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Rendering showing the *Caribbean FLNG* at its jetty with an LNG carrier alongside

Efficient exploitation of stranded gas reserves

CARIBBEAN FLNG To tap into stranded reserves of Colombian gas, Pacific Rubiales Energy Corporation and EXMAR NV have partnered to build and operate a floating LNG liquefaction and storage unit, the *Caribbean FLNG*, which will be stationed at a jetty several kilometres off the Caribbean coast of Colombia for at least 15 years. A crucial component in achieving such a long mooring time is an innovative glass-flake, non-toxic, long-lasting coating system, writes David Phillips, editor of the Journal of Ship Hull Performance.

For economic and environmental reasons, global demand for natural gas as an alternative source of energy to traditional fossil fuels such as oil and coal has surged in recent years. Natural gas burns more cleanly and therefore is responsible for reduced noxious emissions. If it can be produced and transported efficiently, it has the potential to be cheaper than oil and coal.

However, vast natural gas supplies are often "stranded", meaning that they are not exploited for technical and logistical reasons. They are either too remote for economical transport or too hard to get at for economical production. Often this gas remains unexploited and unutilised in its natural gas field, or is flared during oil production.

These huge quantities of stranded gas represent enormous potential revenues for their owners. But monetisation and profit depend entirely on their efficient recovery and transport.

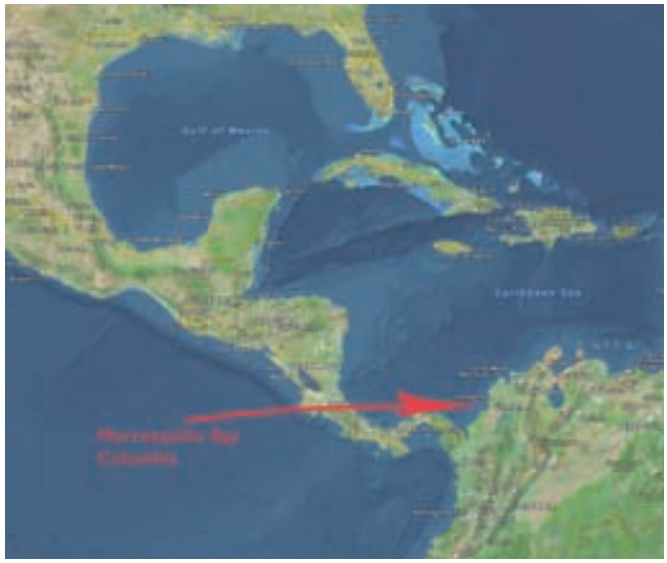
Northern Colombia gas exploitation project

La Creciente is a field in northern Colombia owned and operated by Pacific Stratus Energy (PSE) Colombia, a wholly owned subsidiary of Pacific Rubiales Energy Corporation (PRE).

PRE has taken the initiative of exploiting the stranded gas reserves at the La Creciente field by partnering with Antwerp-based EXMAR NV in a pioneering project. EXMAR has agreed to build, own, operate and maintain an FLNG production unit to be made available exclusively to PRE for 15 years.

Natural gas will be supplied from PSE's La Creciente field to the *Caribbean FLNG* off the Caribbean coast near Tolú via an 88km pipeline with a diameter of 45.7cm. Being built by PSE as part of the project, the pipeline has an initial design transportation capacity of 100 MMscf/d (million standard cubic feet per day). The La Creciente field has 6tcf (trillion cubic feet) or 170bcm (billion cubic metres) of gas reserves, and ongoing studies estimate a potential of 30-43tcf (850bcm-1.2tcm). The *Caribbean FLNG* will be moored in Morrosquillo Bay, about 4km offshore Tolú.

Frederik Van Nuffel, EXMAR's project manager in charge of the design, engineering and construction of the unit, said: "On November 5th 2013,Pacific Rubiales Energy Corp and Gazprom Marketing & Trade Limited announced the execution of a heads of agreement with respect to a five-year sale and purchase ›



The *Caribbean FLNG* will be moored in Morrosquillo Bay, about 4 km offshore Tolú

agreement covering approximately 0.5 million tonnes per year of liquefied natural gas commencing commercial operations in the second quarter of 2015. This LNG cargo will be produced in, and loaded from, EXMAR's *Caribbean FLNG* barge. The FLNG will stay permanently on site for at least 15 years without dry-docking."

EXMAR NV, headquartered in Antwerp, Belgium, has pioneered innovative floating liquefaction and regasification solutions to help bring LNG to the market in the fast, cost-effective, flexible and reliable manner needed for success. The company introduced LNG regasification vessels (LNGRVs) in 2005 and ship-to-ship transfer technology in 2006.

EXMAR CEO Nicolas Saverys said, "This will be the world's first operational floating LNG production unit. We were the first to do regasification on board a ship and the first to do ship-to-ship liquid transfer. Now we will be the first to do floating liquefaction of natural gas. The unique technology on board the unit is the result of EXMAR's innovative leadership in the LNG industry during the past years. The energy markets are short of gas supplies and EXMAR's FLNG unit approach offers the opportunity to add stranded gas to these markets and correct the current imbalance in trade in terms of both price and supply."

Building the *Caribbean FLNG*

EXMAR is investing USD 300 million in the FLNG production unit, which is seen as the beginning of a long-term initiative to develop stranded gas worldwide. The unit will consist of a non-propelled barge equipped to convert natural gas into LNG, and to store for offloading to a permanently moored storage unit or to shuttle tankers.

The *Caribbean FLNG* will have a storage capacity of 16,100m^3 of LNG and be able to accommodate alongside an LNG floating storage unit (FSU). The floating plant will process 69.5 MMcf/d of natural gas and produce about 500,000 metric tonnes of LNG per annum. The FLNG barge is 144m long, 32m wide, 20m high and has a normal draught of 5.4m.

It is being built at Wison's new, wholly owned fabrication facility in Nantong, China, with further support from the company's subsidiary in Houston, Texas, USA.

Black & Veatch was contracted to execute the engineering and procurement of the topside liquefaction equipment and packages using its patented PRICO LNG technology, which employs a single-mixed refrigerant system to accomplish the gas liquefaction with a refrigerant that is a mixture of nitrogen and hydrocarbons ranging from methane to isopentane. By using a single-mixed refrigerant process with one refrigeration loop start-up, Black & Veatch aims to achieve high reliability and availability. Black & Veatch is also supplying all LNG process equipment and providing installation and start-up oversight services to Wison.

Protecting the hull

A key requirement for the *Caribbean FLNG* is that it be able to stay moored at the jetty in Morrosquillo Bay for at least 15 years without the need for dry-docking. At the same time, the unit is being built and will be maintained in strict accordance with all the regulations of a major classification society.

The biggest barrier to this kind of extended dry-docking interval is protection of the hull, which includes the prevention of corrosion and the ability to effectively deal with biofouling. Whether or not the vessel goes to dry dock, periodic inspections by the classification society are required, in this case every five years.

EXMAR is trying various approaches to hull protection and maintenance on its vessels, including traditional biocidal antifouling, foul-release coatings and cathodic protection on bare steel. Based on prior experience and new research, EXMAR chose Ecospeed from Hydrex for the new *Caribbean FLNG*.

The *Caribbean FLNG* being assembled at the Wison shipyard


A fully coated block leaves the fabrication hall ready for assembly

Ecospeed is a hard, non-toxic, long-lasting glass-flake-reinforced coating ideally suited to this kind of application. Of great importance are long-term protection, the ability to be cleaned in situ under water without any damage to the coating, and environmental benignity with no emission of heavy metals or toxic substances during normal use or cleaning.

As long as it is standardly applied and correctly maintained, Ecospeed can be guaranteed for 15 years in this type of application. Another key factor in choosing the hull coating system was the need for a clean hull for the five-yearly class inspections. A weld seam that is coated with inches of macrofouling cannot be properly inspected.

Operating in tropical waters means that the rate of fouling growth is likely to be very high. Although fuel efficiency is obviously not a factor since the barge will not be going anywhere, soft coatings such as biocidal antifouling or foul-release paints would not be able to withstand the onslaught of barnacles and coral and other fouling organisms without penetration right through to the steel. This type of coating could not be cleaned in the water without severe damage to the coating. And these types of coating are toxic and emit heavy metals and/or other toxic substances that would not be tolerable in the sensitive Caribbean waters where the FLNG will be stationed.

EXMAR and Hydrex must still work out the optimum cleaning regimen for the hull. One full cleaning per year will probably suffice. While the hull could be cleaned only once every five years, prior to class inspection, the level of growth after that period would be very considerable and the time and cost required for cleaning significantly greater than if the hull were cleaned annually and the fouling thus kept down.

Construction of the hull of the *Caribbean FLNG* has largely been completed and work on the topside is progressing.

The future

At the project launch event in June 2013, Saverys said, "This contract represents the start of a new era for EXMAR. The *Caribbean FLNG* project highlights the business potential and investment in Colombia. Colombia has the fastest-growing economy in South America and one of the fastest in the world." Colombia is ramping up oil production to 1 MMb/d (million barrels per day) this year. The country's current gas production is estimated at 1bcf/d (28 MMcm/d) of gas.

The future appears to be bright for FLNG projects well beyond Colombia, but EXMAR is taking one project at a time. As for the company's future, Saverys remarked: "There are places where gas production is just impossible. Indeed I can share with you that my ambition is to produce gas from those areas in the next decade. I would like to see that we are the first ones doing more complicated projects by going into harsher environments and handling gas that comes with a sludge, which will need to be cleaned and purified. We will have a real cracking system out there."