THE BUSINESS OPPORTUNITIES OF THE NUCLEAR RENAISSANCE

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Abstract. *After 20 years of nuclear moratory, the renaissance of nuclear energy as a primary source for generating electric energy brings important developments for all organizations involved in the Brazilian nuclear sector with different business opportunities throughout the nuclear fuel cycle and nuclear power generation. In Brazil the uranium is found in association with other elements of great commercial value as, for example, the phosphate (agribusiness) and columbite tantalite (computer / communication). The efficiency of the processing and extraction of the elements is associated with the adaptation of technological processes which are appropriate to the genesis of the Brazilian ore. In the manufacture of advanced nuclear fuels, in addition to the new capacities for advanced calculation and designs, skills are necessary for the development of new alloys and materials. The decommissioning of nuclear power plants demands the development of decontamination of materials for the purpose of recycling and reutilization of sites for new use. This document analyzes the role of business opportunities and the future demands in the value chain of nuclear activities. Institutions of R&D and Brazilian universities play a important role for the formation of the new demanded knowledges and human resources.*

Keywords: *nuclear option, renaissance, business, opportunities*

1. INTRODUCTION

The renaissance of nuclear energy as a viable option for inclusion in the Brazilian electric matrix was considered unlikely by the public and media in general until the end of the year 2006. Since 2004 members of the nuclear industry have already indicated the evidence of this renaissance, which now assumes a concrete and official character in the ambit of the Brazilian government. This new scenario now started also to be disseminated to the Brazilian society.

The National Energy Plan 2030, issued recently by the Energy Research Company of the Brazilian Ministry of Mines and Energy (EPE, 2007), formalized a reference scenario for the renaissance of the nuclear option in Brazil. This scenario includes the completion of Angra 3 Nuclear Power Plant up to 2014 and the construction of four additional nuclear power plants of 1000 MWe: a fourth unit by 2020, a fifth unit by 2025 and the sixth and seventh plants by 2030.

After 20 years of nuclear moratory, the revival of the nuclear option brings important developments for all organizations involved in the Brazilian nuclear sector with different business opportunities.

2. THE REVIVAL OF THE NUCLEAR OPTION

Population growth in combination with industrial development will result in doubling of electricity consumption by 2030. This increase of consumption combined with the increase of the awareness of dangers and effects of global warming and climate changes speed up a movement towards replacing fossil fuels by sources of low-emission greenhouse gases.

From the above mentioned reasons, the nuclear power, as one of the readily available large-scale alternative to fossil fuels for production of continuous, reliable supply of electricity, has returned to the agenda of the energy matrix of various countries.

The problems of global warming have led prominent environmentalists to rethink their objections in relation to nuclear energy. Not only the environmental aspect, but also by economic and strategic reasons, the nuclear renaissance also contains (a) the growth of public acceptance, given the historic demonstration of safety, (b) the economic competitiveness in the cost of generation, (c) the incorporation of innovations and technological developments with impacts on reducing barriers and costs of equity investments and destination of radioactive tailings (Mattos and Dias, 2007a).

The most visible face of this revival is shown by the heating in the international market of uranium with the increases in the price and volume traded. Since the historic low price of 2001, \$ 15/kgU_3O_8, the cost of uranium in order to market reached U.S. \$ 94/kgU_3O_8 in April/2006 and \$ 249/kgU_3O_8 in April/2007 (UxC, 2007), an increase of 16 times in 6 years. Currently the price of uranium reaches \$ 132/kgU_3O_8 (May/2008). The volume of U_3O_8 equivalent of contracts negotiated through the term in 2005 more than doubled the historical record of 1996. As a precautionary measure to speculation these contracts are no long available into open sites.

Currently, 30 nuclear plants are under construction in the world (IAEA, 2007), but the projected growth of 104% in world consumption of electricity between 2003 and 2030, as assessments of the EIA / DOE (2006), is the challenge that persists and means double in about 25 years the generation capacity installed in the twentieth century.

3. THE EXPANSION OF THE BRAZILIAN ELECTRIC SYSTEM

In Brazil, the energy shortage in 2001 indicated clearly the vulnerability of the Brazilian electric system, which is based on water, a renewable source of energy with an indisputable advantage, but which also includes a risk: depend on the natural cycles for its renewal and these cycles presented successions of dry and rainy periods. Consequently, in order to confer reliability to the Brazilian electric system is vital to have a portfolio of different sources of energy. The nuclear source is certainly one of the options to compose this portfolio, since Angra 1 and 2 Nuclear Power Plants had a key role to support the electricity demand and mitigate the impact of the energy shortage in 2001. Both operated continuously at full power along the shortage period.

Besides the shortage risks, the demand for economic growth has been renewed interest in energy-generation projects in Brazil. Policy options under consideration include expansion of natural gas exploitation, biomass, and hydropower generation in the Amazon and nuclear power plants.

Regarding the frontier for expansion of hydropower generation, it should be consider that the topographic conditions of Amazon are quite different from the Southeast region, where are located the big dams for hydroelectric generation and, of course, with major capacity of water reservation. In the Southeast region there is a difference of 700 to 800 meters from sea level to the plateaus. Great water reservoirs have been built using the valleys existent due this uneven. In the Amazon on the contrary the topography is flat. Even increasing the flooded area there is no significant increasing in the water capacity reservation, that in conjunction with the natural environmental cycles (dry and rainy) can amplify the risk of eventual water shortages. In order to prevent lack of electric energy supply in an enlarged hydropower system towards the Amazon, it is important to have thermoelectric support to confer diversification and reliability to the electric system.

The Brazilian options for thermoelectric generation are present at Tab. 1, with their comparative prices. The nuclear source appears as economically competitive, not vulnerable to external influences and environmentally correct option to complement the Brazilian electric system.

Table 1 – Comparison of thermoelectric energy sources – Brazil (Silva, 2006)

Fuel	Price volatility	CO_2 emission	National offer	Generation cost (R$/MWh)
Coal	Stable national	Yes high	Limited localized	~145
Biomass	Stable national	No	Limited localized	~110 follow gas and coal
Natural gas	Volatile commodity	Yes low	Ample need transport	~150
Petroleum	Volatile commodity	Yes high	Ample need transport	> 150
Nuclear Angra 3	Stable national	No	Ample easy transport	~137

The nuclear option in Brazil, until recently defended in its purely strategic dimension, is also being considered as an important contribution in terms of diversification and thermoelectric regulation in order to give reliability to the Brazilian electrical system.

In the current market conditions, the construction of the Angra 3 nuclear power plant could supply energy at a cost of R$ 137.00 per MWh. Additionally, it is a source of generation that does not contribute to emissions of CO2, in line with international requirements related to environmental issue.

4. THE BUSINESS OPPORTUNITIES IN THE BRAZILIAN NUCLEAR FUEL CYCLE

The nuclear fuel cycle is the progression of nuclear fuel through a series of different stages. It consists in the steps of identification of ore occurrence, steps of the preparation of the fuel, steps in the service period in which the fuel is used during reactor operation, and steps in the back end, which are necessary to safely manage, contain, and either reprocess or dispose of spent nuclear fuel (Fig. 1 and 2). If spent fuel is not reprocessed, the fuel cycle is referred to as an open fuel cycle (or a once-through fuel cycle), concept adopted by Brazil; if the spent fuel is reprocessed, it is referred to as a closed fuel cycle.

Brazil has the technological domain of the entire cycle with exception of reprocessing that is not included in the concept of open fuel cycle. Currently, only the reconversion step is not explored in industrial scale.

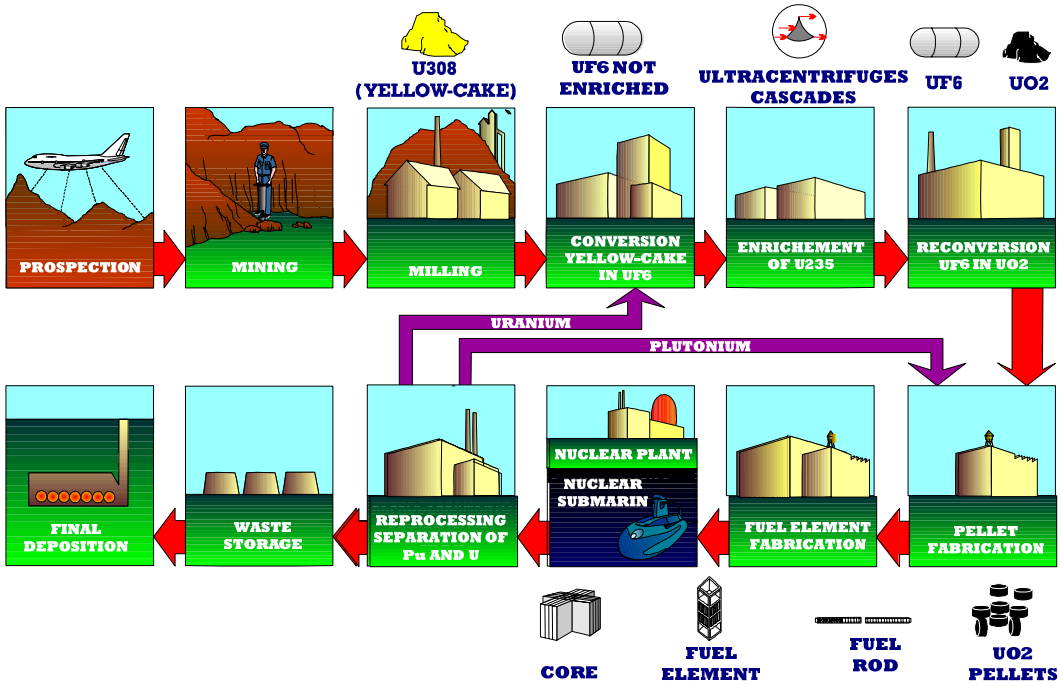

Figure 1. The nuclear fuel cycle

Figure 2. Uranium ore, yellow-cake, UF_6 and nuclear fuel pellets, respectively

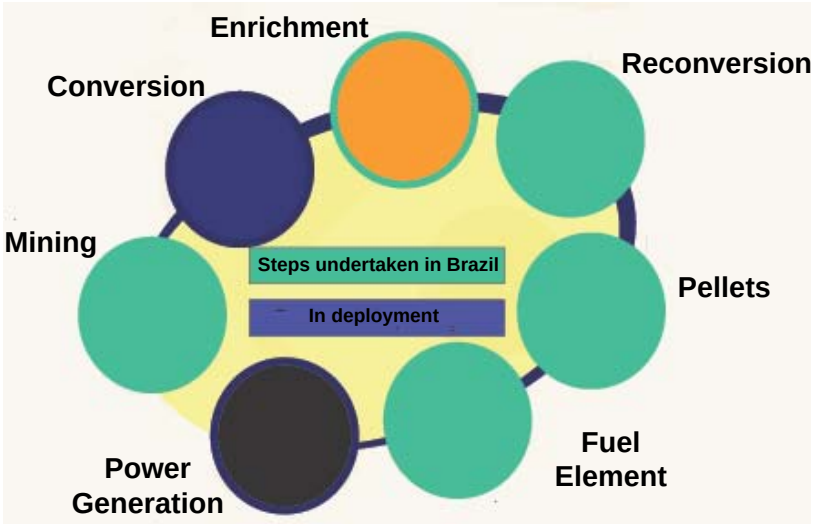

Figure 3. Nuclear Fuel Cycle in Brazil – status of implementation

In Brazil, the Indústrias Nucleares do Brasil – INB, a mixed economy company connected with the Comissão Nacional de Energia Nuclear - CNEN (the Brazilian nuclear regulatory authority) and under the Ministério da Ciência e

Tecnologia (Ministry of Science and Technology), is responsible for the activities of the nuclear fuel cycle, from mining and primary processing up to production and assembly of the fuel elements that power the reactors in the nuclear plants.

It also operates in the area of physical treatment of heavy minerals with prospecting and research, mining, industrialization and marketing of monazite sand and acquisition of rare earths. The status of implementation of the nuclear fuel cycle in Brazil is according the Fig. 3.

The associated opportunities to the development of the nuclear fuel cycle are described below.

4.1. Opportunities in the uranium prospection

With 30% of its territory prospected, the geological reserves of uranium in Brazil reached 309 thousand tons of U_3O_8, as indicated and inferred quantities. In the context of additional resources to Brazilian estimate is 800 thousand tons of U_3O_8 (Tavares, 2004; Silva, 2006) and, according to this assessment, the country becomes the 3rd world reserves.

Most of prospection campaigns were made in the 60´s and 70´s of xx century and since then little work has been done in this field. Promising areas, namely in the north of the country as shown in Fig. 4 are intended to receive investments in prospection in order do get a better characterization and update the Brazilian uranium reserves.

4.2. Opportunities in the uranium mining and milling

Currently, the INB develops shares of mining and processing in the region of Caetité (BA). The production is approximately 400 tons per year, enough to supply the power plants Angra 1 and Angra 2. The mine of Santa Quitéria (CE) will be essential to ensure the uranium supplying to the entire national market. The INB plans to double production of Caetité in the next ten years so that the mine will produce 800 tons of uranium annually. Information from INB (Fig. 4) shows that the reserve of Caetité is estimated at 100 thousand tons of uranium, which would be sufficient to supply the three plants of Angra dos Reis for one hundred years.

Another important point to be emphasized is that the occurrence of uranium is always associated with other minerals of great commercial value. Among these minerals are the occurrence of phosphate and rare elements such as niobium, tantalum, yttrium, etc., which make commercially valuable the exploitation of uranium in Brazil (Esteves, 2006).

In the economic aspect, the occurrence of Santa Quitéria, for example, is associated with the phosphate, whose holding will contribute to the elimination of external dependence and to significant increase in the Brazilian trade balance surplus, since the import of phosphate by Brazil in 2003 exceeded US$ 2.5 billion. The Nuclear Industries of Brazil (INB) is in negotiations to form partnerships with private companies for exploiting the deposit of Santa Quitéria (CE), considered the largest reserve of uranium in the country. Analysis of INB show that the economic viability of the site is dependent on the exploitation of phosphate, or the extraction of uranium is subject to the production of phosphoric acid, which is the input used in the production of fertilizers.

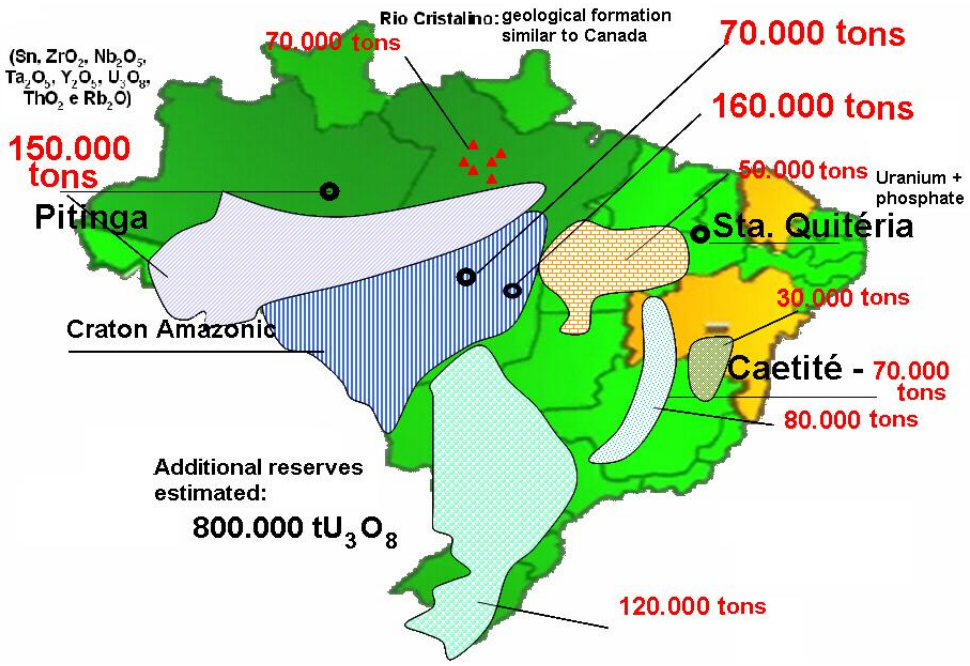

Figure 4. Additional reserves of uranium (Tavares, 2004)

4.3. Opportunities in the uranium conversion

The value added at each stage of the value chain of the nuclear fuel cycle corresponds to: 22% mining/milling, 5% conversion, 47% enrichment, 26% fuel element fabrication. Until few years ago, the Brazilian decision of investing in the conversion step was postponed taking into consideration the size of the Brazilian market, with only 2 nuclear power plants, the availability of buying this service abroad and low value added in the value chain of the nuclear fuel cycle.

The changing in the international scenario regarding the heating of the uranium market, with potential reduction of the service offers and the perspective of increasing of the Brazilian nuclear demand made the investment in the conversion stage a strategic factor for the Brazilian nuclear industry.

As mentioned in Fig. 3, currently the conversion is in process of deployment by means pilot plant carried out by the Navy Technological Center in São Paulo – CTMSP. Once the parameters have been adjusted and when considered appropriate the country could upgrade this stage for a full industrial scale.

4.4. Opportunities in the uranium enrichment

The conclusion of the first phase of industrial enrichment plant was postponed from 2008 to 2010, when the installed capacity - 114 thousand units of Work Separation (UTS) - should meet 60% of the fuel used in power plants Angra 1 and Angra 2. The supply of Angra 3 requires further expansion and the second stage of the project, which increase the production capacity to 203 thousand STU (Dantas, 2005). According to The Ux Consulting Company (http://www. Uxc.com) separative work of enrichment, in order to market, reached U.S. $ 146/UTS in June 2008.

4.5. Opportunities in the fuel element design and fabrication

Figure 5. – Fuel element

In design of fuel elements (Fig. 5) Brazil has the domain of the current state of art without autonomy for developing its own design. These competences include domain of theoretical knowledge and tools (codes, laboratories) and competence to run and manage tests of qualification (Esteves, 2006).

Brazil has capacity in manufacturing the fuel element and partial autonomy for tests, qualification of suppliers and new processes, and licensing. Further investments in infrastructure and cooperation agreements with universities and technological institutes are being made in order to improve the insertion of INB as an international supplier in the fuel market and achieve complete autonomy.

5. THE BUSINESS OPPORTUNITIES IN THE BRAZILIAN NUCLEAR POWER GENERATION

5.1. Opportunities in the heavy components fabrication

Since the suspension of the Brazilian Nuclear Program, 20 years ago, the Nuclebrás Heavy Equipment (Nuclep) experienced a period of under utilization and diversification, adapting its facilities in Itaguaí (RJ) to meet the demands of shipbuilding and offshore industries. With the recent green light for the retaken of construction of Angra 3 nuclear power plant and extension of life of Angra 1, the company returns to its core business.

The 2030 National Energy Plan (PNE 2030) considers four new units of 1.000 MWe in the next 23 years (EPE, 2007). Nuclep is analyzing its layout, equipment and tools in order to face both the resumption of nuclear program as the other projects under way.

5.2. Opportunities in the decommissioning

The safe performance of decommissioning activities is dependent on adequate funds to complete the work without risk to public and worker health and safety, and the environment. In order to meet this principle the funding for decommissioning must be sufficient, available, transparently managed, and used only for the purpose for which the funding was established (IAEA, 2005).

From the consolidation of information on the international experience in decommissioning, Brazil has to develop and incorporate knowledge and technology aimed at the structuring of the Brazilian nuclear power generation sector to cope with the future decommissioning of its units.

The ageing of the technical staff of the Brazilian Nuclear R&D institutions associated with a lack of a mobilizer program like the Brazil-Germany program in the past and the Naval Propulsion Program more recently, bring a risk that the existing knowledge be definitively lost (Mattos & Dias, 2007b)

Considering that the activities related to neutronic, shielding, criticality and thermal-hydraulic calculations are eventual and do not belong to the core business of the nuclear companies, they are usually contracted from the R&D

institutions. The resume of the industrial program does not assure that those competences will be kept because their demand is irregular and eventual. Here is a great opportunity to create a mobilizer program engaging universities and R&D institutions in order to keep the research staff up to date with the evolution of the nuclear sector as well as making their expertise available when the industrial sector needs. There is a need to retain the present staff to educate the new nuclear generation, and here it rests the greater opportunity to put a new mobilizer program in march soon before of the existing personnel be retired (Mattos & Dias, 2007b).

6. CONCLUSIONS

The nuclear option has an important contribution for complementing the Brazilian electric system and to support the development and growth efforts, since it is a source of energy economically competitive, not vulnerable to external influences, able to be installed closed to the demand, low intensive in water and land, and carbon emission free.

The renaissance of nuclear activity in Brazil brings a range of business opportunities that will spread gradually by the productive, R&D and education sectors with important developments for the future of the companies and professionals involved.

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