

BRAZIL COUNTRY UPDATE

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INTRODUCTION

The Brazilian oil and gas industry has been exhibiting a great growth since the middle of 1970's when began the drilling offshore in shallow waters. In 2006 the pre-salt reservoir was discovered and the production showed a large growth (Figure 1). Petrobras had the oil and gas monopoly until 1997 when was decreed of the new Oil Act. Now there are 40 companies working in Brazil, but Petrobras is still the main actor. The main source of Brazil's contribution to the climate change is deforestation. Petrobras and partners don't have target obligations for CO₂. However in order to get permits to extract oil in Pre-salt province, they were not allowed to vent CO₂ associated with the natural gas. Up to 2015 over 1 million tonnes of CO₂ have been re-injected with four FPSO units in operation.

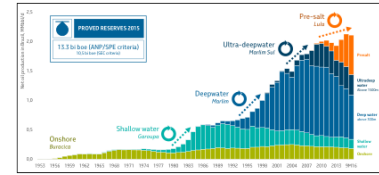


Figure 1 - Evolution of Brazilian Oil Production (Guedes, 2016)

PRE-SALT RESERVOIR

It is a carbonate reservoir of oil and natural gas with recoverable reserves of 8.3 billion barrels of oil equivalent. It is located 5,000-7,000 m below sea level in water depth of 2,000 m in average, under a layer of salt with approximately 2,000 m thickness, in some areas (Figure 2). It is located around 300 km off coast with light oil (30° API), high GOR (> 200), and variable CO₂ content (up to 20%). The Pre-Salt province is off the coast of Rio and São Paulo in the Santos Basin and Campos Basin (Figure 3). There are 3 types of agreements in place: concession, production sharing and transfer of rights (Figure 4).

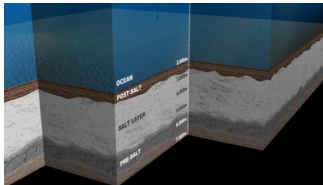


Figure 2 - Pre-salt reservoir (Hayashi, 2015)



Figure 3 - Pre-salt Province (Seabra & Grava, 2014)

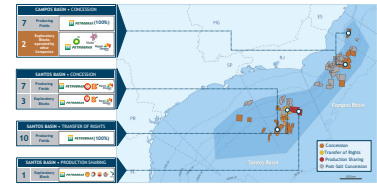


Figure 4 - Pre-salt Province, regimes and partners (Guedes, 2016)

HANDLING OF CO₂ HYDROCARBON FLUIDS

The main challenge to handling of CO₂ hydrocarbon fluids is to have a process that has a high efficiency of CO₂ separation with the smallest footprint and weight. Membranes were chosen due to their high separation efficiency, simple operation and easy maintenance. They have the capacity to deal with a wide range of CO₂ content in the inlet stream. Up to now there are 4 floating production storage and offloading (FPSO) units operating at the Pre-salt Province using membranes technologies for CO₂ separation: FPSOs **Cidade Angra dos Reis**, **Cidade de São Paulo**, **Cidade de Ilhabela** (UOP – spiral wound) and **Cidade de Paraty** (Cameron - hollow fiber). The two firsts are located at the Lula Field and the others at the Sapinhóia field. The spiral wound system has the capacity to process of 5 MMSCMD (million metric standard cubic meter per day) of natural gas with CO₂ content up to 34%. According to the hollow fiber membrane supplier the unit was design to process up to 5.7 MMSCMD of natural gas with the CO₂ concentration in the feed gas from 4% to 61%.



Figure 5 - CO₂ unit using the UOP spiral wound membrane

WAG-CO₂ EOR

Petrobras and partners are using the WAG (water-alternating-gas) injection process with CO₂ (Figure 6). This method is based on the injection of waves of a gaseous or supercritical fluid, preferably miscible with the oil, alternating with water waves, to ensure higher efficiency of displacement of the injected fluid. This technique has been used and evaluated in the Lula Pilot System since June 2013 (Figure 7). The main advantages are the optimization of reservoir management and the expected increase in the oil recovery factor .

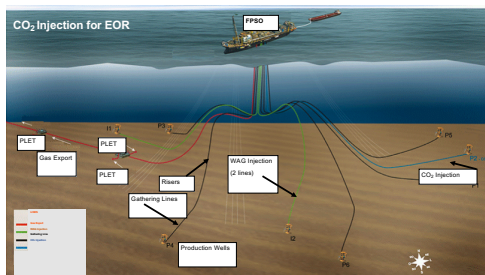


Figure 6 - WAG injection scheme (Seabra & Grava, 2014)



Figure 7 - Lula Pilot System (Seabra & Grava, 2014)

KEY PROJECT MILESTONES

- July 2006: Lula oil field discovered;
- May 2009: Extended well tests commenced to study development options for the pre-salt reservoirs;
- December 2010: Petrobras filed the Declaration of Commerciality with the Brazilian National Agency of Petroleum, Natural Gas and Biofuel (ANP);
- June 2013: Petrobras announced that commercial production from the FPSO Cidade de Paraty had commenced.
- November 2014: Petrobras announced that commercial production from the Sapinhóia Noth FPSO Cidade de Ilhabela had commenced.
- August 2016: Petrobras announced commissioning of fourth CO₂ separation and injection system (aboard the FPSO Cidade de Ilhabela) in the pre-salt Santos Basin. (SOURCE: GCCSI, 2016)

REFERENCE LIST

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Figure 8 - Pre-salt oil production ramp-up (Petrobras, 2017)

