~~Big~~ Mid scale is beautiful

Tom Haylock, Aragon, highlights how new thinking, driven by the evolving LNG market, is challenging the established approach in liquefaction.

The traditional picture inherited from large scale LNG projects to date has been that single large trains of production, with maximised output for a specific driver, is the best approach both technically and commercially. However, like the global LNG industry, this picture is changing thanks to the previously niche LNG sector evolving on both the supply and demand sides.

The traditional LNG approach is having what can be described as an existential crisis and with some players having to consider the difficult proposition that what they once knew to be true may no longer be so.

As an engineering partner with a core focus on FLNG, and small and mid scale LNG production for more than a decade, Aragon has seen at-shore FLNG become more and more established as a competing approach for cost effective liquefaction. It can be argued that it presents an ideal solution for the current market.

Existing LNG facilities constructed in the last 30 to 40 years have been sanctioned based on offtake contracts of typically 20 years, with a small number of A-rated offtakers buying all of the LNG produced. This model has been highly successful and accepted by financiers, enabling project financing for large,

complex, and expensive onshore projects. However, the LNG market has changed. With the significant volumes available on the market thanks to new production coming online, the traditional contract models with long term offtake are no longer the norm. According to Shell & IHS, the average contact length has changed from approximately 18 years (2008) to approximately 7 years (2016). Average contract volume has changed from approximately 2.3 million tpy (2008) to approximately 0.8 million tpy (2016), and credit ratings of buyers has changed significantly from greater than 95% A-Rated with the rest B Rated (2008), to less than 30% A-Rated, approximately 20% B Rated and the remainder Non-Investment Grade.

New projects face a market with more buyers, wishing to buy smaller volumes for shorter durations and with lower credit levels.

Furthermore, the track record for traditional onshore LNG has not been one of on time, on schedule and on budget delivery for many recent projects. Traditional large scale onshore facilities are very complex by their nature and adding the challenge of constructing such facilities in locations with little to no infrastructure and/or local capability results in an exceptionally challenging execution, even for the best in the world.

So, it should not come as a surprise that project finance is not comfortable in this new world and do not have the appetite to finance multi-billion-dollar large scale projects in remote locations, as was typical for LNG projects previously.

The current market is a perfect storm against traditional large scale onshore liquefaction. For liquefaction projects to be credible both in terms of ability to execute and in terms of financing, a new approach is necessary, and the answer is one that is growing in popularity. Mid scale liquefaction solutions, i.e. trains producing 1 million tpy to 1.5 million tpy, applied in multiple to meet the target total production. This is the approach championed by many in the FLNG community, including Aragon, for over a decade.

Mid scale production (1 million tpy to 1.5 million tpy per train) provides the following benefits:

- **More manageable projects** – by having multiple identical trains of liquefaction, the overall complexity for project execution can be reduced due to having identical, multiple trains, typically with simpler arrangements. This allows for staggered deliveries and installation as well as easier modularisation which gives a more optimised design and execution process. By splitting projects into multiple trains, and also potentially into phases, first LNG production is not dependant on single critical items of liquefaction equipment being delivered on time.
- **Standardised solutions** – by applying multiple train solutions, it is possible to apply standardised liquefaction train designs where equipment is rated to a pre-selected driver, designs are largely pre-completed and, in some cases, modularised allowing application both onshore and for FLNG with fabrication in specialist yards further improving efficiency, cost, and project control. Production is then verified for site specific conditions. To achieve the total production, it is simply to add additional trains as necessary. Through using standardised solutions, it is possible to significantly simplify the engineering and design process and benefit from cost savings. There are various standardised designs for different technologies and providers available in the market.
- **Proven hardware** – LNG equipment is normally large, even for mid scale production. A key strength in mid scale solutions is that it is possible to stay within well referenced equipment sizes and apply high efficiency drivers for the production per train to optimise thermal efficiency of a plant. There is no need to take special approaches, consider unproven solutions or re-invent the wheel.
- **Greater operational flexibility and higher production per year** – as already highlighted, if you have multiple trains you inherently have a more flexible ability to produce LNG. Impacts due to maintenance are minimised as it is possible to continue producing through staggering maintenance activities across trains, ensuring relatively stable operation for the upstream pre-treatment plant rather than the need to shut down and restart all systems. Unexpected downtime for a train furthermore does not result in total loss of production as it is unlikely for all trains to have unexpected trips or equipment failures simultaneously. It is also possible to operate across a much wider range of turndown with improved energy-efficiency.

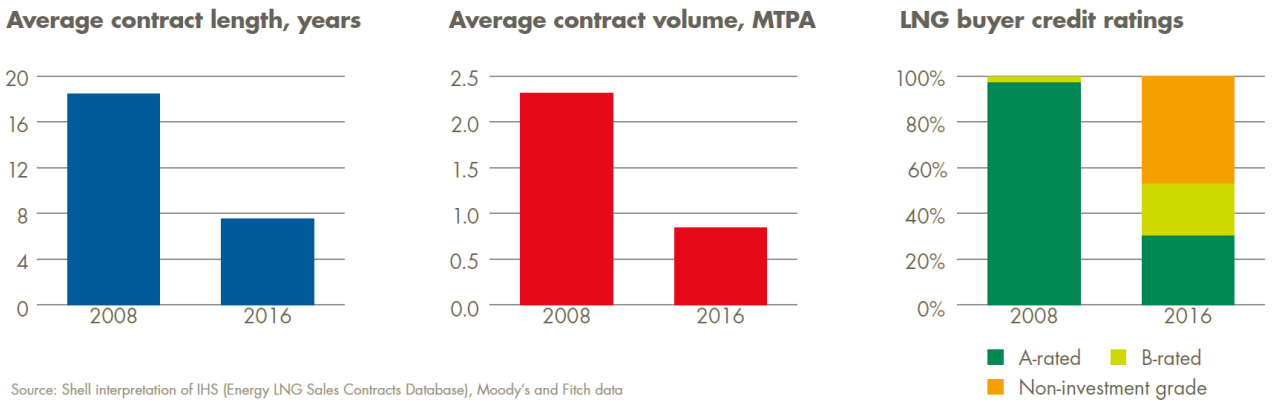

Figure 1. Structural changes in the LNG market. (Infographic courtesy of Shell).

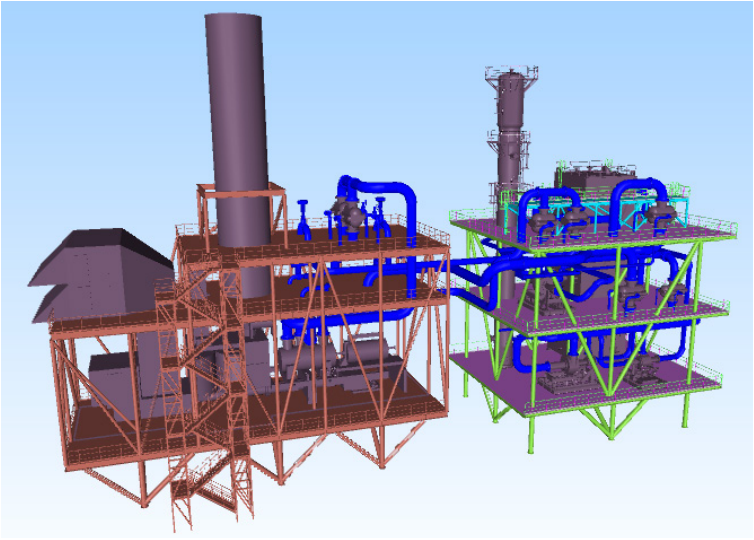

Figure 2. Aragon's standardised mid-scale ODEC liquefaction train design.

Considering all of the above, a project then becomes much more financeable as the risk is lower in terms of initial investment cost, execution, and technical complexity. A good example of this is Tellurian's Driftwood LNG project applying 20 trains of SMR liquefaction to achieve approximately 27 million tpy, intending to achieve a CAPEX target of 550 US$/t LNG produced.

The US is unique though in having an LNG project industry on its front doorstep with all necessary expertise and capabilities with relatively simple access to gas. So, although mid scale solutions address many issues, for projects outside of the US they cannot address the geographical challenges of building a facility in country unless they are applied as part of an FLNG project. For onshore plants, building large scale LNG storage as well as construction activities in country add cost, time, and risk, even when modularising a plant as has been done at projects such as Yamal LNG. The simple solution is at-shore/nearshore FLNG. The schedule, execution, and cost overrun risk is greatly reduced by building a facility in a shipyard specialised in such activities. Even in the US, FLNG has its benefits, for one it is the ability to side step the queue in FERC and apply via the MARAD route, which in theory allows for faster approvals and LNG production.

That is not to say that FLNG is simple to execute. Again, if the wrong approach is applied an FLNG project will not move ahead as it will not be cost effective, and there have been numerous examples of this in the past. Some of the key factors to considers are:

- **LNG production per facility** – it is important to know the practical limit in terms of total LNG production per facility, both in terms of technical practicality for cost and execution, but also in terms of financeability. Do not be tempted by the old argument of maximised LNG production as far as possible. Beyond a certain point the facility grows out of proven hull sizes and into realms of the new and unproven, which results in increased uncertainty and high costs. It is an advantage to set the facility/hull size and then optimise the LNG production for that given area. Should more production be needed, it is simply to build another FLNG facility, which has the added benefit of further LNG storage and offloading facilities to improve offloading availability as well as being a separate asset with its own financing. By applying this approach, the amount of required finance can be kept within acceptable limits with an acceptable risk profile for financiers.
- **Selection of correct liquefaction technology** – considering the above approach of first fixing your available area, it is an error to then select a technology suitable for a single large train and maximise production based on it. A single train liquefaction facility will have poorer total production availability (i.e. LNG produced per year) due to the larger impact of shutdowns and trips for the total facility and also presents a more difficult engineering challenge for acceptable facility design compared to a configuration with multiple trains of smaller production. It is critical for not only CAPEX and OPEX, but also for safe design and operation, that the correct liquefaction technology is selected.
- **Total facility design** – it is easy to be distracted by the choice of liquefaction systems. However, it is important to consider the facility in totality and have a partner that can evaluate, develop, and design the front end, inlet, and pre-treatment facilities, together with liquefaction (whichever technologies are considered) as well as including the utilities and hull/marine scope. Such partners are actually few and far between, as these parties need to have a solid track record for FLNG – including knowing the correct approach to apply, have both topsides and marine capability, and have experience and ability in applying all relevant liquefaction technologies. In reality, there are maybe a handful of such partners globally – including Aragon.

The LNG market is growing, evolving, and becoming more diverse, which is moving it away from traditional models. For liquefaction to be cost effective mid scale solutions as part of an FLNG development are an optimal solution to achieve the risk profile and total cost that results in a bankable project thanks to:

- More manageable scope for design, execution, and installation.
- CAPEX can be kept within acceptable levels by splitting projects into phases that also fit well for optimal sizes for FLNG vessels (up to approximately 3.5 million tpy).
- The project risk profile can be minimised through having greater control of the work and executing fabrication in specialist facilities rather than stick building in country.
- The use of proven equipment sizes and technologies.
- The use of standardised liquefaction designs.
- Partners who know how to apply the correct approach. LNG