MONETIZING PETROBRAS URUCU FIELD NATURAL GAS RESERVES - CNG AS A MARKET AND TECHNOLOGICAL DEVELOPMENT TOOL IN THE AMAZON

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ABSTRACT

The Urucu Production Area is located in the Coari County, the middle of the Amazon jungle, distant some 650 km from Manaus, the capital of the Amazon State. Petrobras started its production activities in Urucu after the discovery of a significant reserve of oil and natural gas in 1986. Presently, up to 6 X 10⁶ m³ per day of natural gas is still re-injected in the reservoir. Gas reserves are presently estimated as capable of providing a production of up to 5.5 x 10⁹ m³ per day, for the next 20 years. In order to properly monetize these reserves, Petrobras is currently carrying out a US$ 500,000,000 investment for the construction of the 660 km long Urucu-Coari-Manaus gas pipeline. As for any industry enterprise of such magnitude, there are several environmental, political and social compensations that are supposed to be covered by the enterprise participating companies. Presently, the natural gas service station low price still usually practiced in Brazil makes it a very appealing fuel option, with significant cost advantages. It is common that local governments exhibit significant political interest on making such an environment-friendly and inexpensive fuel available for their communities. One of the compensations requested by local agencies in order to grant Petrobras with the necessary authorizations for the new pipeline was that a project to supply a limited vehicle fleet in Manaus with compressed natural gas (CNG) be implemented before the gas pipeline actually starts operations. The project would allow all the agents in the natural gas vehicle business chain (government agencies, service and equipment suppliers, etc) to develop the necessary processes and expertise to fully support the future demands of an expanding market as soon as the regular supply from the gas pipeline initiates.

Another specific and difficult aspect had to be dealt with: the special composition of the Urucu Field natural gas. Its low methane (68%) and high nitrogen (18%) contents do not comply with current Brazilian legislation for natural gas powered vehicles (NGV). As a consequence, Petrobras Research Center (CENPES) started a pioneer research to study the impact of this natural gas composition on vehicular applications. The emission tests results obtained indicated that, as long as the proper parameter values were used, the NGV conversion kits would comply with the established emission legislation. Based on these results, National Petroleum, Natural Gas and Bio-fuels Agency - ANP, the Brazilian regulatory authority for these industries, agreed to issue a thirty month authorization for the implementation of the Experimental Project for vehicular use of the Urucu Natural Gas. The project started operations in December 2005. By the end of January 2006 almost 200 taxis were already running on Urucu natural gas in Manaus. The average full transportation cycle actual time has not shown significant deviation from the predicted 14 days. A preliminary data collection procedure is already being executed for fuel consumption and general end users impressions about the performance of the vehicles. A more structured control procedure is being designed and shall involve a more frequent vehicle inspection routine.

Despite the eventual diversity of specific objectives for each of the participants, an Institutional and Technological Cooperation Agreement was signed by Petrobras, its distribution subsidiary Petrobras Distribuidora (formerly, BR Distribuidora), the Government of the State of the Amazon and the Amazon State Gas Distribution Company (CIGAS). The logistics for the project involves a system comprising 18 CNG transport trailers towed by trucks on land legs and boarded on river barges for the fluvial legs. The system is capable of supplying Manaus with up to 27,000 m³ per week of natural gas produced in Urucu.

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Despite the eventual diversity of specific objectives for each of the participants, the implementation of the Experimental Project demonstrates that the general goal of mobilizing all the players on the future NGV industry of the Amazon is being achieved. From the Petrobras point of view, besides the reinforcement of the corporate brand image of an environmentally responsible company, the project will provide the experience of a controlled market development since its initial phase. The lessons learned during the controlled development of that isolated market will certainly contribute to improve Petrobras performance as a major inducer of an organized development of the NGV market throughout the country.
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1. INTRODUCTION

This paper describes the implementation of a project involving the use of compressed natural gas (CNG) as the transportation mean for the early supply of natural gas (NG) to a restricted market before a gas pipeline is available.

Section 2 – Petrobras activities in the Amazon - describes the previous activities of Petrobras in the region and the motivation for the construction of a gas pipeline from the Urucu Production Area to Manaus. It is also shown how the inclusion of the early supply project among the compensation items for the construction of the gas pipeline might represent a marketing opportunity for Petrobras.

Section 3 – Evaluation of the Urucu natural gas for vehicular applications - describes the research program carried out by Petrobras in order to evaluate the impacts of using the Urucu NG for vehicular applications. The results obtained in the tests are also generally described and how they contributed to the regulatory support for the project.

The scope and objectives of the early supply project are presented in Section 4 – The Experimental Urucu Project. The various entities involved and the role they are supposed to play within the project are also discussed in this section.

In order to supply a restricted segment in Manaus with natural gas, a unique logistic system was designed and implemented. Section 5 – Design of the logistic for the project – describes the system, the approach and restriction for its design and a contingency plan for the event of a severe dry season during the project time frame.

Finally, in Section 6 – Initial results and conclusions – the first observations resulting from the operations start up of the project are discussed. It is shown that the designed logistics has been performing properly, but the need for some adjustments has already been identified, including the improvement of the data collection and inspection routines for the NGV fleet.

2. PETROBRAS ACTIVITIES IN THE AMAZON

2.1 The Urucu Production Area

The Urucu Production Area is located in the Coari County, the middle of the Amazon jungle, distant some 650 km from Manaus, the capital of the Amazon State. It received its name after the Urucu River, one of the Solimões River affluents. Petrobras started its production activities in Urucu after the discovery of a significant reserve of oil and natural gas in 1986. Many challenges have been conquered to establish production activities in such a remote area since 1988 when the first commercial well started production. In 1998 the multi-product pipeline Urucu-Coari started operations, transferring the Area production to the port facilities in Coari in the Solimões River.

Presently, local operations in the Urucu Production Area involves up to 900 personnel, working on a facilities complex composed of an airport, two river ports, 70 km of paved roads and 40 km more of non-paved roads, a pipeline network connecting more than 90 geographically disperse wells (among production, gas and water injection wells) to an industrial plant called Polo Arara, where oil and gas are processed (see Figure 1). The required electric power is locally provided by a 16 MW natural gas fired power plant, as does the 40 x 10^3 liters per day demand of diesel, supplied by a Diesel Processing Unit (DPU). The natural gas production is processed on a Natural Gas Processing Unit (NGPU) with a production capacity of 1,100 ton per day of liquefied petroleum gas (LPG). The remaining 6 X 10^6 m^3 per day natural gas production is re-injected in the reservoir by a set of three turbo-compressors.
2.2 The Urucu-Coari-Manaus gas pipeline

The re-injection volumes of natural gas are significant. Urucu natural gas reserves are presently estimated as capable of providing a production of up to $5 \times 10^6$ m$^3$ per day, for the next 20 years. In order to properly monetize these reserves, Petrobras is currently carrying out a US$ 500,000,000 investment for the construction of the 660 km long Urucu-Coari-Manaus gas pipeline. Anchoring the project, two power plants presently consuming fuel oil shall be converted to use the natural gas supplied by the new pipeline and generate a total of some 480 MW. Additionally, five more independent energy suppliers are expected to generate 60 MW each on gas fired power plants. Furthermore, Petrobras Manaus Refinery REMAN will also consume 40,000 m$^3$ per day, while scattered industrial clients will have $500,000$ m$^3$ per day available for their use. Preliminary construction tasks are already underway and operation start up is scheduled for 2007.

Figure 2 presents a satellite photograph of the region, along with the gas pipeline routing from Urucu to Manaus.
As for any industry enterprise of such magnitude, and especially considering the issues related to the construction of a pipeline in the middle of a rain forest, there are several environmental, political and social compensations that are charged to the enterprise participating companies. The Urucu-Coari-Manaus is no exception. Besides all the studies and analyses on the real and potential environmental impacts of the construction, and the definition of appropriate actions to prevent or mitigate them, there is a set of compensations related to social impacts to the population near the pipeline route and also economical impacts due to the introduction of a new energy option on local business.

Presently, the natural gas service station low price still usually practiced in Brazil makes it a very appealing fuel option, with significant cost advantages, mostly for those consumers with a relatively high daily mileage like taxi drivers, either individuals or companies. It is common that local governments exhibit significant political interest on making such an environment-friendly and inexpensive fuel available for their communities. One of the compensations requested by local agencies in order to grant Petrobras with the necessary installation and operational authorizations was that a project to supply a limited vehicle fleet in Manaus with compressed natural gas (CNG) be implemented before the gas pipeline actually starts operations. The project would allow all the agents in the natural gas vehicle business chain (government agencies, service and equipment suppliers, etc) to develop the necessary processes and expertise to fully support the future demands of an expanding market as soon as the regular supply through the gas pipeline initiates.

The potential natural gas vehicle (NGV) market in Manaus is much less significant as a business for Petrobras than the power generation and industrial segments are. Nevertheless, natural gas is known to present significant environmental advantages when compared to gasoline and diesel powered vehicles. Considering that "corporate images are views of the organization developed by its stakeholders; the outside world’s overall impression of the company including the views of the customers, shareholders, the media, the general public and so on" (HATCH, 2003), the appeal for the use of a potentially cleaner fuel in a region so much concerned with environmental issues, might represent a marketing opportunity for Petrobras. The incentive and contribution to the development of a NGV market in the Amazon would reinforce Petrobras corporate brand image as a company committed to properly deal with environmental issues and to pursue ways of doing business in a sustainable way.

However, another specific and difficult aspect had to be dealt with: the special composition of the Urucu Field natural gas. Its low methane (68%) and high nitrogen (18%) contents do not comply with current Brazilian legislation for NG and potentially represent a situation where environmental damages induced by its usage would be greater than the vehicles original fuel. Next section discusses the actions taken by Petrobras to overcome this situation.

3. EVALUATION OF URUCU NATURAL GAS FOR VEHICULAR APPLICATION

3.1 Brazilian NG regulation

The Environmental National Council (CONAMA), is a division of the Ministry of Environment that regulates vehicle emission. Started in 1986, a program named PROCONVE (National Program for Vehicle Air Pollution Control) established the vehicle emission limits in Brazil based on test results done on chassis dynamometer, according to the Brazilian NBR 6601 rule that is similar to the FTP-75 procedure. This program is coordinated by the National Environmental Institute (IBAMA). The emission limits for vehicles manufactured after 1997 are CO (Carbon Monoxide) = 2.0 g/km, HC (Total Hydrocarbons) = 0.3 g/km and NOx (Oxides of nitrogen) = 0.6 g/km.

Due to NGV fleet growth in last years, Standard number 291 was published in 2002 by CONAMA. It states that natural gas vehicles with conversion systems should have emissions levels of CO, NOx and NMHC (Non-methane hydrocarbons) equal or below the original vehicle fuel. The conversion kit companies that meet the requirements of Standard number 291 receive from IBAMA an Environmental Certificate for NGV (CAGN) that will allow the kit to be sold in Brazil.

Additionally, any natural gas commercialized in Brazil is supposed to comply with the National Petroleum, Natural Gas and Bio-fuels Agency (ANP) specifications. ANP establishes natural gas
composition specifications for different areas in the country, as the natural gas used in Brazil has different sources.

3.2 Petrobras Research Program for vehicular use of Urucu natural gas

In 2002, it was recognized that NG produced by Petrobras on Urucu area had a composition with low methane (68%) and high nitrogen (18%), not meeting current NG specifications established by Standard 104 from ANP. The standard establishes 86% minimum of methane and 2% maximum of nitrogen.

As a consequence, Petrobras Research Center (CENPES) started a pioneer research to study the impact of this NG composition on vehicular applications. The main goal was to compare the performance, emissions and fuel consumption of vehicles using their original fuel (gasoline and alcohol) and natural gas, both ANP current specification compliant and Urucu produced. The results shall be presented to ANP for approval of the Urucu natural gas for NGV use, and also to the environmental agencies.

The three types of tests were performed following Brazilian and USA standard procedures as follows:

- Emissions tests - the ABNT NBR 6601 rule was used. This is the Brazilian standard for emission measurement of light duty vehicles, and is based on the USA Code of Federal Regulations (CFR) that uses the FTP-75 dynamometer cycle.

- Fuel consumption tests - the ABNT NBR 7024 rule was used. This is the Brazilian standard for fuel economy measurement. For city cycle, the test is also based on FTP-75 dynamometer cycle.

- Performance tests - SAE procedure number J1491 (Vehicle Acceleration Measurement) was suitable for running performance tests on the laboratory chassis dynamometer. A very precise data-acquisition system, model CORREVIT, was used for recording test data. Two different performance tests were done for each fuel, both with full open throttle and starting at 40 km/h. The first test, measured the vehicle time from 40 km/h up to 80 km/h in third gear and the second was from 40 km/h up to 100 km/h in fourth gear.

Two vehicles were used on the tests:
- One gasoline vehicle, 1.0 liter, 1999, 50 HP, 4 cylinder, multipoint electronic fuel injection system, compression ratio – 9.2:1, 15,000 km;
- One alcohol vehicle, 1.8 liter, 2002, 103 HP, 4 cylinder, multipoint electronic fuel injection system, compression ratio – 11.3:1, 4,000 km

The conversion kits used were of the third generation type, with stepper motor and lambda sensor. They were chosen for the job because of their capacity to attain current emission limits and also because they are available on the market for both vehicles.

As to allow for the intended comparison, four different fuels were used on the tests. Besides the original vehicles fuels (gasoline and alcohol), an ANP specifications compliant natural gas (from the Rio de Janeiro State in Southeast Brazil) and the natural gas from Urucu were used.

3.3 Research program tests results

It was necessary two kit adjustments to run with each natural gas type, because of the large difference in compositions. The target of the tuning was to meet CONAMA’s requirement that gas emissions of a NGV to be lower than the original vehicle. Excellent test results were obtained for both vehicles after the kit adjustments. Both vehicles, when fueled with natural gas from Urucu and properly tuned, could achieve CO and NOx results lower than the original vehicle fuel results and not higher than results. Furthermore, for the original gasoline 1.0 liters vehicle, CO emission results
showed no statistical difference for either natural gas. The conclusion is that CONAMA’s requirements may be achieved, given a proper tuning of the conversion kit is made.

During the fuel consumption tests, for each natural gas a different kit tuning was used, namely the same used for the emission tests. Results showed that the natural gas from Urucu induces an increase in urban fuel consumption of some 14.6% for the original gasoline vehicle and 6.8% for the original alcohol vehicle, compared to the ANP specifications compliant gas. This is readily explained by the lower net heating value of the Urucu natural gas, and such results were actually expected beforehand.

As previously described, the performance tests were done in a chassis dynamometer with the CORREVIT data acquisition system. The vehicles were pre-conditioned for about 30 minutes to get normal working temperatures before the speed recovery tests. Six tests were done for each type of fuel. Besides showing that this procedure produced a very good repeatability, the obtained results also indicated that only the original alcohol vehicle exhibited some significant power loss in the 40 to 100 km/h speed recovery test. The most common use for the driver is represented by the speed recovery from 40 to 80 km/h in third gear. Tests results also showed, for this condition, a power loss of just 3% (0.15 seconds), which will hardly be noticed by the driver, meaning that this will not be a problem for the vehicular use of the natural gas from Urucu.

For a detailed description of all the tests performed and its results, reference is made to CORDEIRO DE MELO, 2005.

These results and conclusions were presented to ANP, that issued a 30 months temporary authorization for the use of the Urucu produced natural gas in Manaus, as long as: (a) only third generation conversion kits be used; (b) that all conversion kits have been granted with the CAGN certificate; (c) end users be properly informed about the power loss and fuel consumption issues. This authorization became the legal support for the implementation of the Experimental Project for vehicular use of the Urucu Natural Gas. This would satisfy one of the required compensations for the construction of the Urucu-Coari-Manaus pipeline, as mentioned in Section 2. This project is described in the following sections.

4. THE EXPERIMENTAL URUCU PROJECT

Given the proper authorization from ANP, Petrobras and the Government of the Amazon State, represented by its State Secretariat of Sustainable Development and Environment (SDS), designed the Experimental Urucu Project. The main objective of the project is to settle the conditions for the early development of the necessary processes and expertise of all the entities that will be involved on the NGV market in Manaus as soon as the new gas pipeline starts normal natural gas supply. On the technological side, the project includes a series fleet monitoring activities. This shall produce the necessary data to confirm the laboratory results obtained by CENPES, and will support the pledge for a permanent authorization for the use of the Urucu natural gas to ANP.

In order to properly establish the scope of the project and the responsibilities assigned to all the participants, a Institutional and Technological Cooperation Agreement was signed by Petrobras, its distribution subsidiary Petrobras Distribuidora (formerly, BR Distribuidora), the Government of the State of the Amazon and the Amazon State Gas Distribution Company (CIGAS). Petrobras Distribuidora was called by Petrobras to join the project due to its long experience on logistic operations in the Amazon, and will also be responsible for providing one of its service stations in Manaus with all the necessary conditions to fuel the test fleet with natural gas.

The Amazon State Government, through SDS, will provide institutional support to the project, and will act as the main interface with other local government agencies and companies, mainly the Amazon Traffic Department (DETRAN-AM) which is responsible for the execution of periodic vehicle inspections and the issuing of transit authorizations, and CIGAS, which is partially State owned. Also, definition and application of the criteria for the selection of the end users (taxi drivers) participating in project was done by SDS. One main factor included in the criteria was the absence of traffic infractions.

Verwijderd: tuning
Met opmaak: Tekstkleur: Auto, Engels (V.S.)
Met opmaak: Tekstkleur: Auto, Engels (V.S.)
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Conversion shops are also necessarily involved in the project. They have to be properly authorized to perform conversion kit installations and need the necessary technical training for this activity. In that sense, the Industrial Learning National Service of the State of the Amazon (SENAI-AM) that hosts a local branch of the Gas Technology Center (CTGAS) plays an important role. CTGAS is a nationwide joint initiative of Petrobras and SENAI sharing, specifically for the natural gas industry, the SENAI mission of providing the Brazilian industry with technically skilled labor power. Petrobras' CENPES will also technically support SENAI-AM on its activities related to the project that will mainly include coordinating the tests for the proper adjustment of the kits to the Urucu natural gas characteristics, what will be fundamental for reaching the emission levels required by legislation.

The project is proposed to operate for as long as the gas pipeline is not yet operational. The prospects are that the pipeline construction will be completed by mid 2007. That is considered a sufficient time frame for the project to achieve its objectives and is still comprised within the limits of the temporary ANP authorization.

5. DESIGN OF THE LOGISTICS FOR THE PROJECT

5.1 General configuration

Access to the Urucu Production Area is only possible by air or through the winding and narrow Urucu River. At the location named Porto Evandro, on the Urucu River banks, Petrobras has long established docking facilities for the river barges serving the production area with the supplies and equipments not suitable for air transportation. Therefore, the natural choice to transport CNG from Urucu to Manaus was the use of river barges.

An initially considered option would involve specially adapted barges for CNG transportation, with high-pressure containers assembled directly on the barge deck. It would provide a large storage capacity resulting on lower operational costs to supply a given CNG volume. On the other hand, the construction costs for such barges would represent a too high initial investment, especially considering the temporary characteristics of the project – once the gas pipeline starts operations it would be quite difficult to find any commercial application for the barges. Furthermore, none of sparsely located injection wells from which the natural gas would be collected is close enough to Porto Evandro as to allow for the construction of a temporary feed line for CNG containers aboard the barges. And the same situation is true on the other end of the river transportation phase – it would be necessary to build specific facilities to take the natural gas from the barges in the Manaus Port to the service station appointed to the project. It was therefore necessary to adopt a different solution, including road transportation.

Several CNG distribution projects are already operational in Brazil (POLI, et al, 2005). Most of them use CNG transportation trailers equipped with several high-pressure steel cylinders, which are pulled by trucks. The operational experience, along with established service and equipment suppliers are already available in the country for this kind of system. Given these conditions, the solution adopted for the project involves CNG transportation trailers, towed by trucks on the land legs and boarded on conventional river barges for the fluvial leg.

5.2 Dimensioning of the logistic system

Dimensioning of the transport system, and the resulting supply capacity, was mainly constrained by the size of the usually available barges in the region and by its maximum length as to allow for maneuverability while sailing along the Urucu River. Also, the Brazilian legislation imposes a maximum weight limit for trailers traveling on federal roads that, for CNG transport trailers, leads to the usual design of 5,000 m$^3$ of CNG capacity trailers, which are the most readily available from local suppliers. Given these conditions, it was selected for the project a barge size of 800 ton displacement, which would carry up to 6 CNG transport trailers at a time, representing a total 30,000 m$^3$ transport capacity.

It was necessary to build a complete CNG loading station in the Urucu production area for the project. Among the existing gas injection wells it was selected one relatively close to Porto Evandro, with good paved access and providing enough area to park and maneuver the trailers and install the...
necessary equipments: a split branch from the gas injection line, a pressure reduction station (injection pressure is much higher than the 250 kg/cm² required for CNG loading), and a high pressure odorizing system (odorizing systems are usually designed for lower distribution pressures). Volume measurements will be performed following an operational procedure that will take under consideration the residual volume carried by the trailers. The location selected was injection well LUC-9 (East of Urucu number 9), distant some 15 km from Porto Evandro.

Table 1 shows the distances and the time required to cover each leg of a complete cycle from Manaus to Urucu (LUC-9) and back, using the selected equipment.

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<thead>
<tr>
<th>Leg</th>
<th>Distance (km)</th>
<th>Time (days)</th>
<th>Notes</th>
</tr>
</thead>
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<tr>
<td>Manaus → Porto Evandro</td>
<td>911</td>
<td>7</td>
<td>• River distance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Up river</td>
</tr>
<tr>
<td>LUC-9 ↔ Porto Evandro</td>
<td>15</td>
<td>1</td>
<td>Including CNG loading time in LUC-9</td>
</tr>
<tr>
<td>Porto Evandro → Manaus</td>
<td>911</td>
<td>6</td>
<td>• River distance</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>• Down river</td>
</tr>
</tbody>
</table>

Table 1: Distances and travel times for each leg of a complete transportation cycle

Due to the power limitation of the booster compressor usually employed at service stations, the actual usable capacity of a 5,000 m³ trailer is reduced to some 4,500 m³ of CNG (this is a conservative assumption). Considering continuous cycles and the times presented on Table 1, a transport system comprising 1 barge and 12 CNG transport trailers would deliver net 27,000 m³ of CNG every 2 weeks to Manaus. It would lead to a rather small test fleet – not more than 128 vehicles consuming up to 15 m³ per day. In order to increase the size of test fleet, but still keeping the 15 m³ of CNG per vehicle per day limitation, the number of equipments composing the system was increased to 3 barges and 18 CNG transport trailers. The resulting system would present a net delivery capacity of up to 27,000 m³ of CNG every week, enough supply up to 300 vehicles with 15 m³ per day. Figure 3 shows schematically the transport system adopted for the project.

![Figure 3: Schematic representation of the logistic system](image)
5.3 Winter season contingency plan

Any fluvial logistic system in the Amazon is subjected to the variations on the navigability conditions of the rivers in the region. The climate in the Amazon is typically equatorial presenting two distinct seasons: a rainy summer and a dry winter. The 2005 winter registered a record as the driest of the previous 30 years, bringing about serious environmental, social and economic consequences.

For situations not as severe as the one recently observed – the start up of the project had to be postponed – it has been anticipated an alternative solution to overcome a reduced navigability condition on the most critical part of the fluvial leg – the final 470 km from Coari to Porto Evandro along the Urucu River. From Manaus to Coari the barges sail the Solimões River where reduced navigability conditions that would affect the large barges are not expected even during severe dry seasons. In the event of the occurrence of a severe winter during the project time frame when the originally selected 800 ton barges would not be able to travel along the Urucu River, smaller barges of 400 – 500 ton, carrying up to 4 CNG trailers, would be applied to cover the leg between Coari and Porto Evandro. There would be a reduction on the supply rate to Manaus as the smaller barges, even being faster and more easily maneuvered, would have to perform more trips to and from Coari, and would be operating on restricted conditions.

It is important to notice that, even under extreme conditions, like the 2005 winter season, when the transport system would have to halt operations, the final users would still be able to use theirs vehicles. NGVs using conversion kits are intrinsically dual fuel vehicles. In a no natural gas supply situation, end users may keep on rolling on their original fuel, until climate conditions return to normality.

6. INITIAL RESULTS AND CONCLUSIONS

The project started operations in December 2005, immediately after the navigability conditions in the Urucu River became acceptable, following a record draught. The first six CNG loaded trailers arrived in Manaus on Christmas Eve and, by the end of January 2006 almost 200 taxis were already running on Urucu natural gas in Manaus.

Despite the fact that only a few transportation cycles have already been executed, certain variability on the times required for each leg was observed. Nevertheless, the average full cycle actual time has not shown significant deviation from the predicted 14 days.

A preliminary data collection procedure is generating records on fuel consumption and general end users impressions about the vehicles performance. A more structured control procedure is being designed by CENPES, along with SENAI-AM. It shall involve, besides the fueling control at the service station, presently being executed by CIGAS, arrangements with DETRAN-AM for the definition of a more frequent vehicle inspection routine. Presently, Brazilian legislation requires that any vehicle be inspected once a year for maintenance and safety conditions, including CO, HC and CO₂ emission tests. In order to achieve the project objectives, a more frequent emission test should be performed, including NOx measurements. Also, as any converted vehicle is intrinsically dual fuel, the fueling control at the service station is inadequate for natural gas consumption inference. Therefore an additional consumption test routine will be necessary.

All those measurements and data collection require that end users make their vehicles available. This represents the expected contribution of the end users for the project. On the other side, end users are technically consumers and are entitled to the guarantees expressed on Brazilian Consumers Protection Code. Therefore, and in spite of the fact that they are supposed to explicitly agree to collaborate with the project in order to join it, an intensive communication and motivational campaign is been carried on, and shall be even more intensified as to guarantee the end users commitment to the project objectives.

Despite the eventual diversity of specific objectives for each of the participants, the implementation of the Experimental Project demonstrates that the general goal of mobilizing all the players on the future NGV industry of the Amazon is being achieved. From the Petrobras point of
view, an additional result from the project, besides the reinforcement of the corporate brand image of an environmentally responsible company, will be the experience of a controlled market development since its initial phase. The Amazon NGV market is an isolated system, and the prospects are that it will remain so for quite a while. Its sole supply source is the Urucu Production Area, and its natural gas presents characteristics that put it apart from the rest of the country. The lessons learned during the controlled development of that isolated market will certainly contribute to improve Petrobras performance as a major inducer of an organized development of the NGV market throughout the country.

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Figure 2 – Satellite photograph of the region and the Urucu-Coari-Manaus gas pipeline routing.
Figure 3 – Schematic representation of the logistic system
MONETIZING THE NATURAL GAS (NG) RESERVES OF PETROBRAS IN THE URUCU FIELD REPRESENTED A SERIES OF CHALLENGES OF DIVERSIFIED NATURES. FROM THE TECHNICAL AND ENVIRONMENTAL RESTRICTIONS TO THE CONSTRUCTION OF A GAS PIPELINE IN THE MIDDLE OF THE AMAZON JUNGLE, TO THE BUSINESS AND ECONOMIC CONSTRAINTS TO BE OVERCOME IN ORDER TO MAKE THE WHOLE VENTURE FINANCIALLY FEASIBLE. BUT BESIDES THESE ASPECTS THERE STILL WAS AN ADDITIONAL DIFFICULTY: THE COMPOSITION OF THE NATURAL GAS FROM URUCU PRESENTS A HIGH LEVEL OF NITROGEN AND A LOW LEVEL OF METHANE. SEVERAL STUDIES WERE PERFORMED IN ORDER TO DETERMINE THE NECESSARY MODIFICATIONS ON THE EQUIPMENTS OF THE MAIN CONSUMERS FOR THE

IN THAT SENSE, THE USE OF NATURAL GAS FOR NGV (NATURAL GAS VEHICLES) IS ALSO A VERY SIGNIFICANT MARKET SEGMENT, DESPITE THE MUCH LOWER VOLUME LEVELS IT REPRESENTS WHEN COMPARED TO POWER GENERATION. THE MAIN ASPECT HERE ARE THE LOWER ENVIRONMENTAL IMPACT COMPARED TO GASOLINE OR DIESEL POWERED VEHICLES AND THE COST SAVINGS IT MIGHT PROVIDE FOR END CONSUMERS. THE NATURAL GAS SERVICE STATION LOW PRICE USUALLY PRACTICED IN BRAZIL MAKES IT A VERY APPEALING FUEL OPTION, WITH COST ADVANTAGE

IT IS SPECIALLY TRUE (AND COST ADVANTAGEOUS) FOR TAXI DRIVERS, EITHER INDIVIDUALS OR COMPANIES.

It is common that local governments exhibit significant political interest on making such an environmental-friendly and inexpensive fuel available for their communities.
IN BRAZIL, THE USE OF NATURAL GAS TO POWER VEHICLES (NGV) IS BASED MAINLY ON THE CONVERSION OF ORIGINALLY GASOLINE POWERED VEHICLES BY THE USE OF CONVERSION KITS. NATURAL GAS IS POTENTIALLY A MORE ENVIRONMENT-FRIENDLY FUEL BUT UNLESS THE CONVERSION KIT IS CONVENIENTLY ADJUSTED, A CONVERTED NGV CAN PRESENT EVEN HIGHER EMISSION LEVELS THAN THE ORIGINAL. IN ORDER TO ESTABLISH THE APPROPRIATE SET OF TUNING PARAMETERS FOR A NGV AND UNDER CONTROLLED CONDITIONS ACCORDING TO FTP-75 DRIVING CYCLE AND THE EMISSION RESULT (CO AND NOX) OF THE CONVERTED NGV SHOULD BE EQUAL OR LOWER THE ORIGINAL. THIS PROCEDURE IS accepted by Brazilian emission legislation as a satisfactory proof of the compliance of conversion kits to environmental legislation. PETROBRAS HAD ALREADY PERFORMED SOME PIONEERS TESTS FOR A COUPLE OF CONVERSION KITS USING THE NATURAL GAS PRODUCED IN URUCU. THE EMISSION RESULTS OBTAINED INDICATED THAT, AS LONG AS THE CONVERSION KIT PROPER PARAMETER VALUES WERE USED, THE NGV KIT WOULD COMPLY WITH THE ESTABLISHED EMISSION LEGISLATIONS. BASED ON THESE RESULTS, AGÊNCIA NACIONAL DO PETRÓLEO - ANP, THE BRAZILIAN REGULATORY AUTHORITY FOR OIL, NATURAL GAS AND BIOFUELS, AGREED TO ISSUED A THIRTY MONTH AUTHORIZATION FOR THE EXPERIMENTAL USE OF THE NATURAL GAS FROM
Urucu for a restricted NGV fleet in Manaus. The objective of such authorization was to allow for additional emission field tests to be performed before a final clearance of the Urucu natural gas would be granted for use on NGV.

**UNDER NORMAL CONDITIONS, THE MARKET AGENTS WOULD USUALLY ACCEPT THE NECESSARY INVESTMENT COSTS TO TEST AND CERTIFY THEIR CONVERSION KIT PRODUCTS.** The green field NGV market of the Amazon, however, would not catch their interest, specially considering that the Urucu-Manaus natural gas pipeline start-up was scheduled for only two years ahead and there are still unresolved environmental issues related to the Urucu natural gas composition.

**THE NECESSARY MARKET ORIENTED POLITICAL DECISION TO RESOLVE THAT TIE DOWN SITUATION WAS TAKEN BY PETROBRAS ALONG WITH THE GOVERNMENT OF THE STATE OF AMAZON.** BY MEANS OF A TECHNOLOGICAL AND INSTITUTIONAL COOPERATION AGREEMENT, A PROJECT TO IMPLEMENT A UNIQUE COMPRESSED NATURAL GAS (CNG) transportation logistic was carried on to supply the test fleet with the necessary natural gas, from the Urucu field to Manaus, long before the pipeline is completed.

**THE URUCU PRODUCTION AREA EXTENDS OVER XXXX SQUARE KILOMETERS IN THE MIDDLE OF THE AMAZON JUNGLE, DISTANT XXXX KM FROM MANAUS AND RECEIVED ITS NAME AFTER THE URUCU RIVER, ONE OF THE SOLIMÕES RIVER BANKS THERE ARE**

**FACILITIES FOR THE RIVER BARGES SERVING THE PRODUCTION AREA WITH THE SUPPLIES AND EQUIPMENTS NOT SUITABLE FOR AIR TRANSPORTATION – THE ONLY OTHER WAY TO REACH AT THE LOCATION NAMED PORTO EVANDRO ON THE URUCU RIVER**
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