CHALLENGES OF GAS DEREGULATION FOLLOWING THE ON-GOING IMPLEMENTATION OF A NEW ELECTRICITY SECTOR MODEL IN BRAZIL

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**ABSTRACT**

BRAZIL debates gas deregulation as its electricity sector model is replaced. This replacement includes mechanisms for using central planning to expand the system and aims to ensure supply and keep tariffs charges to a minimum.

In this paper the fundamentals of the electricity and gas markets are analyzed as well as the potential drag of the in-progress regulation of the well-established electricity sector on the on-debate deregulation of the developing gas sector.

We conclude that that only price volatility for gas and electricity is likely to foster the growth of futures markets and promote the efficient allocation of resources. A deregulated gas market will not work properly if not only prices reflect levels of consumption, investments and productions but also contract schemes are available to hedge agents against the intrinsic volatility of spot prices.

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**Met opmaak**

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

**Verwijderd:**

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 $6 \times 10^6$ m$^3$ 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 $5.5 \times 10^6$ 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. 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 participants.

In order to properly establish the scope of the project and the responsibilities assigned to all the participants, an Institutional and Technological Cooperation Agreement is being achieved. From the Petrobras point of view, besides the reinforcement of the corporate brand image, the technological development in the controlled development of that isolated market will certainly contribute to improve Petrobras performance as a major inducer of diversified challenges of diversified natures. From the techni...
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1. INTRODUCTION

The current movement to implement the regulatory framework to the new electricity sector model and to restructure Brazilian electricity generation contracting markets and make them more competitive may lead to changes in the financial risks and demands on the supply and transportation infrastructures for natural gas used in electricity generation. This article examines the potential impacts of restructuring the Brazilian electric power industry on the natural gas market for electricity generation.

Electric power sector in Brazil has been changing over the last years from a regulated industry with central planning to a market-based power generation competitive industry and, more recently, to a new model that resumes mechanisms for expanding the system based on centralized planning while promotes electric power generation competition. Where power generation was once dominated by vertically integrated state-owned utilities owning most of the generation capacity, transmission, and distribution facilities, the electric power industry now has many new companies that produce and market wholesale and retail electric power. Today, a few vertically integrated state-owned utilities still produce a huge amount of the country’s electrical power (about 89 per cent of generated electricity) while investor-owned utilities supply 80-90% of the retail electric power.

In 2004, Brazil’s installed capacity was approximately 91 thousand MW \(^1\). Although the country is heavily depended on hydropower, accounting for nearly 76 per cent of generation capacity and 83 per cent of electricity generated in 2004, natural gas is starting to play a major role in contributing to the reliability of the National Interlinked System. In 2004, natural gas already generated 5 per cent of the electricity needs, reaching a growth of 374 per cent in the last five years, rising from 4067 GWh in 2000 to 12,264 GWh in 2004.

![Figure 1 - Brazilian electric energy supply growth by source.](image)

Figure 1 shows the growth evolution on natural gas consumption for power generation vis-à-vis other sources considering the generated power by each source in 1999 as reference.

The year of 1999 is major reference to the Brazilian natural gas industry. In July 2001 the Bolivia Brazil Pipeline (GASBOL) started its commercial operation, grounding a governmental program named – Emergency Thermal Power - launched in 2000, aiming to encourage investment in gas-fired power plants and to diversify the country’s electricity generation mix. The program was supposed to reduce dependence on hydrological conditions and to reduce transmission system weaknesses.

The governmental program was a response to the energy crisis of 2001 and also included a widespread electricity-rationing program to prevent rolling blackouts by requiring customers in the Northeast, Southeast and Midwest regions to reduce electricity consumption by an average of 20% compared to the same period of the previous year. The rationing programme was very successful, but left damages. Persistent reduction in demand, coupled with the increase in installed capacity after 2001, created excess supply in the market, adversely affecting generators and some utilities.

The Emergency Thermal Power Program established a fixed price cap for gas-fired power plants. However, even with this guaranteed fuel price, it not achieved its goals, for instance, just 15 out of 49 planned power plants were built. Governmental effort to push to diversify its electricity generation sources weakened. Above-average rainfalls in the following years have replenished the reservoirs to normal levels in most of the hydrological basins. Additionally, the power-pricing regime established by the power sector regulation was far away from spurring thermal independent power projects. As a consequence, power companies reassessed their investments, placing most of the Emergency Thermal Power Program projects on indefinite hold.

Despite the governmental programme failure to provide strong enough incentives for new investment for new investment, it actually added new generation capacity and introduced gas-fired power plant as a strategic option to reduce its dependence on hydropower and balance supply and demand.

2. THE ELECTRICITY SECTOR

2.1. ELECTRICITY MARKET

The Brazilian electric power industry is changing to catch up with pace of the electricity demand that is now expected to grow at an energetic pace after resuming, in 2005, the level prior to the rationing programme, an aftermath of the shortage of electricity during July-December 2001. Steady increases in population together with the rise in demand due to the economic recovery are the underlying drivers to the reversal of the demand curve presented in Figure 2.

![Figure 2 - Population and electric demand](image_url)

Brazil has a modern and unique electricity industry since it depends heavily on hydropower, which accounts for 76 per cent of generation capacity and nearly 83 per cent of electricity generated in 2004. The electric-power distribution market is currently being serviced by 64 distribution utilities, which provide public services countrywide. About 47 million consumer units are serviced, of which 85% are residential consumers in almost 100% of Brazilian municipalities. The consumption market is located
in the South and Southeastern regions, where most of the industry is established. The Northern Region is served mainly by small power plants, the majority being composed of diesel-oil thermoelectric plants.

The electric-power market is growing on the order of 4.5% per year, and is expected to reach the 100,000 MW by 2008. Over the last two decades, power consumption has raised much faster than the Gross Domestic Product (GDP), which is the result of demographic growth concentrated in urban areas as well as of the economy growth. As a consequence, electricity demand is expected to continue to grow in the coming years.

The Brazilian power system presents many peculiarities:

First, the hydro system is linked to a thermal power system, which is much smaller than the hydro system. Differently form many other countries with mature natural gas industry; Brazilian thermal system does not operate in base load.

On the contrary, natural gas-fired power plants are switched on and off according to hydrological conditions and expectations. The National Electricity System Operator controls the dispatch of all power plants (excluding auto-production plants). The system is able to store energy, in the form of water accumulated in huge reservoirs, and takes advantage of different hydrological cycles, given the possibility of "transferring capacity" through transmission lines, greatly optimising the whole system. The level of water in the reservoirs is managed adequately over two- to five-year periods, depending on the varying hydrological dry-rainy cycles (Winter-Summer) of the respective basins. So, if one basin is expected to become drier in a given year, water from another basins accumulated in previous years is used or "transferred" in the form of electricity from region to the other. Hydrological conditions determine the modus operandi of the Brazilian electricity system. Conceived in this way, fossil fuel plants are only supposed to operate when it is most useful for the system—that is, to compensate for energy not generated by the hydroelectric plants which are in a period of accumulating water for the next cycle.

Second, distance between generation facilities and load centres are very large. Brazil's electricity system is highly interconnected. Brazil has got one of the largest transmission networks in the world, given the long distances between power stations and consumers and the need for back-up circuits to ensure alternative supply routes and optimal regional balance in supply. The high-voltage transmission system plays a major role in optimising hydropower generation from the different hydrological basins. The possibility of exchanging energy capacity among regions allows the hydrological system to produce up to 30 per cent more output than if the systems were not interconnected, working on a stand-alone basis. Of course, transmission losses are also high. Brazil still has large untapped hydro resources. However, those located closer to the load centres in the South and Southeast regions are largely exploited. Most of the remaining reserves are located in the North region. Environmental considerations mainly related to the flooding of large areas and the construction of transmission lines through the Amazon region will likely delay new hydro projects if not preventing some of them at all.

2.2. REGULATION

The Brazilian electric power industry is changing to resume its planning capacity. In the first half of 2004, the legal provisions for the basis of the new Brazilian electricity sector model came into force. A new model that includes mechanisms for expanding the system based on central planning replaced previous competitive market solution. This model requires that the distributors guarantee energy to 100% of their markets through regulated contracting, while the generators must provide evidence of underlying energy sources, either their own or based upon third part contracts. The model to be implemented is designed to guarantee supply and promote modest tariff charges.

Under the new model, the sale of electricity will occur through two different so-called Environments: the Regulated Contracting Environment (ACR), a sort of "Pool", via auctions, and the Free Contracting Environment (ACL), under which sale prices among market agents will be freely negotiated and governed by bilateral purchase and sale contracts.
The electricity distributors may only contract in the regulated environment.

In the free environment, contracts are freely negotiated among market players (those that are not distributors). The prevailing legal framework establishes that the generation of energy can be effected under three different sets of rules: public service, independent production and self-production. Both the public service power-utilities and also the independent producers and self-producers with a surplus may sell their energy in the two environments.

Although in the future, large consumers (above 10 MW) will be required to give distribution concessionaires a 3-year notice if they wish to switch from captive condition to become free consumer and a 5-year notice for those moving in the opposite direction a transition period is envisaged during which these conditions will be made more flexible. Considering that with few exceptions distribution concessionaires have exclusive rights to transport and sell electricity to captive consumers within their respective concession area, the development of the free environment depends on the possibility of captive consumers becoming free consumers. Consumers consuming more than 3,000kW, at any tension, would qualify as free consumers.

However, the introduction of new generation facilities has been far from seamless. Main hurdles are the environmental restrictions on the installation of new hydroelectric investments and the long distances of available high electricity generation potential hydrological resources.

Because it provides the capability to move power over long distances, the transmission system plays a major role in the Nation’s electric power industry. Nevertheless, the cost of expanding the electricity system based on medium to large hydro units is expected to rise in the light of the need to install even more complex systems. This is in addition to the already highly complex integrated national network with an accompanying expansion in transmission infrastructure for harnessing hydro resources that are more and more distant from the main centres of demand.

The prospect of an increase in electricity consumption in a scenario of sustained economic growth in Brazil against an expansion in generation capacity indicates no restriction on supplies over the next three to four years. However, some events could reverse this situation creating the need to anticipate additional supplies of energy. Among these events are higher economic growth rates with a reflection on electricity consumption and the reduction of guaranteed energy from generating operations and from imports.

2.3. INSTITUTIONAL

The Brazilian administration began to restructure the electricity sector in the mid-1990s, with the creation of a new regulatory agency, ANEEL. The government also established a national transmission grid operator, National Electricity System Operator (ONS), and a wholesale power market, the Wholesale Energy Market (MAE).

While this first reform enabled the privatization of several distribution and generation concessionaires, updated the legal framework, established new relationship among the electricity’s sector players and finally introduced several new important concepts to the sector, its implementation was poorly carried out and not fully completed. The problems arising from such deficient implementation, amplified by the losses caused by the rationing, created the conditions for the federal government to advocate and introduce a new model.

In 2004, the Law 10,848/04 and its accompanying executive decree 5,163/04 established a new legal framework to the electricity sector. The new legal framework and model resume planning capacity and reinforces the role of the Ministry of Mines and Energy in long-term planning.

The regulated environment contemplates two specific public auctions: one for the sale of electricity generated by existing plants and another for the sale of electricity generated by new plants. The Electric Energy National Agency (ANEEL), directly or through the Chamber of Commercialization of Electric Energy (CCREE), the successor of the Electric Energy Wholesale Market, would organize these public auctions in accordance with guidelines set by the Ministry of Mines and Energy (‘MME’) and the
estimates of consumption annually supplied by generators, brokers, distributors and free consumers to the MME, beginning in 2005.

The MME and the Energy Research Company (EPE), a new state-owned entity charged with the planning of the expansion of the electricity system, would determine the amounts of electricity that would need to be purchased at the auctions and identify the generation plants that should supply the electricity. EPE will submit to the Ministry its desired technological portfolio (i.e., the shares in supply of electricity produced through hydropower plants, gas-fired plants, and other renewable fuels), and a list of strategic and non-strategic projects.

Finally, the Ministry of Mines and Energy will submit this list of projects to the National Energy Policy Council (CNPE). Once approved by CNPE, the strategic projects will be auctioned on a priority basis through the Pool. Companies can replace the non-strategic projects proposed by EPE, if their proposal offers the same capacity for a lower tariff.

Another new institution is the Electricity Sector Monitoring Committee (CMSE), which will monitor trends in power supply and demand. CMSE may propose corrective measures to avoid energy shortages, such as special price conditions for new projects and reserve of generation capacity. The Ministry of Mines and Energy will host and chair this committee.

3. NATURAL GAS: AN EMERGING INDUSTRY

Petrobras is the largest producer of natural gas in Brazil. The company reportedly controls over 90 percent of Brazil’s natural gas reserves.

Brazil’s largest natural gas production occurs in the Campos Basin in Rio de Janeiro state from offshore fields. Most onshore production occurs in Amazonas and Bahia states, though natural gas produced here is mostly for local consumption due to the lack of transportation infrastructure. However, several new transport infrastructure projects hope to facilitate increased production in these regions.

Over the past twenty years, natural gas has increased its share of global energy supplies from 20.1% in 1982 to 24.3% in 2002. Over the same period, oil’s share of the cake fell approximately five percentage points, accounting for about 37.5% of the world energy matrix in 2002. In line with global tendencies, the share of natural gas in Brazil’s total energy requirements has risen from 2.7% in 1987 to 7.5% in 2002, according to the National Energy Balance published by the Ministry of Mines and Energy. Petrobras has contributed to the development of this market with a growth of 32% in natural gas sales volume between 2002 and 2004.

The increasing importance of this primary energy source is due to the enhanced level of natural gas reserves, as well as the expansion in the natural gas distribution infrastructure and growing pressures for the use of more environmentally friendly fuels. Industrial deregulation and restructuring have also been contributing to the global push in natural gas sales, principally in the form of liquefied natural gas (LNG), and to encouraging integration of energy flows among neighboring countries. Working in the same direction, natural gas is increasingly used for the chemical transformation into liquid fuels - gas to liquids (GTL), methanol and fertilizers.

Production of natural gas relates to gas volumes, which are lifted from the reservoirs through producing wells and delivered for sale once certain quality specifications have been satisfied negotiated (methane, sulfur, water content, etc.).

To meet the growing demand during the year, Petrobras imported 19.5 million m3/day of natural gas. This volume corresponds to 41% of total Brazilian imports.

4. NATURAL GAS INDUSTRY INFRASTRUCTURE: FUNCTIONS AND COMPONENTS

Petrobras is the largest producer of natural gas in Brazil. The company reportedly controls over 90 percent of Brazil’s natural gas reserves.
Despite the opening of the sector to private actors in the late 1990s, foreign investment has not been relevant. Dutch Shell is the only foreign company with oil production in the country, operating a single, relatively small field in the Campos Basin. Other companies with interests in exploration blocks include Statoil, Repsol-YPF, and Chevron. Main reasons appointed by oil industry analysts are:

- High federal and state taxes on oil production;
- Poor exploratory drilling results and
- Unappealing licensing terms.

The fundamental structure of the natural gas industry in Brazil has been based on vertical integration of utilities, i.e., their involvement in the three functions of natural gas supply: production, transport and distribution. In the next sections are presented Petrobras' shares in each of these functions.

4.1. NATURAL GAS PRODUCTION

Petrobras production of natural gas (excluding NGL) was 42.1 million m3/day, 5.8% more than in 2003. Onshore production of oil and NGL was 250.6 thousand bpd, 0.9% more than in 2003 (248.4 thousand bpd). The average lifting cost per barrel or equivalent was US$ 4.26.

Petrobras has been posting strong growth in this segment with sales volume up 19% in 2004, reaching 33 million m3/day. The Brazilian market as a whole performed well during the year due to the expansion of the logistics infrastructure and growing pressures for the use of more environmentally friendly fuels.

In 2004, Brazilian production reached an average of 42.2 million m3/day, a year-on-year growth of 6%. Meanwhile, the supply of domestic and imported gas for sale increased 23%, reaching 37.7 million m3/day.

4.2. NATURAL GAS TRANSPORT SYSTEM.

Transpetro is the main gas transmission company and operates a pipeline network of 10,032 kilometers of which, 6,989 kilometers are oil and oil product pipelines and 3,191 kilometers of are gas pipelines (excluding the Brazil–Bolivia pipeline), of which 148 kilometers were added in the network in 2004 with the commissioning of three E&P gas pipelines (known as the Malha Bahia).

Signed in 2004, the Networks Project (Projeto Malha) will guarantee the supply of demand from the industrial sector in the Northeast and Southeast regions. It will also stimulate the dissemination of the use of natural gas, in co-generation projects and for residential or industrial heating and refrigeration processes. The project will place Transpetro in the position of carrier of choice for existing and future installations and expand the supply of gas to 9 million m3/day to the Northeast Region (14 million by 2012) and 13 million m3/day to the Southeast Region.

Still in the gas segment, Petrobras concluded a further phase of the Cabiúnas Project, with the commissioning of a further liquid gas recovery unit. The project is designed to increase the supply of processed natural gas from the Campos Basin to 20 million m3/day to meet demand from the Rio de Janeiro Gas-Petrochemical Complex.

Petrobras has established a new concept in the market with the setting up of the Basic Natural Gas Transportation Network (RBTGN). This is a four thousand kilometer pipeline network running from Fortaleza to Porto Alegre and from São Paulo to Bolivia. The Network is vital for supplying gas to solve the energy deficit in the Northeast over the long term and for developing the natural gas market throughout Brazil.

In 2004, the conclusion of the environmental licensing process and the start of work on the Basic Gas Pipeline Network are of particular importance in expanding the infrastructure for natural gas transportation and distribution in Brazil. Investments of US$ 3.9 billion in building the Network are forecast up to the end of the decade.
The network will bring the production fields closer to the end consumer, ensuring gas supplies to the main consuming centers, and an annual domestic market growth rate of 14.2% up to 2010. The project is in line with the strategy of developing production in the Santos basin and expanding activity in the 48 offshore blocks along the route of the RBTGN, since this will permit the off-take from future discoveries of fields with associated or non-associated natural gas reserves.

The first phase in the integration of the Basic Gas Pipeline Network was begun in September with work starting on the Campinas–Rio Gas Pipeline at an investment of R$ 900 million and a length of 453 kilometers, for conclusion in October 2005. This project integrates the Southeastern network, and will link into the future Northeastern network and the Southeast-Northeast Pipeline (Gasene) as well as existing pipelines, thus expanding today’s network in operation (8,860 kilometers) by a further 4,200 kilometres.

The implementation of the Southeast-Northeast Interconnection (Gasene) project was seen as the best alternative for meeting demand from the Northeast Region in the short to medium term and providing a definitive solution to the problem in the long term. In addition to the Cacimbas (ES)–Vitória (ES) pipeline, the Gasene project consists of two further stretches, Cabiúnas (RJ)–Vitória (ES) and Cacimbas (ES)–Catu (BA), which are in the early environmental licensing approval stages, the negotiation of the Engineering, Procurement and Construction (EPC) package and the legal and financial structuring. Capital expenditures are estimated at US$ 1.1 billion.

Brazil imports natural gas from Bolivia via the Gasbol pipeline. TBG operates the Brazilian section of Gasbol - the longest gas pipeline in Latin America (3,150 kilometers), linking Santa Cruz de La Sierra in Bolivia to Canoas in the Brazilian state of Rio Grande do Sul. On July 2003, the Bolivia-Brazil Gas Pipeline attained its full capacity of 30 million m³/day of natural gas.

Brazil receives natural gas from Argentina via the Uruguaiana–Porto Alegre. TSB – Transportadora Sulbrasileira de Gás S.A., is a Special Purpose Company (SPC), based in Porto Alegre and constituted for constructing, operating and owning the Uruguaiana–Porto Alegre Gas Pipeline (615 kilometers). At present, only two extremities of the pipeline are ready and operating, supplying approximately 3 million m³/day of natural gas to the Uruguaiana Thermoelectric Power Plant and the Triunfo Petrochemical Complex (RS).

TMN owns the Meio-Norte Pipeline (1,616 kilometers), which is to be constructed from the state of Ceará to the states of Piauí and Maranhão. The project is to be funded from the Energy Development Account (CDE), created by Law 10,438 of April 26 2002 and regulated by Decree 4,541 of December 23 2002, the purpose of which is the development of feasible power projects in the states. On July 9 2004, Gaspetro’s Board approved a 45% stake in the company’s capital.

Transportadora Norte Brasileira de Gás S.A. – TNG was set up for designing, engineering, construction, installation, ownership, use, financing, operation and maintenance of the Urucu–Porto Velho Pipeline and associated installations. The pipeline, which will carry natural gas from the Urucu region in the state of Amazonas to Porto Velho in the state of Rondônia, runs a distance of 516 kilometers with a capacity of 2.2 million m³/day. Work scheduled to begin on construction in April 2005, is contingent on the issue of the environmental license. The pipeline will allow Petrobras to supply gas to the states of Rondônia and Acre as well as ensuring the operational feasibility of the thermoelectric power plants in the region.

Transportadora Amazonense de Gás S.A. - TAG objective of which is to build, operate and maintain the Coari–Manaus Pipeline. The pipeline links the municipalities of Coari and Manaus in the state of Amazonas, has a length of 397 kilometers and a capacity of 7.5 million m³/day. Capital expenditures are estimated at US$ 407 million. When complete the pipeline will meet demand from Manaus and neighboring markets for natural gas. Construction is to begin in April 2005.

Transportadora Capixaba de Gás S.A. - TCG purpose is to prepare the feasibility studies, the project, design, planning, the construction, installation, operation and maintenance of a gas pipeline (127 kilometers) for linking the gas treatment station at Cacimbas in the state of Espírito Santo to the cities
of Linhares and Vitória as well as other pipelines and feeder lines that may eventually be built in the state, plus respective complementary installations.

Transportadora Nordeste-Sudeste – TNS has been constituted for transportation of natural gas in the Northeast of Brazil (2,057.1 kilometers) and the Southeast (1,453.2 kilometers). Petrobras transferred the existing pipeline network assets to the company as a capital injection. TNS is the leader of a consortium made up of TNS itself, Transpetro (which will be the operator), NTN (Nova Transportadora do Nordeste S.A.) and NTS (Nova Transportadora do Sudeste S.A.). The latter two are owners of the new assets of the Northeastern Network and the Southeastern Network, respectively. The consortium will be responsible for the transportation, operation and maintenance of all existing and future installations to be built between 2006 and 2007.

4.3. NATURAL GAS DISTRIBUTION

Through the intermediary of its Gaspetro subsidiary, Petrobras has a stake in 18 piped gas companies. These companies have a total gas pipeline network of 2,900 kilometers, responsible in 2004 for selling an average of 16.4 million m³/day of natural gas, with net revenues of about R$ 2.6 billion, against R$ 2.4 billion in 2003.

5. NATURAL GAS AND POWER GENERATION

The electric power and natural gas industries are both network industries, in which energy sources are connected to energy users through transmission and distribution networks. As the restructuring of electricity market moves forward, the development of institutions, such as futures contract market through auction mechanisms is likely to build up a greater integration of the electricity and natural gas industries. As a consequence, the unpredictable dispatch of gas-fired power plants by the National Electricity System Operator brings to the table the debate on how to deliver natural gas whenever it is requested for power generation without promoting gas transport capacity inefficiency.

First of all, we shall understand that despite the similarities between natural gas and electricity industries, there are some remarkable differences. A major difference is that natural gas has a more sophisticated and complex cost structure than electricity.

Regarding to variable costs, let us cut a long story short and focus on increasing marginal costs of oil and gas fields that tend to increase with the production due to field depletion. As a well produces, the reservoir pressure typically drops, causing the production to decline. Secondary and tertiary recovery techniques add costs to oil and gas production in order to enhance recovery of oil or gas from a reservoir beyond the oil or gas that can be recovered by normal flowing and pumping operations. These techniques involve maintaining or enhancing reservoir pressure by injecting water, gas or other substances into the formation or using sophisticated techniques such as heating the reservoir to reduce the viscosity of the oil. Variable costs also include the distance from the source and massive investments of capital in natural gas infrastructure.

Regarding to fixed costs the usually extremely expensive development of new fields requires long-term forward contracts to reduce the uncertainty of returns.

The expected life and depreciation of natural gas transmission systems are typically quite long. This fact brings a lot of issues that must be adequately addresses if thermal generation is to be inserted in the Brazil energetic matrix:

- What happens to the return of any such dedicated assets if the generator ceases to operate prematurely or switches on and off because of favourable hydrological conditions?
- Are other ratepayers going to pay the remaining costs of these assets?
- Who are these others ratepayers: natural gas consumers, electricity consumers or taxpayers?
- What contractual provisions should be required to ensure other ratepayers are not left paying?
• Will an excessive reliance on gas-fired generation result in stranded gas assets if gas is displaced by another mode of generation?

In Brazil, Petrobras operates in the electricity sector through its stake in nine (out of 15) gas-fired power plants. Electricity sold by Petrobras in 2004 increased by about 126% (in MWh) compared to 2003 due to contracts signed in 2002/2003 with delivery scheduled to begin in 2004. During the year, Petrobras’ Units increased their participation by 137%.

The changing circumstances of the electric power sector with demand being largely satisfied from hydro plants eliminated the need to dispatch these thermal plants. Petrobras as a national oil company (OIC) is able to assume this as a strategic decision to avoid the risk of future rationing and to contribute to the reliability of the electric system. What about private agents? Will they accept the risk if before mentioned issues are not adequately addressed?

A further relevant issue concerns the location of gas-fired generating plants relative to natural gas transmission infrastructure and electricity transmission infrastructure. If on one hand, locating a power plant close to the required gas transmission facilities would minimize investment in such infrastructure, but could require significant invest in electric transmission facilities. On the other hand, locating a gas-fired power plant near a load centre would minimize the need for additional electric transmission infrastructure or its strengthening but may increase more or less significantly the infrastructure cost on the gas side depending on how far it is from the gas transport facilities. These considerations brings to the debate the need of an integrated unbiased planning covering both the natural gas and electricity sectors to ensure the most efficient combination of gas and electricity infrastructure requirements be determined and to prevent unnecessary or duplicative costs. The institutional framework in Brazil recently set includes enough entities to deal with this challenge. The new Brazilian electricity sector model resumed electricity central planning function. In the natural gas industry, Petrobras as the dominant player and responsible for most of the investments in the gas industry in Brazil, develops it own business plan, including gas transport alternatives for its product. A coordinated initiative could bring together both natural gas producers and generators and electricity utilities with their future plans for major facility investments. That could unfold potential synergies and contribute to the promotion of modest tariff charges.

Last but positively not least, we need to address the issued of third-party access and by-pass. These are probably the core issues in the course of the debate on gas deregulation.

Third-part access is the usual method for introducing competition in the transportation segments considering that economies of scale are large and relevant vis-à-vis the transportation market. In Brazil, that is not the case. Our natural gas infrastructure is poorly developed. Under these circumstances, third-part access will generate significant risks for investors besides increasing gas companies’ transaction costs. We might think of by-pass as a sort of third-part access to the distribution network.

In Brazil, gas regulation is constitutionally separated between federal and state level authorities. Transport pipelines are also under ANP jurisdiction while gas distribution is regulated at state level. This division adds complexity to an already difficult issue. As a consequence, no consistency exists between regulation at state and federal levels.

An alternative for regulatory inconsistency promoted by the jurisdiction distinction between gas transmission and distribution would be the implementation of complementary legislation so that a uniform national framework would be applied to access to natural gas transmission and distribution pipelines. Of course, that would mean to alter the Brazilian constitution but positively that would facilitate the development and operation of a national market for natural gas and prevent abuse of monopoly power as well as provide for resolution of disputes. It should also provide rights of access to natural gas transmission and distribution pipelines on conditions that are fair for both service providers and users and allow the recovery of the capital invested in the infrastructure.

In particular, any proposal must address issues related to gas-fired power generation that include but are not limited to the conditions under which the generator would be authorized to connect directly to the transmission pipeline. In that case, would the gas related infrastructure be required from the
regulated utilities? It is interesting to point out that the Brazilian electricity regulation allows a large consumer, under certain conditions, to implement the infrastructure to connect directly to the main electricity transmission system.

A work addressing regulatory issues for natural gas supply and electricity supply industries (Almeida and Oliveira, 2000) argue that this dichotomised jurisdiction led to a fundamental market power asymmetry between players positioned in the upstream (subject to competition) and players positioned in the downstream (monopoly organization) and list long term consequences:

• “First, it represents a premature selection of dominant market players because monopolists can take advantage of their contracting power both upstream and downstream to decide the rhythm and pattern of new investments. Downstream, these players can, for instance, chose to direct their gas supply to thermal power instead of residential or commercial users of gas. Upstream, they can select which players will receive their contracts to provide gas to the market and to transport this gas to the city gates. Therefore, they will be the gatekeepers that new players will have to deal with.”

• Second, gas distributors can use that asymmetry for rent seeking strategies in inter-fuel competition. Since there is no restriction for gas utilities to enter the electricity or the oil markets, they can operate their monopoly power at the gas end to use cross subsides in order to avoid inter-fuel competition. This will be made easier if gas utilities take positions in many segments of the energy market.”

6. FINAL REMARKS

Natural gas is expected to assume an important place in the Brazilian energy balance. The new electricity sector established new electricity commercialisation procedures as well as resumed the planning capacity of the country. Not only a new institutional structure was established but also the roles of the agents are clearer. Additionally, new discoveries in the Southeast of the country increased future availability of natural gas for electricity generation. That all opens the opportunity for coordinating initiatives between agents of both natural gas and electricity sectors in order unfold to potential synergies and discuss the expansion of the energy system as a whole.

The country still lacks a comprehensive energy policy considering the current stage of both industries, addressing simultaneously electricity, gas and oil sectors and considering the current development stage of each one.

The ability of generating units to switch from natural gas to other fuels at high demand for gas could balance natural gas and electricity supply/demand. Increasing fuel diversity and the installation of new fossil fuel power plants with fuel switching capability could add flexibility the operation of the electricity system and optimize the natural gas transmission infrastructure.

We may not get back to already known mistakes. In the past, to spur development of gas-fired power plants and eliminate risks associated with commodity price volatility, a fixed price for power generation was established. Even so, with guaranteed fuel price, this proposal was not successful. This type of measure not only does not solve the problem but also provides the wrong signal to gas exploration and production and discourage investors. We conclude that only price volatility for gas and electricity is likely to foster the growth of futures markets and promote the efficient allocation of resources. A deregulated gas market will not work properly if not only prices reflect levels of consumption, investments and productions but also contract schemes are available to hedge agents against the intrinsic volatility of spot prices.

REFERENCES


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Figure 1 – Brazilian electric energy supply growth by source.
Figure 2 – Population and electric demand.
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 $6 \times 10^6$ m$^3$ 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 $5.5 \times 10^6$ 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. 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 through 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 experimental use of the natural gas from Urucu. This authorization became the legal support for the implementation of the Experimental Project for vehicular use of the Urucu Natural Gas.

In order to properly establish the scope of the project and the responsibilities assigned to all 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 m$^3$ per week of natural gas produced in Urucu.

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, the implementation of the Experimental Project demonstrates that the general goal of mobilize 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.
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 Urucú Urucu natural gas – a PETROBRAS refinery in Manaus and power generation plants in the area, which are typically diesel fuelled.

Nevertheless, the appeal for the use of a potentially cleaner fuel in a region so much concerned with environmental issues represents an additional incentive to overcome those barriers. 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 do 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 specially mostly for those consumers with a relatively high daily mileage, like it is specially true (and cost advantageous) for taxi drivers, either individuals or companies. Naturally, 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 conversion of originally gasoline powered vehicles by the use of conversion 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 conversion conversion kit it is necessary to perform a series of emission tests. Those tests are performed on certified chassis dynamometer emission laboratories 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 usually accepted by Brazilian emission legislation as a satisfactory proof of the compliance of conversion kits to environmental legislation.

PETROBRAS had already performed those 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 identified proper parameter values were used, the equipments NGV kit would comply with the established emission level constraints legislations. Based on these results, Agência Nacional do Petróleo - ANP, the Brazilian regulatory authority for oil, natural and gas and Biofuels, agreed to issued a thirty month temporary authorization for the experimental use of the natural gas from Urucú 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 (GNCNG) 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 affluents. At the location named Porto Evandro on the Urucu River banks there are exists a docking facility 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 those regions. Therefore, the natural choice to transport GNC CNG was the use of river barges. Unfortunately, none of the sparcely availables 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 GNC CNG containers aboard the barges. It was therefore necessary to adopt a different solution involving trucks pulling CNG trailers that would travel xx km on the road from Porto Evandro to the nearest injection well where a complete CNG loading facility, with metering and...
odorizing stations, was built. The CNG loaded trailers are boarded on the barge and transported to the Manaus Port where they are transferred by trucks to the service station appointed to the project.


5. Design of the logistics for the project
   5.1 General configuration
   5.2 Dimensioning of the logistic system
   5.3 Winter season contingency plan

6. Initial results and conclusions

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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 10^6 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.

![Figure 1: The Polo Arara Complex – Urucu Production Area](image)

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 5.5 x 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.

![Figure 2 – Satellite photograph of the region and the Urucu-Coari-Manaus gas pipeline routing](image)

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 minimize 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 in 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 Hydro carbons) = 0.3 g/km and NO\textsubscript{x} (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, NO\textsubscript{x} 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 NO\textsubscript{X} 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 6.9% 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.

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/cm$^2$ require 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.

<table>
<thead>
<tr>
<th>Leg</th>
<th>Distance (km)</th>
<th>Time (days)</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manaus → Porto Evandro</td>
<td>911</td>
<td>7</td>
<td>• River distance • 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 • 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 m$^3$ trailer in reduced to some 4,500 m$^3$ 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 m$^3$ of CNG every 2 weeks to Manaus. It would lead to a rather small test fleet – not more then 128 vehicles consuming up to 15 m$^3$ per day. In order to increase the size of test fleet, but still keeping the 15 m$^3$ 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 m$^3$ of CNG every week, enough supply up to 300 vehicles with 15 m$^3$ 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 larges 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.

Despites 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.

REFERENCES


LIST OF TABLES

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