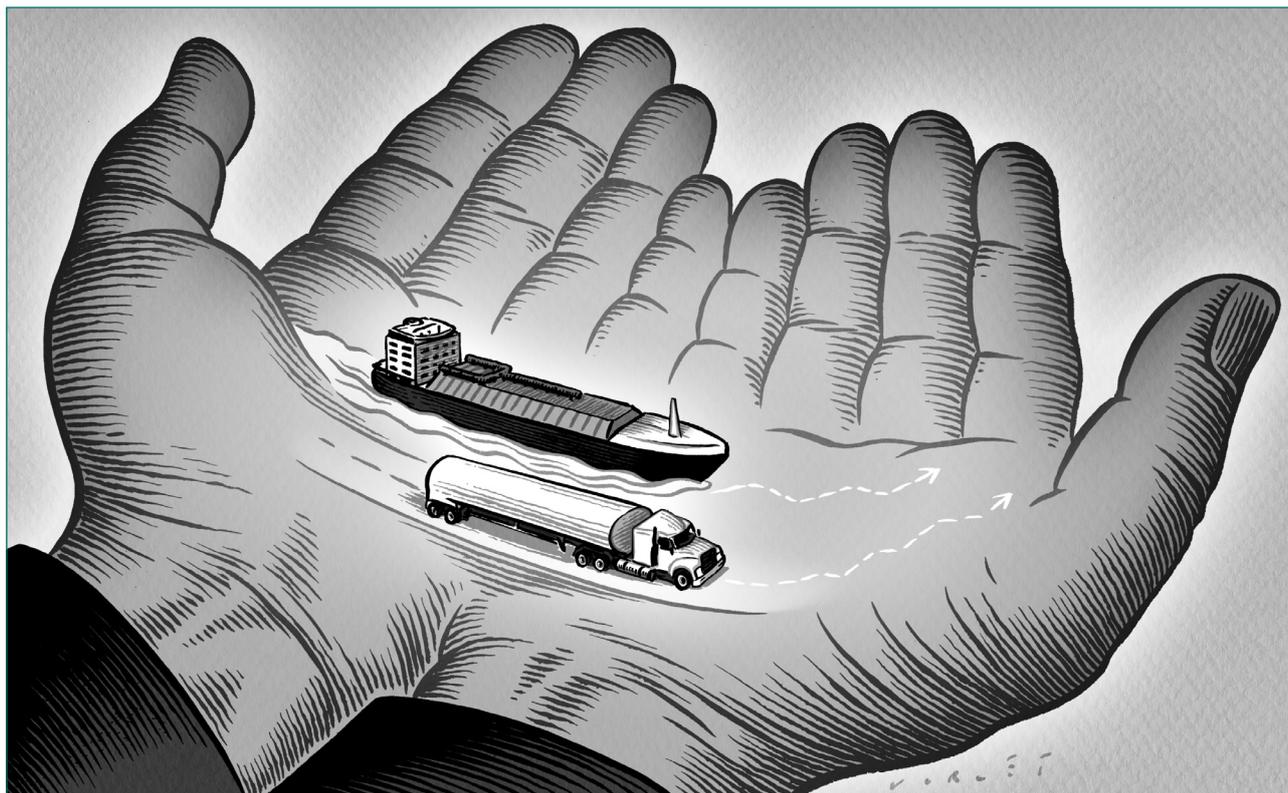


LNG Business Review

Global perspectives for LNG management

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VOLUME 4 ISSUE 1

LNG Business Review goes beyond straight news reporting to effectively address and provide a global perspective on the issues facing LNG management today and in the future. From resources, projects, technical and commercial developments, prices, supply/demand and market trends – the entire LNG value chain is represented in *LNG Business Review*.

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Letter from the Editor

For most people the LNG business is based on large-scale production and maritime transport of LNG. But the commercial application of LNG started on a far smaller scale in 1938 with a peak-shaving plant in West Virginia.

This original use of LNG is still an important part of supply/demand balancing in several countries, and today further small-scale applications are gaining ground, such as “distributed LNG” and LNG as a transportation fuel.

While the total scale of these activities is currently dwarfed by the “conventional” maritime LNG trade, such schemes are growing in number and could grow to significant scale in time. In the cover story for this issue, LNG Business Review takes a look at the “other world” of small-scale LNG applications.

Other features in this issue include:

- LNG activity on the third quarter of 2010 continued the trends seen in the first six months of the year. Global supply and demand grew by 11.1 mt (24.6%) in the quarter taking the total increase for the first nine months of the year to 31.8 mt (24.2%). **LNG Business Review** takes a close look at the numbers.
- 2010 has seen a remarkable turnaround in both the Korean economy and its imports of LNG. The recovery has increased the urgency for Korea to secure new long-term LNG supplies. We look at the reasons for the recovery in Korean LNG demand and review the progress that is being made in negotiations with sellers for new long-term supplies.
- The North American shale gas revolution has been such a game changer that Kitimat LNG in northwest Canada, once an import project, is now set to become the continent’s second LNG export project after Kenai in Alaska. Could Canada really become an LNG exporter? **LNG Business Review** takes a look.
- The recent discovery of the Libra oil and gas field offshore Brazil - the largest discovery since Kazakhstan’s Kashagan field in 2000 – has confirmed the Brazilian pre-salt basins as the most promising E&P province outside the Middle East. **LNG Business Review** looks at how the challenge of monetizing these phenomenal resources could offer a unique opportunity for large-scale LNG, GTL and CNG technologies to co-exist and complement each other.
- As always **LNG Business Review** updates you on the latest news and progress on LNG projects across the globe, drawing on the experience and insight of our experts.

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Please contact me if you have any comments or thoughts on the features from our latest issue. Your feedback is always welcome.

Regards,
Jason O’Connell
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World scale gas projects needed to unlock Brazil's huge oil finds

The recent discovery of the Libra oil and gas field offshore Brazil - the largest discovery since Kazakhstan's Kashagan field in 2000 – as well as the significant recent upgrade of the Tupi and Iracema field reserves have confirmed the Brazilian pre-salt basins as the most promising E&P province outside the Middle East.

When the Tupi field was discovered in 2006 state oil and gas company Petrobras was producing just under 2 million bpd of oil. Now Petrobras plans to more than double production to 4.2 million bpd by 2020. To unlock this oil potential sustainably, Brazil will need to secure large base-load domestic and export gas markets, as the country will be significantly long on gas associated with the oil reserves. The challenges of monetizing the phenomenal pre-salt resources therefore offer a unique opportunity in principle for large-scale LNG, GTL and CNG technologies to co-exist and complement each other. In this article, LNG Business Review looks at some of the challenges, and a potential model to develop world-scale gas export projects, optimizing cost and flexibility.

Brazilian Trade Minister Miguel Jorge has indicated that Petrobras may invest close to \$400 billion through 2020 as it seeks to develop the pre-salt crude discoveries. Petrobras will revise its investment plan next year to include the development of new reserves bought from the government as part of a \$70 billion share sale, the largest in history. And Chinese direct investment and long-term commitments into Brazil this year has surpassed \$70 billion, up from \$83 million in 2009.

The pre-salt basins hold considerable volumes of lighter oil which are expected to displace current light crude purchases from Iraq and Saudi Arabia. According to Petrobras Supply Director, Paulo Roberto da Costa, by 2020 Petrobras should have refining capacity of 3.2 million barrels of oil per day (bbl/d) and production of near 4 million bbl/d, providing the country with the ability to export 800,000 bbl/d, equivalent to over four times today's volumes. Sceptics say these plans are overly ambitious and suggest Petrobras could miss production targets, as significant technical challenges exist in producing hydrocarbons from the pre-salt basins.

The pre-salt basin is located approximately 300 km off the coast of Brazil in the Atlantic Ocean, stretching from Espírito Santo State to Santa Catarina State, some 800 km long and 200 km wide. The region is dubbed "pre-salt" because the oil is held beneath deep and ultra-deep waters of around 2,000 m, another 1,000 m of sand and rock, a thick layer of salt which in some places exceeds 2,000 m, and an additional layer of sand and rock of approximately 2,000 m - making extraction substantially challenging over the 7,000 m distance from the reservoir to the surface. (see figure)

Extracting the crude oil safely will require multiple feats of engineering to overcome reservoir challenges including technical feasibility of water and gas injection; well engineering (hydraulic fracture in horizontal wells, deviation of wells into the salt zone, salt layer approaching granite hardness with high pressure and CO₂ content); flow assurance issues (near freezing temperatures, paraffin deposition, hydrate and scaling control); associated gas handling (over 300 km offshore, 2,200 m deep and pipelines larger than 18" in diameter); shifting ocean currents and marination of production systems in a remote location without infrastructure.

Tad Patzek, chairman of the petroleum and geosystems engineering department at the University of Texas at Austin, said during testimony before the US Congress on the causes of the Deepwater Horizon oil spill in the Gulf of Mexico earlier this year, that ultra-deep water oil rigs have become more complex and harder to control than some oil companies would prefer to admit. Drilling remotely at depths that would crush a submarine requires complex technological systems akin to space exploration, as opposed to mining where the oil industry has its roots.

How much gas needs to find a home?

In early November, BG Group, Portugal's GALP and Petrobras upgraded estimates of gross resources for the Tupi, Iracema, and Guará fields in the Santos Basin by 2.7 billion barrels of oil equivalent (boe). Oil and gas consultants Miller and Lents provided independent verification that Tupi and Iracema's mid-point gross recoverable resources have increased from 6.5 billion to 9.1 billion boe implying an improvement in recovery factor from 27% to 38%. Guara had a smaller upgrade from 1.55 to 1.62 billion boe.

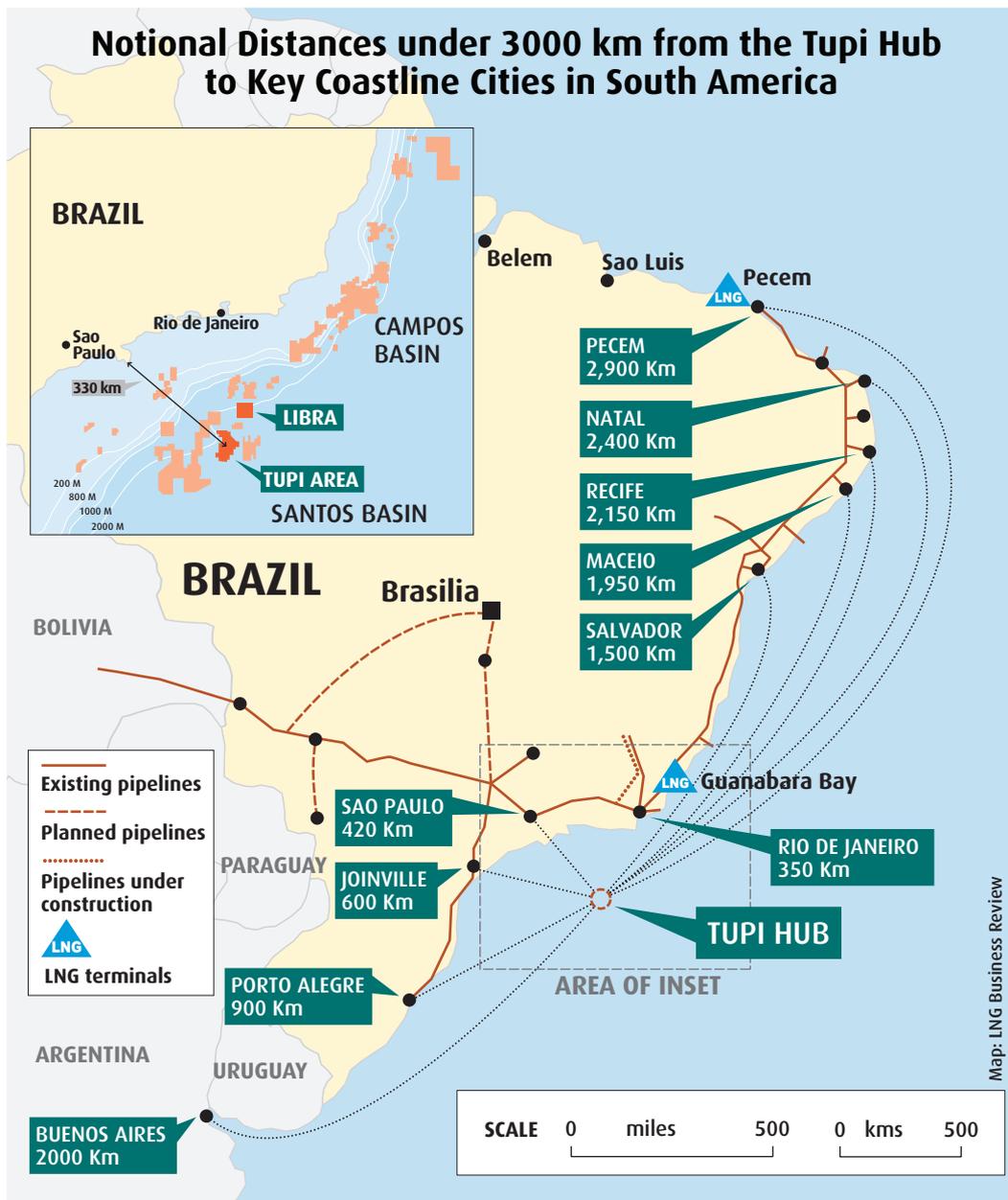
If similar reserve upgrades are possible with Iara, Jupiter, Parati, Caramba, Carioca and Bem-Te-Vi, an additional 2.1 billion barrels of oil and 1.3 Tcf of gas could be produced. This would bring the total recoverable oil and gas from Tupi/Iracema, Guara, Iara, Jupiter, Parati, Caramba, Carioca, Bem-Te-Vi and Mexilhao to 18 billion barrels of oil and 24 Tcf of recoverable gas, of which 15 Tcf would be associated gas. If the significant Franco and giant Libra fields confirm their potential, an additional 19.5 billion barrels of oil and 11 Tcf of recoverable associated gas could be produced, totaling gross recoverable oil reserves of 38 billion barrels and gas reserves of 35 Tcf.

After one year of substantial seismic studies, preparation and planning, Exxon Mobil and Hess Corp. began drilling the Sabia well. This is the third well in the BM-S-22 block in the pre-salt Santos Basin and is expected to spud before year end. The first well, Azulao-1, found signs of hydrocarbons and according to media and analyst reports, the block was expected to contain a similar find to Tupi, Iara, Guara or Jupiter. The second well, Guarani, failed to find hydrocarbons. There is significant expectation from the Sabia well, as the two largest oil finds, Tupi and Libra, are in the same area of the Santos pre-salt Basin. If Sabia is successful and a resource half the size of Tupi is discovered, this could represent another 4.5 billion barrels of oil and 2.8 Tcf of gas, suggesting that the total recoverable reserves of this area could reach 42 billion barrels of oil and 38 Tcf of natural gas, of which 24 Tcf would be associated gas.

World scale gas export projects needed to unlock oil production

The Santos pre-salt gas supply potential is sufficient to supply a 20 mtpa onshore LNG project for 22 years and a world scale GTL plant capable of producing 120,000 bbl/d of Ethane and NGLs and 140,000 bbl/d of middle distillates (similar in size to Shell's Pearl GTL in Qatar). The combined total capital expenditure of both plants would be approximately \$44 billion. Alternatively, the gas could supply a massive 30 mtpa onshore LNG plant at an approximate cost of \$32 billion.

Such estimates exclude the complex and expensive solution of developing gas gathering facilities to deliver over 5 Bcf/d to shore (assuming all fields produce at the same time



with even and constant production profiles, a simple premise). The reserves lie over 300 km from the coast in water depths over 2,000 m, and challenging terrain. Such a system would be a world first and could cost several billion dollars.

Alternatively, gas could supply 10 offshore Floating LNG FPSOs, each capable of producing 3 mtpa of LNG, assuming upstream gas supply could be efficiently and evenly apportioned between all Floating LNG FPSOs and producing fields, an optimistic premise at best.

An alternative solution to offshore gas gathering system could be provided by Compressed Natural Gas (CNG) technology. Last month LNG Business Review covered the current state of development in the marine CNG business (see CNG as a competitor to LNG – should the LNG industry be worried?, November 2010) and the search for technology and project proponents for the “golden triangle” where CNG would be an effective solution for gas monetization versus pipeline and LNG. CNG’s relatively low gas transportation capacity,

approximately one fifth of an LNG ship of equal size, could render it an ideal solution for a flexible remote offshore gas gathering system where pipelines are too technically complex, costly to develop and lack the desired flexibility. CNG could act as a “flexible floating compressed natural gas pipeline” providing the economic efficiency over shorter distances and smaller loads that LNG provides for longer distances and larger loads. It would also provide the flexibility that a major gas pipeline transmission system would lack.

Smaller fields, unable to sustain the minimal flow to make a Floating LNG unit economically attractive, would be equipped with a double berth loading facility to provide a seamless and continuous oil production and gas offtake. The CNG vessel could transport the compressed natural gas to a “floating gas hub” where a floating liquefaction unit is moored receiving gas supply from the larger fields directly and CNG cargoes from the smaller satellite fields within reasonable proximity. Such a model could provide flexibility to accommodate unforeseen production fluctuations and maintenance, and maximize the utilization of production facilities with minimal routine gas flaring.

Within a delivery range of 350 km to 2,900 km, CNG vessels could also deliver compressed natural gas to the major urban and industrial areas along the Brazilian coastline. All cities from Porto Alegre in Rio Grande do Sul up to Pecem in Ceara, and Buenos Aires in Argentina fall within this distance envelope (see map) and could be within the CNG “golden triangle” according to calculations from various industry representatives. LNG deliveries from Santos pre-salt could be made to the existing or relocated regas terminals in line with regional gas supply needs, or possibly exported to other South American and Atlantic Basin markets.

Alternatively, a complex and costly high-capacity gas transmission system could be installed utilizing the same right of way of the Tupi-Mexilhao-Caraguatatuba pipeline, providing evacuation of large volumes of associated and non-associated gas from the current main fields in the Santos Basin. Caraguatatuba is some 20 Km away from the Petrobras Sao Sebastiao Marine Terminal, and could provide a potentially suitable onshore site nearby for a large gas export project. The remaining fields not captured by this system would be connected via CNG vessels to major floating gas hubs with a floating liquefaction unit.

Many alternatives and some key technical uncertainties remain involving pre-salt oil and gas production, however, it is becoming increasingly evident that as Brazil becomes long on gas resources significant gas export projects in the form of FLNG, world-scale onshore LNG and/or GTL plants are needed to unlock the significant oil growth planned. Marine CNG seems to provide valuable flexibility as part of an upstream gas gathering system, as well as being an efficient way to deliver smaller quantities of gas to suit regional market needs along the Brazilian coast, complementing the existing LNG terminals. This combination could potentially offer substantial flexibility to the massive and expensive floating production systems with minimal routine gas flaring, unleashing the significant hydrocarbon production over the next decade expected to place Brazil in the top five global oil and gas producing countries. **LBR**

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