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THE RISE OF SMALL-SCALE LNG/FLNG PROJECTS AS AN ALTERNATIVE APPROACH TO SUSTAIN GLOBAL GAS SUPPLY

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A) Background

With strong LNG demand globally and an increasing number of importing countries, numerous smaller LNG projects from stranded gas fields in remote locations around the world have been proposed.[1] A combination of strong global LNG demand, more advanced technology, and attractive oil-linked LNG pricing opens doors of opportunity for these stranded gas fields to be monetized. These projects may be onshore or floating LNG ventures, although the first floater has yet to be built. They may supply international markets via shipping, as is the case with full-sized projects, or—particularly for in-land gas reserves—produce LNG to be distributed by truck to meet domestic gas requirements, as occurs in China and the US. Regardless of the marketing strategy chosen, however, small-scale projects, almost by definition, face diseconomies of scale in comparison to larger plants. For this reason, while the number of small-scale LNG projects is expected to grow, they are likely to remain a minority in the overall global LNG supply stack.

Why use small-scale LNG?

The two key drivers behind constructing small-scale LNG plant are small stranded gas resources and lower initial capital investment required. The first key driver, small stranded gas resources, is quite straightforward as large LNG cannot simply be built with

[1] In this paper, we will define a project less than 3 million tons per year (MMt/y) of LNG production as a small-scale project.

limited gas resources. The second factor, lower initial capital investment required, is especially relevant for small companies with limited financial resources, which may opt for small-scale LNG even if the size of the underlying resource is enough to support a full-scale LNG plant. InterOil's venture in Papua New Guinea is an interesting case in point. It has opted to pursue two small-scale projects, one onshore and another FLNG, instead of building a consolidated large LNG complex to monetize its gas resources in PNG. InterOil plans to make only a minimal initial investment on the project directly, relying on innovating financing across the value chain to make up the shortfall. Its development decisions are not driven by reserves size: in a recent presentation (IPAA Oil & Gas Investment Symposia presentation on 2nd February 2012), it indicated that its Elk and Antelope source fields have estimated low-case reserves of 6.5 trillion cubic feet, with a best case of 8.6 Tcf.

It is true that there are advantages that small-scale plants could capture along the LNG value chain, such as faster construction time, simpler liquefaction processes, and lower maintenance burden, but these advantages are merely ways to optimise or help the economics of small-scale LNG plant. These strategies should not be confused with the key drivers of constructing a small-scale LNG project.

Many factors can potentially benefit both large and small-scale LNG, and so therefore cannot be considered drivers to constructing small-scaled LNG. These include geographical area, types of resources, liquid credits from oil and condensate production, flexibility of using small ships, and optimisation across LNG value chain. All could certainly provide opportunities for small-scale plants, but it is not true to say that large LNG plant will not likewise gain benefits from these factors.

B) Discussion

Regional Variations

Existing and potential small to mid-scale LNG markets have diverse locations, including China, Australia, Indonesia, Norway, USA, and Latin America. The size and nature of the opportunity vary regionally.

Potential small scale LNG development (< 3MMt/y)

Many of the small-scale projects require high, oil-linked LNG price for the project to be economically viable. This gives Asia Pacific markets an advantage in attracting LNG sellers over the Atlantic basin markets. Most planned small-scale projects for supplying international markets (our primary focus in this paper) are in Australia and Indonesia, which can readily access markets with premium Asian pricing. Examples of potential small-scale marine based LNG projects are as follows:

Small-Scale LNG Projects - A Partial Inventory

Project	Countries	Capacity (MMt/y)
Fisherman's Landing	Australia	1.5-3
Southern Cross	Australia	0.7-1.7
Metgasco Flex LNG	Australia	2
South Australia LNG	Australia	< 3.0
Abbot Point	Australia	1
LNG Newcastle	Australia	< 1
PTTEP Cash Maple FLNG	Australia	2
Bonapart LNG	Australia	2
Liquid Niugini FLNG	Australia	2
Port Douglas LNG	Canada	1.8
Sengkang LNG	Indonesia	2
Petronas FLNG	Malaysia	1.2
Pechora LNG	Russia	2.6
	Total	**25.3**

Source: Poten & Partners

Potential international small-scale LNG project sponsors in the Atlantic find development more difficult due to longer distance to such premium markets. Atlantic Basin gas is traded in lower-priced gas-on-gas markets such as the US (Henry Hub) and UK (National Balancing Point - NBP). Even in continental European markets where gas is still largely sold under long-term contracts indexed to oil or baskets of refined products, gas prices are relatively low compared to Asia.

Although not a main focus of this paper, we note that small-scale, inland LNG is particularly in vogue in China, where there are many stranded gas fields and still limited energy infrastructure. The small-scale solutions (up to 0.4 MMt/y) target power generation, industrial and residential urban markets, and transportation, with truck-based distribution of LNG for transportation fuel having a range of up to 4,400 km from the source plant. The US also has long been a major venue for small-scale LNG where it has been used primarily to meet winter peak demand.

The volumes of small-scale projects may seem a natural fit to up-and-coming niche Asian LNG importers such as Thailand, Vietnam, and the small floating regasification units under development in Indonesia, as these destinations offer the opportunity to lift the entire output of small-scale supply projects, potentially simplifying marketing and logistics. However, the attractions are likely to be less than compelling for the buyers. While new importers aim to grow LNG imports rapidly, small-scale projects have at best limited possibilities for volume expansion. Concerns with security of supply may further deter buyers from relying on a single source.

Large vs. small LNG projects

As discussed below, small-scale LNG projects have logistical problems that complicate the determination of optimal ship size and storage and marine infrastructure. These issues constitute a disadvantage vis-à-vis full-scale projects that can only be partially mitigated. Nonetheless, small-scale LNG onshore projects have continued to be proposed, largely because their developers do not have any, or enough, large-scale fields on which to focus. The desire to make lemonade from lemon fields, though, is not the sole reason why small-scale LNG has attracted attention. Advocates for small-scale projects argue that they can compensate for their diseconomies by through measures such as the application of simpler (though less efficient) liquefaction processes, the use of imported power generation/electric drivers and potentially the construction of smaller storage and marine facilities. The total capital requirements for the project are also generally less, which can allow participation from a wider (i.e., less well-heeled) group of owners, buyers and engineering resources than larger projects.

Diseconomies of scale of onshore small-scale LNG can also be dwarfed by other features of the project, such as labour cost, making a straightforward comparison of small-scale and full-size LNG cost difficult. Indonesia’s Donggi-Senoro project illustrates this point. In January 2011, Japan’s Mitsubishi Corp announced that the final investment decision had been taken to build the 2 million ton per year Donggi-Senoro LNG project in Indonesia’s Central Sulawesi, and put the cost of the plant at $2.8 billion. This suggests a liquefaction cost of service (COS), assuming a 12% rate of return, of around $2.9/MMBtu. This liquefaction COS is about 30% higher than that of Peru LNG, but about 10% below Poten’s estimated COS for Kitimat LNG in Western Canada. Meanwhile, large projects in a high cost environment such as in Australia, have liquefaction COS of $6 per million Btu or more.

Floating LNG projects does not yet have a track record. Shell’s full-scale Prelude project is years away from completion, and even so it is well ahead of other FLNG ventures. Several small-scale projects, such as the Santos-GdF Bonaparte project and the PTTEP

Cash-Maple project—both in Australia—and InterOil's floater in Papua New Guinea, might not make a Final Investment Decision (FID) for some time, despite sponsors' protestations to the contrary. Petronas' 1.2 MMt/y FLNG project in Malaysia may be the only small-scale floater closing in on a Final Investment Decision. The designs for the various floating projects nonetheless make it clear that small-scale FLNG projects tend to focus on source fields with lean and clean feedgas, in order to minimize treatment before liquefaction and reduce the amount of equipment crammed on board the vessel. Such focus could conceivably give a cost advantage while avoiding engineering headaches, but it strongly restricts the range of application. There is not that much gas that comes out of its primordial home at near-pipeline quality.

Small-scale FLNG projects are touted to have lower capital cost, at around $1,200/tpa, but the range of potential costs is likely be wider than for large FLNG projects, due to greater uncertainties inherent to a slate of purely pre-FID projects. That range for small-scale FLNG is around $1,200 - $1,800 per ton of annual capacity, vs. around $1,400-$1,700/tpa for large FLNG projects seem to cost around. Poten's view is that the expected cost of small-scale floating LNG projects is likely to increase as the FID date looms closer.

Transportation of LNG from small-scale projects is another important issue. The optimal ship size for small-scale projects is likely smaller, as this reduces the total capital cost required for the project, but small-scale shipping is more sensitive to distance. The main problems are that storage and loading facility costs increase with ship size, not production rate. This means, however, that small-scale projects may be only economically feasible relatively close to markets. Smaller ships mean many more trips. For example, in order to deliver 0.24 MMt/y of LNG to a market around 3,500 nautical miles away from the loading point, a 30,000 m3 vessel (~13,300 tons) would need to make 19 trips a year. A 125,000 m3 vessel—still small by today's standards—would need just four trips per year to deliver the same volume.

There are other logistical disadvantages. Small vessels require loading facilities suited to their size, which limits their options for employment at large-scale ventures and further reduces their charter rates should they become available for lease. The use of small vessels is less attractive to suppliers due to the multiple ship arrivals for very small cargoes which complicate scheduling and tie up berth space for a relatively small volume. Although loading will be much quicker, the use of small-scale vessels will utilise almost as much port time as conventional vessels, which deliver many times more LNG volume per vessel. Moreover, small-scale vessels may be incompatible with existing project infrastructure. The potential compatibility issues relating to ship size were brought home in 2007, when several Japanese terminals in Nagoya bay had to upgrade importing infrastructure to accommodate Qflex and Qmax ships, which range from 209,000 m3 to 266,000 m3 in size. Fenders and mooring dolphins had to be reinforced to accommodate the increased displacement weight of the larger vessels.[2] In

[2] Fenders are cushioning devices typically constructed of rubber, foam elastomer or plastic, and used to prevent damage to vessels and berthing structures, while mooring dolphins are isolated marine structures for berthing and mooring of vessels.

Korea, dredging was also required at the Incheon's number two berth and Pyongtaek's number two berth to increase acceptable draft limitation at the berths in order to safely clear Qflex vessels.

Alaska's Kenai LNG—a small-scale LNG project from the olden days, started up in 1969—illustrates the difficulties. Kenai sponsors decided to switch to a costly SPB ship in 1993, due to the extreme sea condition and limited shipping capacity. The original 71,500 m3 Swedish-built membrane vessels were replaced with SPB ships with a capacity of only 89,880 m3.[3] It is likely that the potential increases in storage and loading facility cost and logistical requirements weighed heavily on the decision to stick with a vessel size far below the average for the early 1990s of 125,000-155,000 m3.

How can niche small-scaled LNG projects overcome disadvantages?

It is generally true that larger ships provide better economies of scale per unit of energy carrying LNG to markets. The main mitigation strategy for sponsors of small-scale projects is to seek markets closer to home. In addition, the drawbacks of small-scale LNG can be minimized by optimizing across the LNG value chain via good design strategy on the storage and loading capacity, marine facilities, ship size, and marketing.

This whole value chain optimisation exercise is complex, and requires in depth and sophisticated modelling tools to determine the best combination of the project, which is beyond the scope of this paper. Nonetheless, for purposes of illustration, a small-scale LNG plant of 2 MMt/y might conceivably, for cost reasons, opt for a large Q-Flex ship. For a voyage distance of 3,000 nautical miles and a ship speed of 440 nm per day, the round voyage time for the ship is about 14 days plus a day loading and a day unloading, or 16 days per voyage in all, allowing about 21 voyages per year per ship. For a Q-Flex ship with 210,000 m3 capacity, loading around 95,000 tons of LNG per voyage, a full years' cargo thus equates to the full 2 MMt/y. The project consequently would need just one ship to meet its trading requirements. Such a project would, however, need a large storage tank and marine facilities, significantly increasing its capital investments. It could be at considerable risk in the event of planned or unplanned maintenance and weather delays.

Sponsors of small-scale LNG face trade-offs that are common to plants of all sizes, yet nonetheless may be critical to overcoming the challenges of diseconomies of scale. They could be tempted to go with the low-cost option, even at the cost of some performance issues. For example, sponsors on a budget might consider the possibility of acquiring used ships for the project, which could be available at low cost given their limited usefulness for mainstream projects. Low prices could offset higher boil off rates and lower fuel efficiency, perhaps enhancing overall project economics.

[3] SPB ship is a LNG carrier developed by Ishikawajima-Harima Heavy Industries (IHI) with a self-supporting prismatic containment system constructed outside the hull. SPB tanks are generally costly due to a considerable quantity of stainless steel plate and complex fabrication, but have proven record of operations under extreme conditions and sloshing prevention.

Choice of technology in developing a small-scale project is important for cost. For example, a small-scale project may want to consider using membrane LNG storage tanks, which are able to offer cost savings and a reduction in the typical 36-month construction time. Membrane tanks require only a very thin layer of stainless steel which can be manufactured off site in large panels, and this uses less material and simplifies construction therefore reduces construction times. Moreover, as membrane tanks transfer the load of the LNG via the insulation to the outer concrete wall less structural support steel is needed which will also reduces material and construction costs, but, membrane tank usage is perceived to be less durable than other tank designs.

Other issues, including liquid credits from condensate and LPG production, strong LNG pricing, fiscal terms and commercial negotiation amongst sellers, buyers, and government, and LNG project structuring, could make a further differences in the project development.

The size and expectations of specific developers play an important role in determining the attractiveness of a small-scale LNG project. An attractive field for a smaller firm may be too small to bother for large international oil companies (IOCs). Ingenious bootstrapping financial arrangements for a cash-poor company may be wholly unattractive for a deep-pocketed IOC. It is no accident that most of the proposed small-scale LNG projects are developed and proposed by non-IOCs. These include some very substantial companies such as Mitsubishi, GDF Suez, and PTTEP, but also smaller companies like Beach Energy, Energy World Corporation, LNG Limited, LNG Impel, Flex LNG, and Metgasco, as well as InterOil.

Small-scale plants should have shorter development and construction schedules than larger plants, reducing time to market, as well as simpler liquefaction processes. Small-scale plants typically use processes that require less equipment with reduced operational complexity and lower maintenance burdens. This increases the range of liquefaction technologies, equipment vendors and qualified engineering and construction resources available to the project. This in turn can create stronger bidder competition relative to large-scale developments. The smaller plant size also increases available choices for equipment drivers, allowing the venture, for example, to consider a wide range of gas turbine vendors or the potential use of electric motors.

Smaller plants also may be able to draw power requirements from the existing grid rather than needing dedicated power generation capability, while plot space requirements are also an order of magnitude smaller than larger-scale LNG facilities. Finally, modular construction becomes distinctly more manageable with smaller facilities, as more yards are capable of building these smaller modules and more equipment is capable of lifting and transporting them.

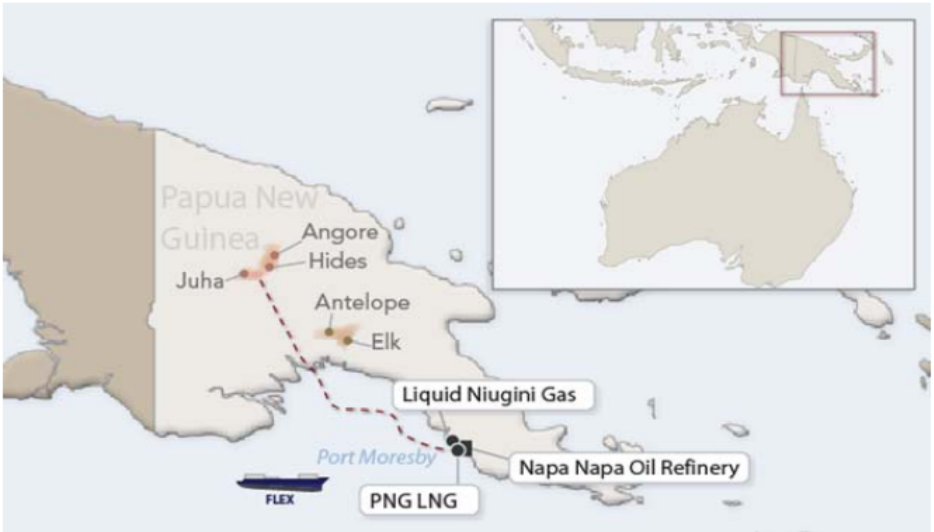
Once again, though, developers should keep in mind that once LNG plant becomes very small, the capital costs associated with marine facilities and offsites no longer decrease as the design production rate is made smaller, which rapidly drives up unit costs. Because of these constraints, the estimated minimum size for a small-scale marine based of around 0.5 MMt/y of capacity. Truck-based supply chains can be downscaled more than marine-based chains due to the truck's smaller loaded batch size (and hence reduced storage and loading requirements).

Case in Point: InterOil project structure enables small player grow

InterOil is an interesting example of an innovative project concept which–if everything works out as the company hopes–would use contractor financing for different components of a combined small-scale onshore and FLNG project in Papua New Guinea. This approach is intended to sharply reduce InterOil's cash flow requirements during both pre- and post-FID phases of the project. Success would utterly transform InterOil, which is a small refining company with small earning of $24 million during the first half of 2011, as it anticipates equity cash flows from the FLNG project of $1.2 to $1.3 billion per year. InterOil's scheme envisions it making only small upfront investments to bring the projects on-line.

Liquid Niugini Gas, the project company, is owned by InterOil and Pacific LNG. Other players in the whole construction venture consist of Mitsui & Co., EWC, Flex LNG, and upstream partners. The plant will be located in the Gulf Province with an onshore plant capacity starting at 2 MMt/y and a FLNG with a capacity around 2 MMt/y. For the onshore facilities, EWC is to contribute all initial equity and debt financing for development, construction, and implementation, of the Train 1 LNG Facilities and any first expansion of LNG. Mitsui & Co. will finance the condensate stripping plant. Upstream partners are responsible for the financing and construction of upstream development. For the FLNG facility, Samsung Heavy Industries is to provide construction financing, accepting one heavy tail-end payment from InterOil's partner, Flex LNG, at time of delivery.

PNG's Potential Gas Infrastructure



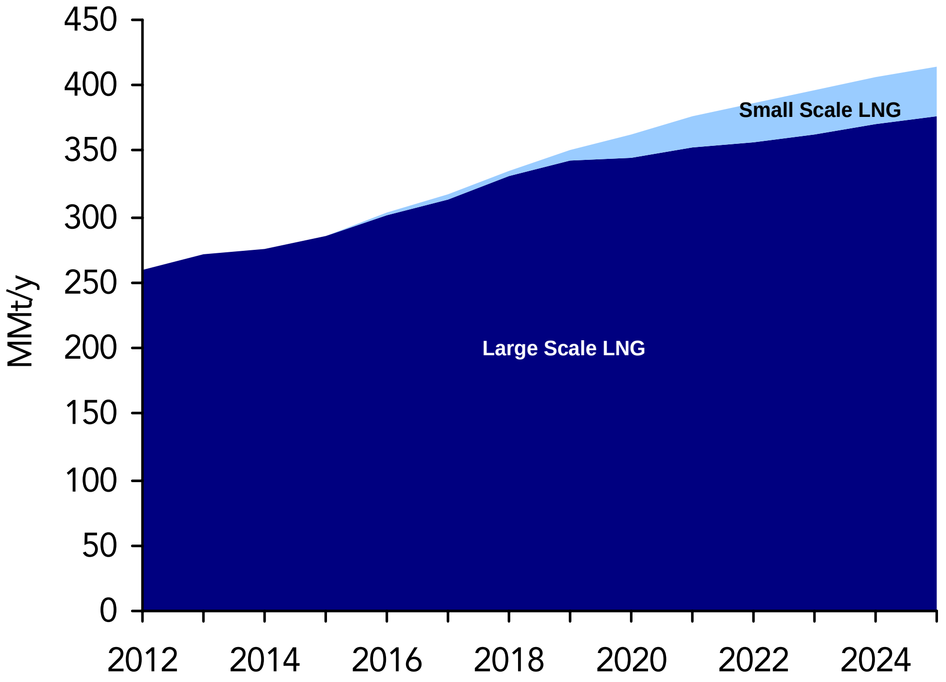
Source: Poten & Partners

The complex contractual and financial arrangements are far from risk-free. For example, If InterOil's onshore condensate stripping scheme with Mitsui stumbles, it would likewise derail the FLNG project because the wellhead gas stream is very rich and there are no plans to process the rich gas as part of the floating project. The floater only expects to have condensate storage capacity of 5,000 cubic meters and LNG storage capacity of 170,000 cubic meters. Finally there are questions regarding the size and quality of the source field itself, the Elk field. InterOil has tried everything to dispel these doubts. Its efforts even include inscribing the field in the Guinness Book of Record for its flow test volume.

Small-scale LNG to remain a minority in LNG supply stack in 2025

Poten's forecast of likely production from small-scale international LNG projects reflects the sobering realities of project development. We expect very little volume from these projects to come onstream before 2019. Our forecasted total volume contribution from small-scale projects reaches just around 10% of to international LNG trade by 2025.

Forecasted World LNG Supply for International Trade



Source: Poten & Partners

Although small-scale LNG projects are expected to grow, long-term prospects for small-scale LNG projects in global LNG supply picture are likely to remain a minority in the overall global LNG supply stack. With Kenai winding down after pioneering international LNG exports from the US to Asia Pacific, Donggi-Senoro is on its way to become the only small-scale marine based LNG project with planned project start up in 2016. The 2016-2020 windows could see a few small projects coming online from countries like Australia, Indonesia, Russia, and Canada. The stronger growth from both small onshore and FLNG project start ups potentially may slip to the post-2020 period. Australia is likely to become a leader in small LNG project with numerous projects in development. These include Fisherman's Landing, Southern Cross, Metcasco, Abbot Point, South Australia LNG, and New Castle LNG. Indonesia's Sengkeng, Canada Port Douglas, Russia's Pechora small-scale FLNG could also join the club in the next several years.

C) Summary

The world of LNG project development has evolved, but only to a certain extent. More stranded gas resource coupled with strong Asian demand for gas and LNG have created opportunities for small-scale LNG and FLNG projects around the world. However, in order for small-scale LNG projects to be economically feasible, several key factors need to be addressed, including optimisation across LNG value chain, competition from large-scale projects, and gas marketing.

Small-scale LNG projects will likely to face tough competition from large-scale LNG project development around the world. More advanced technologies have helped small-scale projects to become more viable, but they are likely to struggle to advance in the project queue against as-yet undiscovered giant gas fields and existing large gas fields in various parts of the world that are still undeveloped for reasons ranging from government policy to local/international politics to simply the huge amount of preparatory work needed to get a mega-project right.