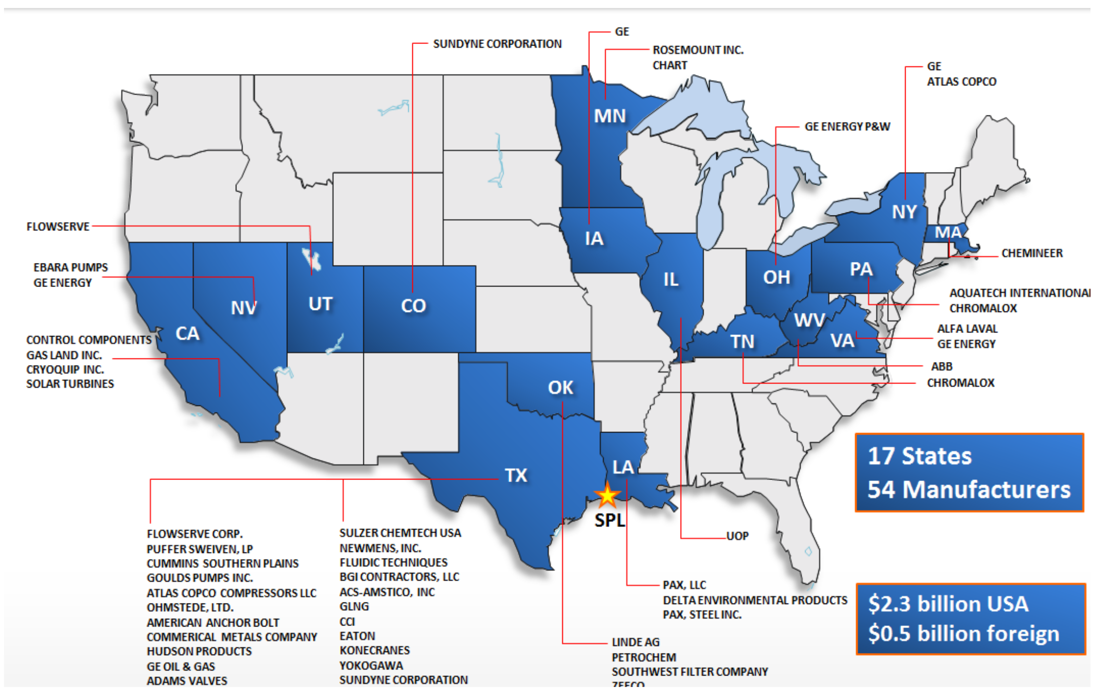

Figure 8 - Sabine Pass Liquefaction Trains 1-4 Investment in American Manufacturing

Bechtel self-performed all aspects of procurement from purchasing, expediting, supplied quality programs, transportation and logistics to procurement support at the site. Significant effort was deployed by the Procurement and Transportation specialists in executing the complex logistics of sourcing from multiple geographic regions, material supplier quality inspections, insurance and shipping- while maximizing U.S. content in the equipment delivered to site. Bechtel was responsible for the control of transportation of all equipment and materials from the vendors' point of origin to its designated location via ocean cargo, truck or air freight; over three hundred major movements were managed from over twenty countries.

3.2 Construction

Bechtel self-performed the entire construction scope, hiring skilled craft professional from the population of construction workers in the Gulf Coast. The site conditions were very challenging and naturally prone to settlement. The area had previously been utilized for dredged material placement by the U.S. Army Corps of Engineers during the construction and maintenance of the Sabine-Neches ship channel. Complex calculations were executed by the geology specialists to determine the method of improvement to ensure the required bearing pressure of the surface. Cement, dry soil, and lime mix was required for site preparation- prior to driving the piles into the ground for equipment foundation support, as shown in Figure 9. Over 30,000 pre stressed 90' – 105' concrete piles have been driven to support major equipment foundation loads.

Figure 9 - Pile Driving at Sabine Pass Site

In order to accelerate schedule Bechtel implemented a pipe material pre-buy program, enabling the early availability of piping material at the time the design was completed. Piping and construction coordinated the liquefaction construction sequence plan, which in turn established the piping isometric drawing release fabrication sequence plan. Piping isometric drawings were released after the three-dimensional model reviews, isometric check against process and instrumentation diagrams culminating in the timely delivery of pipe spools to site.

The cold boxes were moved from the jobsite construction dock to the ISBL foundation by self-propelled module transporters (SPMTs) as shown in Figure 10. The CO_2 absorber being 120' tall and weighing 600 tons was the heaviest crane lift on SPL (Figure 11).

Figure 10 - Cold Boxes Delivered via SPMT

Figure 11 - Heaviest Crane Lift - CO2 Absorber

A staggered approach in constructing the liquefaction trains provided the opportunity to optimize construction resources as they moved on from key activities on one train to the next, qualified personnel taking with them the experience from complex operations on one train to the next. Bechtel was able to direct hire craft, including iron workers, electricians, and boiler makers from the Gulf Coast with an extensive quality training program that enabled a very high level of construction quality into the trains.

Construction had a clearly laid-out work execution plan that was sequenced with pre-commissioning/commissioning activities by the commissioning and startup group, which helped in the seamless handover of work areas from construction to commissioning.

Project manpower loading shown in Figure 12 for Trains 1 through 4 illustrates how Bechtel was able to transition the craft from one Train to the next.

Figure 12 - SPL Workforce Planning

The success on SPL is a testament to successful project management, including construction set-up, work planning, execution, and coordination among key disciplines, that enabled the delivery of four LNG Trains six to nine months apart one after the other. NTP for Train 5 did not occur at an optimal time, but much of the workforce can transition to minimize most inefficiency in execution.

Train	EPC Contract Substantial Completion	LNG Cargo Ship Load
1	December 2016	February 2016 Actual
2	September 2017	August 2016 Actual
3	June 2017	January 2017 Actual

4.0 FACILITY DESIGN

Liquefaction capacity is being added to the LNG terminal in a staged approach for a total of six LNG trains. SPL liquefaction trains utilize the existing five LNG tanks (storage capacity of 16.9 billion cu.ft) and the marine facilities (two docks that can handle vessels up to 265,000 cu.m)that were originally built and operated as an import terminal.

The liquefaction facility design is based on 6 GE LM2500+G4 SAC (water injected) turbines per train - each train capable of approximately 4.5 MTPA LNG, arranged with two propane refrigeration turbine/compressor sets in parallel, two ethylene refrigeration turbine/compressor sets in parallel, and two methane refrigeration turbine/compressor sets in parallel. Refrigeration turbines are equipped with evaporative cooling to enhance turbine power at high ambient temperature.

Each liquefaction train contains the following equipment:

- Gas treatment facilities to remove solids, CO_2, sulfur, water, and mercury
- Six standard annular combustor aeroderivative LM2500+ G4 gas turbine-driven refrigerant compressors, each rated at 34.7 MW, using water injection for emissions control
- Ethylene cold box, methane cold box, and core-in kettle heat exchangers for cooling and liquefying the natural gas
- Heavies Removal Unit with demethanizer, debutanizer, and condensate stabilizer columns with associated pumps, exchangers, and vessels
- Condensate storage tank with truck loading facilities
- Waste heat recovery systems for regenerating the gas driers and amine system
- Approximately 160 induced draft air coolers for cooling the refrigerants
- Associated fire and gas detection systems and safety systems
- Associated control systems and electrical infrastructure
- Utility connections and distribution systems as required
- Piping, pipe racks, foundation, and structures within the LNG train battery limits
- Interconnections to existing facilities
- New and remodeled buildings to accommodate increased equipment
- LNG storage and boil-off gas compression (five existing storage tanks will be used)

Utilities and support facilities include:

- Wet and dry flares
- Marine flare
- H2S removal system and thermal oxidizer
- Refrigerant storage
- Miscellaneous storage (lube oil, chemical, etc.)
- Fuel gas system
- Effluent and wastewater disposal
- Electric power generation and distribution (four existing GTGs)
- Fire water systems
- Heating medium system (using waste heat recovery)
- Compressed air (plant and instrument air)
- Nitrogen system
- Service water, potable water, and water demineralization
- Defrost gas
- Buildings

Additional modifications to the SPLNG terminal that were made to accommodate LNG liquefaction trains include:

- Replacement of ten existing in-tank LNG pumps
- Accessibility/roads to new liquefaction facility
- Expansions to security and perimeter access control systems
- Expansions to telecom, IT, CCTV, and other systems
- Expansions to existing DCS systems
- Modifications to existing terminal buildings and addition of new buildings (warehouse, materials, offices, remote I/O, substations, shelters, etc.)
- Check valve modified on LNG unloading (to facilitate LNG loading/bi directional capability)
- Four new New LM2500+ gas turbine generators

The LM2500+4 (PGT25+G4) is a high efficiency gas turbine shown in Figure 13. It has a two-stage power turbine operating at 6100 RPM. These gas turbines drive centrifugal compressors as shown in Figure 14.

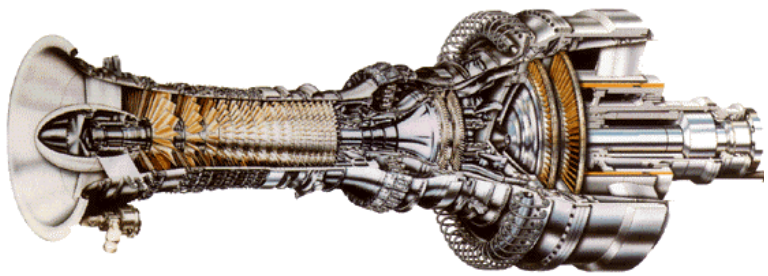

Figure 13 - High Efficiency Aero-Derivative Gas Turbine on SPL [courtesy of GE Oil and Gas]
Engine salient Parameters: 34 MW, Efficiency = 41%, Pressure Ratio = 23:1,

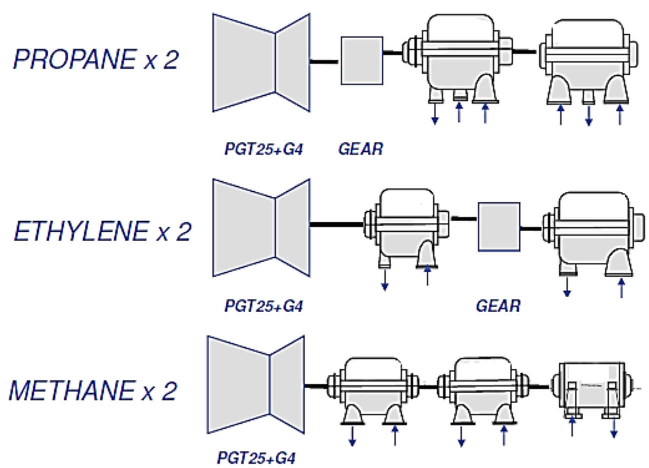

Figure 14 - Gas Turbines-Driven Centrifugal Compressor [courtesy of GE Oil and Gas]

To enhance the thermal efficiency of the plant, gas turbine waste heat is utilized for hot oil service and regeneration heat (as shown in Figure 15).

Figure 15 - Waste Heat Recovery on Ethylene Gas Turbine Exhausts

For power augmentation especially at high ambient temperature, evaporative cooling is utilized. On extremely hot days, significant reductions in turbine inlet air temperature can be derived using evaporative coolers, thus providing additional gas turbine power.

5.0 LIQUEFACTION TECHNOLOGY

The liquefaction plant design is based on the ConocoPhillips Optimized Cascade® process technology, which utilizes a "two-trains-in-one" reliability concept that has been successfully proven in more than four decades of plant operation.

The simplified diagram in Figure 16 illustrates the basic features of the process. It is the pioneering liquefaction process in operation utilizing high efficiency aero-derivative turbines, first employed at the Darwin LNG facility that came online in 2005. A key advantage of this process is that it can be operated at significantly reduced rates even when a compressor is offline. This ability results in high plant availability to maximize overall LNG production. The schematic below illustrates how the Optimized Cascade® process LNG. The raw gas is first treated to remove carbon dioxide (CO_2), Hydrogen Sulfide (H_2S) and other sulfur compounds, water (H_2O), organometallic mercury compounds, particulates, and other contaminates before it is routed to the liquefaction section of the plant. The treated gas is then chilled and condensed to approximately -162°C in successively colder heat exchangers using predominantly pure propane, ethylene, and methane as refrigerants. The LNG product is then pumped into insulated storage tanks where it remains until shipment. Boil-off gas and ship return vapors are captured and recycled through the Optimized Cascade® process for efficient re-liquefaction.

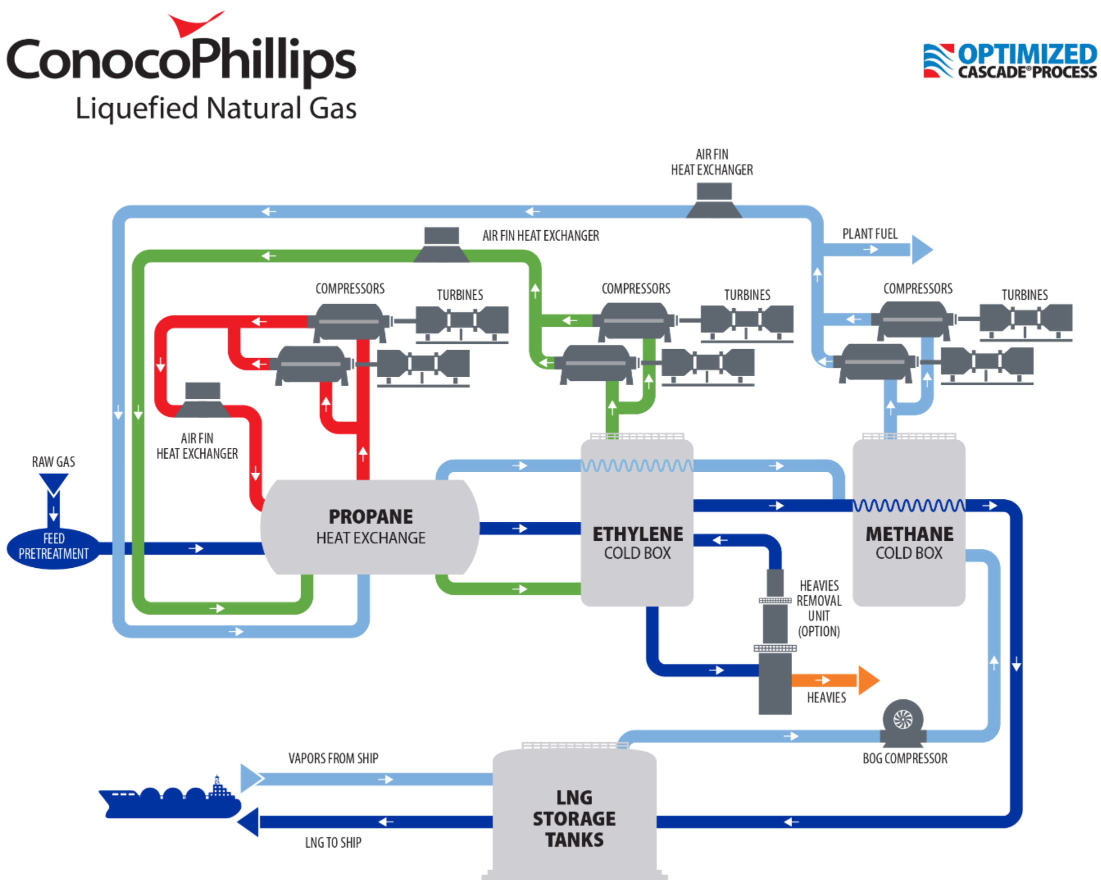

Figure 16 - ConocoPhillips Optimized Cascade® Process Technology [courtesy of ConocoPhillips]

Due to the propensity of heavy feed gas contaminants precipitating and freezing in the cold section of the plant, each train is equipped with a heavy hydrocarbon removal unit.

The heavy hydrocarbon removal unit is designed to remove heavier hydrocarbons from the natural gas, .i.e., hexane, heptane, octane, nonane, and C10+ including aromatics such as benzene, toluene, ethyl benzene, and xylene (BTEX). These heavy hydrocarbons that could freeze in the liquefaction process are efficiently removed by concentrating into a stabilized condensate product that is stored and later transported to market by truck.

Heavy hydrocarbons have the propensity to freeze when present in the feed gas concentrations even at concentrations lower than a few ppmv. The presence of freezable components and the potential for variations in pipeline feed gas composition required the design of a HRU capable of reliable and efficient operation across all ranges of pipeline feed gas composition. Prior to the heavy hydrocarbon removal unit, the feed gas is cooled in the propane and ethylene systems. Since the heavy hydrocarbon removal unit is closely integrated with the LNG plant, a careful selection of optimum column operating parameters ensures a higher overall LNG production efficiency.

The design of the Heavies Removal Unit at SPL is robust and flexible to handle pipeline feed gas composition variations while maximizing LNG plant production capacity, without freezing. This was accomplished by rigorous process simulation and design, appropriate selection of equipment with optimum equipment design margins, followed by additional process rating case simulations that set the operating envelope for the facility.

6.0 PLANT COMMISSIONING AND START-UP

Key discussions with LNG technology and startup specialists in the early stages of the project were critical in identifying the design elements that would be required to start the plant, e.g., turbine waste heat from compressor runs to condition front-end gas for initial defrost in the absence of a startup fired heater. In addition the nuances of operating a liquefaction facility that was still a regasification facility were identified and appropriate adjustments to typical procedures were made.

The active involvement of startup specialists continued during the engineering phase of the project as they reviewed process and instrumentation diagrams, alternate equipment operating conditions during startup, and provided input to multiple design documents, including HAZOP recommendations while drafting the detailed commissioning and startup procedures. Startup scoped design documents, including process and instrumentation diagrams and single-line diagrams to control and manage their work.

Startup schedulers developed the important milestones critical to commissioning and startup activities as early as four to six months in advance of construction turnover. Waterfall charts were prepared in sync with construction schedules to identify critical paths and plan for a seamless startup.

Typical commissioning activities, including system walk downs, loop checks, motor rotation, pipe pressure tests, system flushing/cleaning, etc., were efficiently organized using schedules, charts, commodity curves, work plans, status reports, and closely coordinated with design office engineering support.

Plant startup activities were judiciously scheduled in a logical manner (Figure 17) and executed with great precision, commencing with critical utilities commissioning, flare light up, fuel gas system, compressor mechanical runs, front-end operation, defrost gas to dry refrigerant systems, introduction of refrigerants, and operating the refrigeration compressors to commence plant cool down, leading to first LNG.

Bechtel, ConocoPhillips, and Cheniere personnel with significant LNG experience were able to smoothly startup and successfully performance test the liquefaction trains before handing over the operating plants to Cheniere.

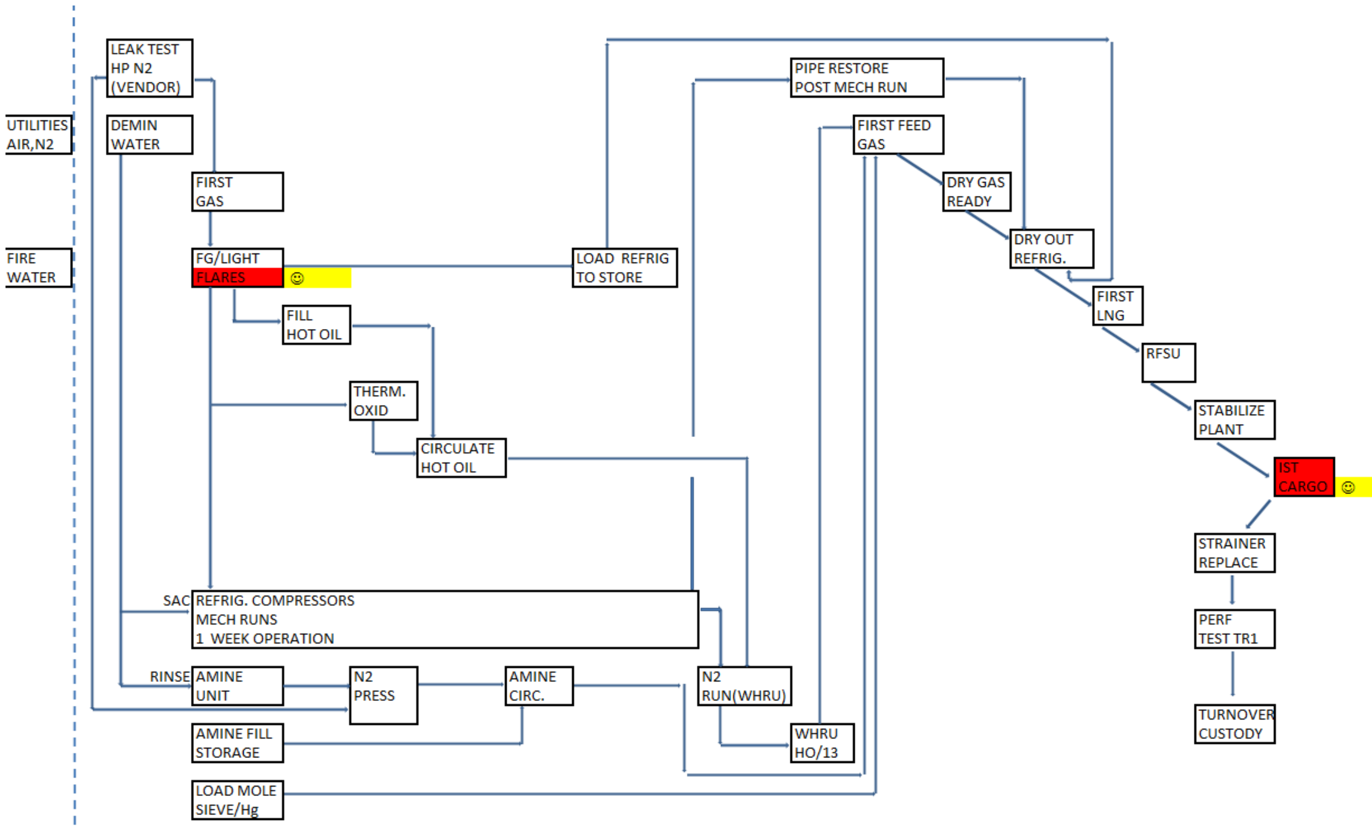

Figure 17 - Start Up Logic Flow Chart

7.0 CONCLUDING REMARKS

Cheniere, having successfully operated a world-class 4 bcfd LNG import and regasification terminal at Sabine Pass, made a strategic decision to capitalize on the paradigm shift in US natural gas market conditions by adding LNG export/natural gas liquefaction capacity to their existing LNG terminal. Being a first mover with a short time to market for US LNG export and an attractive offtake model, Cheniere was able to generate significant interest from capital investors and LNG buyers alike.

Cheniere's pragmatic approach in efficiently managing the project application process, securing financing, marketing LNG to buyers, and making sound and timely project decisions collectively with Bechtel's best-in-class turnkey (concept to commissioning) LNG project execution, ensured a fully operational world-class LNG facility commissioned ahead of the scheduled date.

Cheniere's success with Trains 1 and 2 is expected to be repeated on the remaining Sabine Pass liquefaction trains. A sister plant is also being built by Bechtel for Cheniere at Corpus Christi, Texas. The two LNG trains under construction there are essentially duplicates of Sabine Pass, thus continuing the synergies and experience of the project teams. Cheniere's vision is to be recognized as the premier global LNG company. The success shown at Sabine Pass Liquefaction is just the beginning of fulfilling that mission

Acknowledgements:

We thank the management of Bechtel, Cheniere, and ConocoPhillips for their support and guidance.

NOMENCLATURE

AAV	Ambient Air Vaporizer
BOG	Boil-Off Gas
CAGR	Cumulative Annual Growth Rate
EPC	Engineering, Procurement and Construction
FEED	Front-End Engineering Design
FERC	Federal Energy Regulatory Commission
FID	Final Investment Decision
HRU	Heavies Removal Unit
LNG	Liquefied Natural Gas
LSTK	Lump Sum Turn Key
SCV	Submerged Combustion Vaporizer

REFERENCES

[1] Terry Yen, (2016) "Most natural gas production is expected to come from shale gas and tight oil plays," (2016), EIA Energy Outlook Jun 7, 2016.
[2] NeaL Shear, (2015) ***"Cheniere Energy, Inc. 2015 Annual Report",*** *Cheniere*, 2015.
[3] Darron Granger, (2013) ***"Sabine Pass Project Update",*** *ASME-South Texas Section- Houston*, 2013.
[4] Darron Granger, (2013) ***"Adding Liquefaction Capability to an existing LNG Regasification Terminal",*** *Gastech- - London*, 2012.
[5] Jack Fusco, (2016) ***"Adding Liquefaction Capability to an existing LNG Regasification Terminal",*** *CEO Energy-Power Conference,* 2016.
[6] David Thames, (2012) ***"Securing Gas Supply",*** *Investor/Analyst Day Conference,* 2012.
[7] Charif Souki/Keith Teague, (2014) ***"Securing Gas Supply",*** *Investor/Analyst Day Conference,* 2014.