CRYOGENIC
INDU

FROSTBYTE

A newsletter from Cryogenic Industries | Spring 2015

[redacted]

A developer wishing to install a natural gas liquefier is faced with the question of how much capacity to install and when. At first thought, a single train that meets the projected demand for the life of the project would make the most economic sense. However, if the plant is not fully utilized and is operating at reduced capacity to match a growing market demand, taking into account the time value of money, a developer may be better off installing multiple smaller plants. In addition to the economic benefit, multiple trains also provide the developer and its customers, assurance of supply.

LNG adoption for vehicle, rail, marine and high horse power use is still in the early stages and many developers are faced with the challenge of raising capital for LNG production while attempting to secure sales contracts for product. Multiple-train scaling to match production is not only more cost effective, but also mitigates risk associated with market growth forecasts. Additionally, this approach also defers the requirement for capital which is appealing to lenders.

Given these not-so-obvious factors, it is very likely that the more cost effective approach for a developer is p i tą Ÿ l ʿ ms m@ dAny rabe c y t at p l ƞ l ụ ᶠ Mworecasts.2A this a p ḫ ŵc a one m Ḙ s ၧ Ḝ m pith s ᵠ ɔ s ᵠ p я l ᵠ ɜ†] r gm Ḙ a these benefits with a simple case study.

There are many benefits of installing capacity in smaller increments, the most valuable of which is the ability to postpone capital investment.

Furthermore, a developer that projects the futur " ӟ e added to the first 150,000 gallon-per-day train. The flexibility to match the demand growth curve for LNG by slowing down or speeding up orders for additional trains may be well worth the trade-off in capital expenditure to many companies, especially if the full projection capacity for the market is not expected to be reached for several years or is not well defined.

ach also allows a developer the ability to 'test' a market inimum of capital investment. Companies rushing a market have to make decisions about how much ve the market can handle even before having nailed h end-users. By going into a market first with a small pliers can show their potential customers that they are arket and allow both parties the opportunity for a test-hip.

Other considerations which are sometimes overlooked are the losses associated with stopping and starting and running too far turned down. By installing smaller plants, a developer can realize significantly lower operating costs when compared to the costs of running one large train. In the early stages of a project, when market demand is small, a developer that decides to install one large train for the life of the project will need to operate the plant at reduced capacity or routinely stop and start the plant to match the current market needs. Running the plant in a turned down mode or routinely starting and stopping the plant will result in a power penalty when compared to running the plant at full capacity, continuously. When starting up a liquefier, the cryogenic process takes time to cool down before liquid is produced and the power consumed during this period is essentially wasted, since it does not contribute toward making any product. A more closely matched, smaller plant will require fewer stops and starts.

Running in turned-down mode has limitations and power penalties as well. It is typical to turn down the plant output to match demand, however there are limitations as to how far a plant can be turned down due mostly to inherent characteristics with rotating machinery. In addition, plants do not turn down linearly, meaning a developer will not realize an equally corresponding savings in energy with the same percentage of production turn down. Furthermore, at some percentage of turndown

Continuing with the study, a present value of the capital associated with each of the configurations in Figure 1 is calculated using a discount rate of 15%. The capital values assume the following design basis. First, natural gas is liquefied using a nitrogen expansion cycle. The simple design, wide range of operating flexibility, and low capital cost of a nitrogen cycle liquefier makes this technology the optimum choice when considering capacities of this size. Furthermore, nitrogen liquefaction cycles use standard "off-the-shelf" machinery which lends the technology to offering liquefiers of various sizes. Second, the developer will install the infrastructure necessary for the entire capacity required for the life of the project, up front. This infrastructure includes gas pretreatment for the 850,000 gallons-per-day of required capacity and a field erected storage tank. In a more rigorous analysis, this assumption can be further explored to determine the optimum pretreatment and storage capacity build-out rate.

The results of this present value calculation finds that though the nominal capital cost of the single (850,000 gpd) train is significantly less than for any other build-out mode, when the investments are discounted back to present value the two-train approach (2 x 450,000 gallons-per-day) it actually costs less.

Next, a present value for operating expenses is calculated. In this case study, the OPEX model only accounts for energy (electrical) consumption. It assumes an electrical price of $0.12/kWh and takes into account the varying efficiencies of running the plants at different rates of turn down while demand grows. When the OPEX present value is added to the CAPEX present value, the three-train solution becomes the overall lowest cost approach.

Figure 2 below depicts the CAPEX and OPEX contribution to the present value result for each of the plant configurations modeled. The differences in present value between the 2, 3 and even 4 train build outs are small in this analysis. Further refinement of the model will lead to a clearer picture of the optimum solution. However, it is clear that the one train approach is not the optimum solution.

For clarity, the summary table [Figure 3] on the next page is an example of the table of values used to calculate the CAPEX and OPEX contribution depicted in Figure 2. A similar table was built for each of the options modeled.

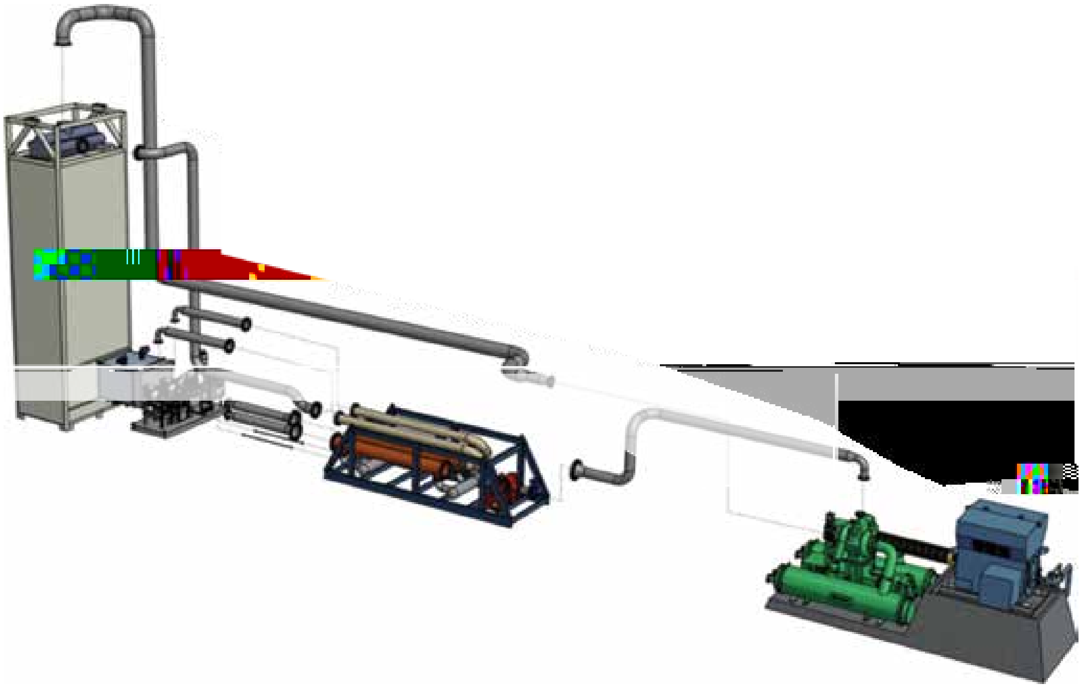
It is important to explore the sensitivity of the model under the given circumstances. Modifications to the IRR, demand growth rate, or projected maximum demand can each have a significant impact on the results of the analysis. In the given example, raising the IRR to 19% pushes the lowest-cost build-out to the 4-train approach, and likewise decreasing it to 13% pushes the lowest-cost build-out to the 2-train approach. Increasing the demand growth rate to 26% points to fewer trains, whereas decreasing it to 14% points to more trains. And changing the maximum projected market demand to 725 thousand gallons a day decreases the number of plants in the optimum train build-out mode, while changing it to 1.25 million gallons a day increases the number of plants in the optimum train build-out mode. The results of the analysis may be fairly conclusive to changes in some of these variables, but on some variables, the results may lie in between two optimum solutions. In that case, it will be worth considering the results in both situations and determining which leaves the developer more flexibility to change its m ɿ ᵀ ŎM
In t ʿ wilM

Mc o
Ɛ ! ebu ` s
o he nἷ ⁱ M s ! ʿ s char

Summary Table For Three-Train Build-out Analysis

Years	Market Demand, GPD	Trains Installed	Installed Capacity	Turndown Ratio	Electrical Demand, kWh		Capex, MM		Opex, MM
0	90,000	1	283,333	0.32	47,258	$	135,840,000	$	1,980,000
1	106,200	1	283,333	0.37	54,197	$	-	$	2,280,000
2	125.316	1	283,333	0.44	63,683	$	-	$	2,670,000
3	147,873	1	283,333	0.52	76,654	$	-	$	3,220,000
4	174,490	1	283,333	0.62	94,390	$	-	$	3.960,000
5	205,898	1	283,333	0.73	118,639	$	-	$	4,980,000
6	242,960	1	283,333	0.86	151,793	$	-	$	6,380,000
7	286,693	2	566,677	0.51	147,798	$	34,460,000	$	6,210,000
8	338,297	2	566,677	0.60	181,244	$	-	$	7,610,000
9	399,191	2	566,677	0.70	226,974	$	-	$	9,530,000
10	471,045	2	566,677	0.83	289,500	$	-	$	12,160,000
11	555,833	2	566,677	0.98	374,990	$	-	$	15,750,000
12	655,883	3	850,000	0.77	388,429	$	39,950,000	$	16,310,000
13	773,942	3	850,000	0.91	499,835	$	-	$	20,990,000
14	( )Tj	EMC	3.4850,000	0	Td(20,990,000)Tj/Span/ActualText	$	FE17 -	$	20,4,37000

14



Quality of the Steam

The condition of the steam is essential for proper operation as well as longevity of the unit. There are several factors to keep in mind:

Saturated – The steam needs to be injected at saturation temperature so the heat can be absorbed by the water in the tank.

Super-Heated Steam – Super-heated steam requires a special design to ensure that the heat of the steam is absorbed by the water. In

Special Features / Options

-

North America

ACD • Atlanta • California • Houston • Pittsburgh • Red Deer • Toronto Cosmodyne • Cryoquip • Energent

South America	Australia	South Africa
Cryoquip	Cosmodyne Packaged Plants	ACD • Cryo