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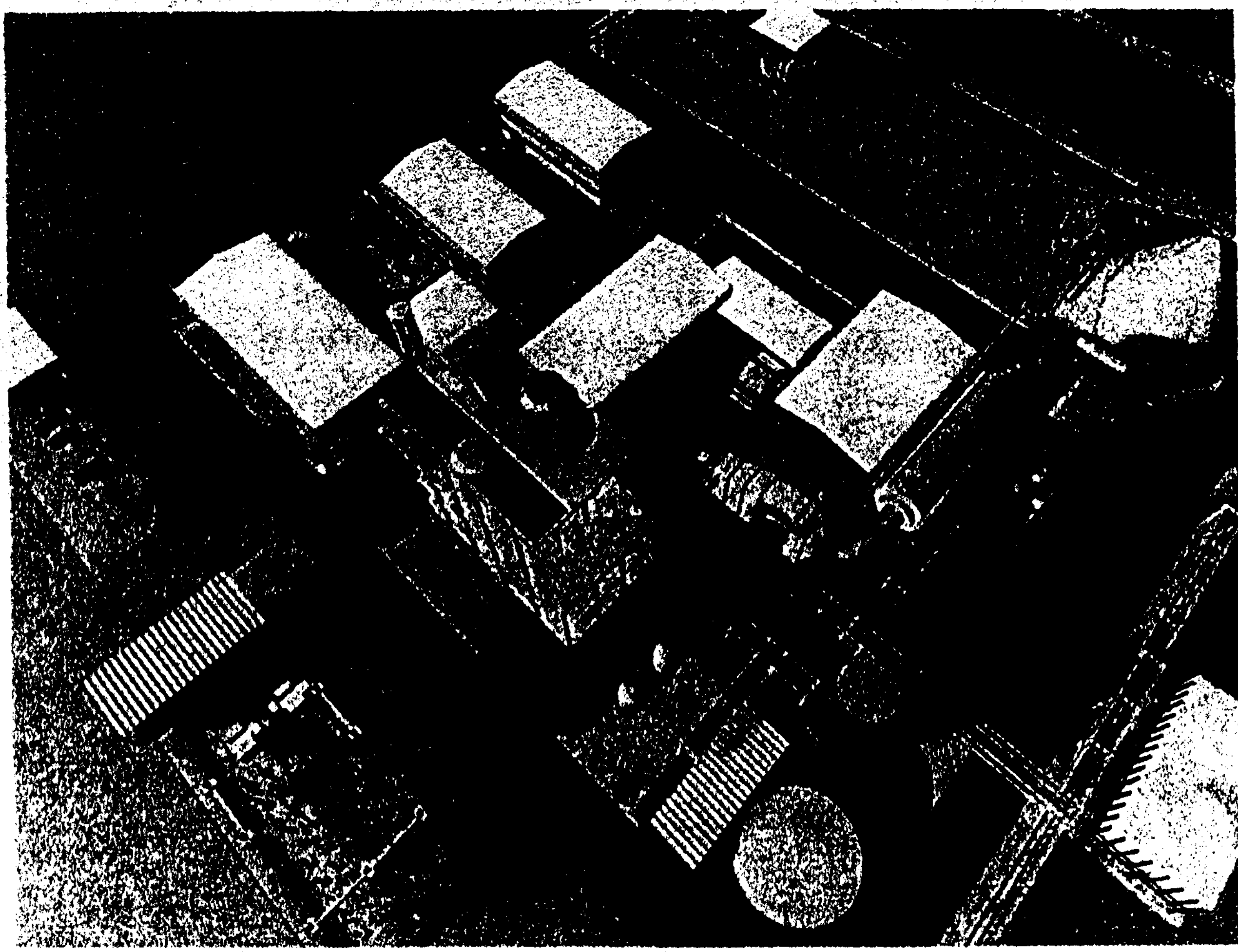


# BRAZILIAN WOOD BIG-GT DEMONSTRATION INTEGRATED WOOD GASIFICATION SYSTEM PROJECT - WBP

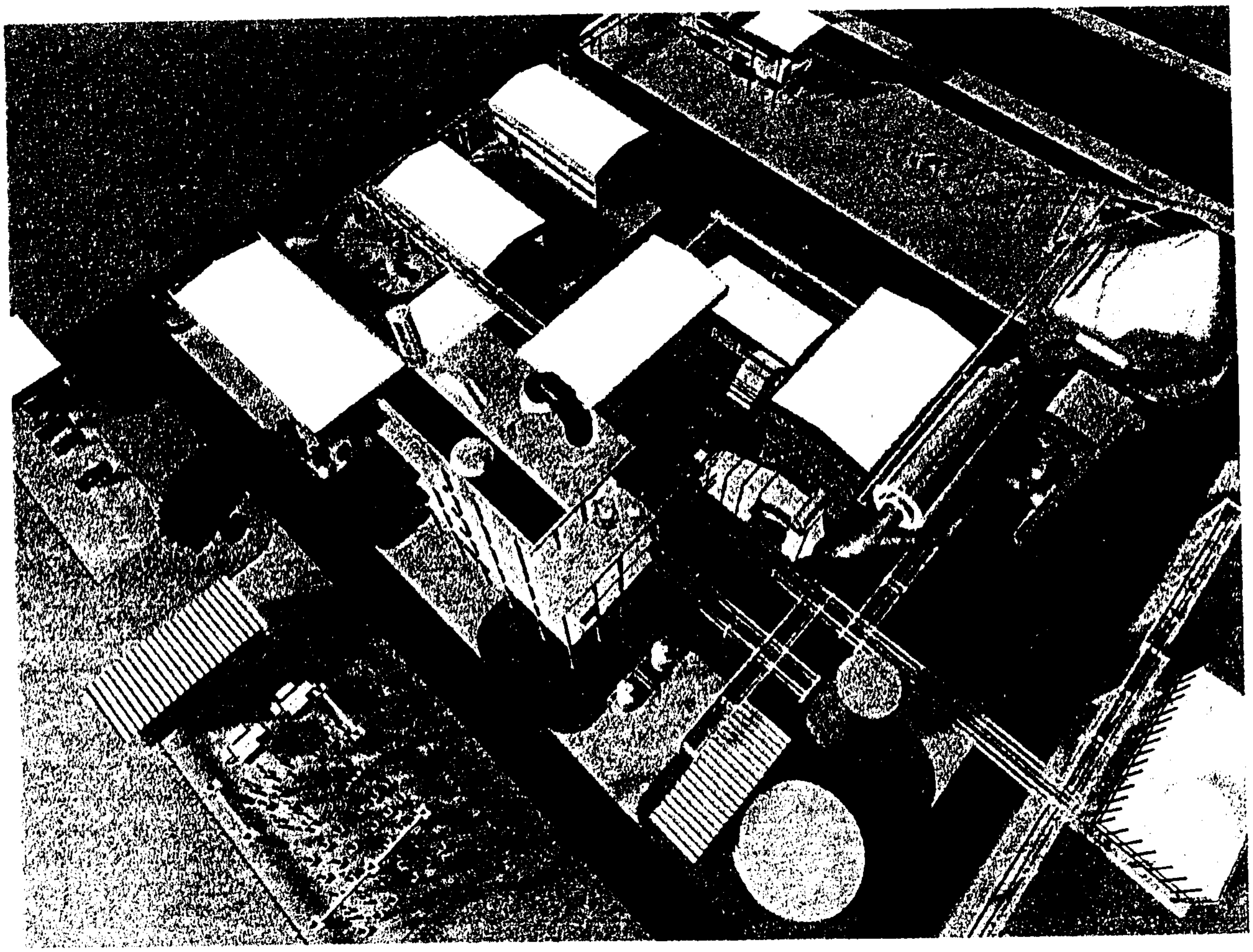
## FINAL REPORT ON PHASE II

**Participants:**

CHESF
CIENTEC
CVRD
ELETROBRÁS
SHELL

United Nations Development Programme - UNDP

Ministry of Science and Technology - MCT



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# 0 EXECUTIVE SUMMARY

## 0.1 Overview of Project

The purpose of the project BRAZILIAN WOOD BIG-GT DEMONSTRATION PROJECT/Integrated Wood Gasification System for Producing Electricity (WBP/SIGAME), is to show the commercial feasibility of generating electricity from wood (biomass) by using gasification technology integrated to a gasification turbine, operating in a combined cycle (BIG-GT Technology, Biomass Integrated Gasification – Gas Turbine).

It is also the result of the sum of interests of a group of companies and of Brazilian government agencies, in developing the BIG-GT technology, with the environmental preservation objectives of the Global Environment Facility (GEF).

The coupling of such interests enabled the MCT and the Participants, a group of companies composed of ELETROBRÁS, CHESF, SHELL, CIENTEC and CVRD, to receive a donation, initially of US$ 7.7 million and later increased to US$ 8.115 million, for developing the technology and basic engineering.

The WBP-SIGAME project as a whole was conceived in five phases, as follows:

- Phase I - Initial studies (already completed);
- Phase II - Development of equipment, basic engineering and incorporation of Phase II (object of this report);
- Phase III - Installation of plant;
- Phase IV - Trial operation;
- Phase V - Commercial operation.

The formal organisation of the project and of the group of bodies and companies involved with the GEF and with the United Nations Development Programme (UNDP), which is responsible for managing the GEF donation, was done through the following documents:

- "Project Document": Establishes the relationship and responsibilities between the MCT and the UNDP.
- Memorandum of Understanding (MOU): Establishes the relationship and responsibilities between the Participants and the MCT, as well as the organisational and managerial structure for implementing Phase II.

The Phase II estimate foresaw a total of US$ 8.115 million donated by international organisations, of which the weightiest items referred to developing the gasification technology (US$ 3.8 million), to modifying the gas turbine (US$ 1.65 million) and to the basic engineering (US$ 1.317). At the end of April 1997, there was a balance of US$ 0.38 million, essentially intended for complementary studies and reports.

In Phase III, the GEF will allocate, also as a donation, funds of US$ 35.0 million, while the remaining capital of approximately US$ 78.5 million, will be raised among the present participants and possible new investors interested in the project (US$ 25.0 million) and through a loan from the World Bank (US$ 53.5 million).

Phase II, which could be considered a preparation for installing the Demonstration Plant, besides the Development of Equipment and Basic Engineering of the Plant, also aims to prepare the Institutional and Organisational infrastructure necessary for implementing Phase III.

The activities carried out during Phase II were:

- development of equipment;
- basic engineering;
- fund raising;
- preparing institutional and organisational infrastructure;
- choice of site;
- fuel supply contract;
- energy sale contract;
- economic and financial studies;
- planning of Phase III.

The Phase II schedule foresaw the start of activities in November 1992, while the work to be done by BIOFLOW, TPS and GE would be concluded by January 1995. JPE would join the process in September 1993 and would continue with the basic project, after the conclusion of the EDs' work by April 1995. The CD's work, due to its inherent process management characteristics, begins before and continues after those periods. This phase was somewhat delayed and was extended until October 1997. A small remaining part of the scope has been transferred to Phase III.

As a way of optimising the use of the funds received, a sense of competition was introduced in Phase II since its start, through the parallel development of two basic projects: one using atmospheric gasification technology, TPS and the other pressurised, BIOFLOW. In the second half of 1995, TPS was chosen to supply the technology to be used at the Demonstration Plant. Thereafter, the basic engineering of the plant was complemented and an estimate of the consolidated investment was prepared.

## 0.2 Summary of Phase I

This phase was carried out with funds from international agencies (Rockefeller Foundation, Winrock International, US Environmental Protection Agency and US Agency for International Aid). Its technical basis consisted of studies made by Princeton University, General Electric, CHESF and SHELL, which indicated the technology's technical and economic feasibility.

That phase was concluded in March 1992, with the preparation of the Final Report on Phase I. Besides analysing the project's initial feasibility, the studies of Phase I broached the following principal points:

- appraisal of technological studies, to arrive at a preliminary concept of the plant;
- deciding on manufacturing companies and/or research bodies able to and interested in developing the gasification plant integrated to the heat cycle;
- deciding on gas turbine manufacturers able to and interested in developing the application of the gas turbine to the project;
- identifying alternative sites for the plant and wood supplies;
- organisational and managerial studies which ended with the preparation of the Memorandum of Understanding;
- planning and budget of Phase II;
- preparation of consolidated proposal for obtaining funds from the GEF.

## 0.3 Summary of Phase II

Phase II, begun in April 1992, basically contemplated the following activities: Technology Development, Basic Plant Engineering, Feasibility of Wood Supply, Contract for Selling Electric Energy, Economic and Financial Studies, Plant Location Studies, Environmental Studies and the Incorporation of Phase III.

In order to achieve those objectives the following companies, with their summarised scope of work, were contracted:

BIOFLOW - A Swedish-Finnish company resulting from a joint venture between Ahlstrom and Sydkraft, responsible for developing the pressurised gasification technology and the basic engineering of the thermoelectric plant's main systems.

TPS - A Swedish research and development company, responsible for developing the atmospheric gasification technology and the basic engineering of the thermoelectric plant's main systems.

GE - An American company, leader in the supply of gas turbines, responsible for modifying the LM-2500 aeroderivative gas turbine.

JPE - A consulting engineering company, responsible for accompanying the development of the equipment, for complementary basic engineering and for specific studies (environmental studies, studies for interconnection with the energy distribution system, etc.).

Below is a summary of the principal activities of Phase II and an evaluation of its present status:

0.3.1 Development of Equipment

As already mentioned, the development of the gasification technology and its integration to the Plant was done by two separate companies, BIOFLOW (pressurised gasification) and TPS (atmospheric gasification), in the line with what is known as the "Two Legged Strategy", whose purposes were: long-term objectives, maximising the probability of success, technological state-of-the-art and maintaining competitiveness.

The adaptation of the gas turbine to burning wood gas and to the process was done by GE.

- BIOFLOW

BIOFLOW's scope of work throughout Phase II included designing the plant (process engineering), developing and testing a new fuel feed system, testing and evaluating the gasification using Brazilian eucalyptus and the plant's basic engineering (restricted to the preliminary engineering until the choice of the technology to be used).

BIOFLOW concluded the PLANT'S preliminary basic engineering in the 2nd quarter of 1995. The feed system and gasification tests were carried out from August 1994 through to June 1995.

- TPS

The services included in TPS's scope comprised gasification tests in its pilot plant; laboratory testing of Brazilian eucalyptus, of dolomite, etc.; process studies covering critical parts of the plant (gas cooling, gas scrubber, integration of the gasifier with the gas turbine, etc.) and the plant's basic engineering (preliminary up to the choice of the technology to be used).

The process studies and the plant's preliminary basic engineering were concluded in the 2nd quarter of 1995. The gasification tests were concluded in November 1995 and the basic engineering in October 1996.

- GE

GE's scope of work during Phase II included analysing and simulating the gas turbine's performance; developing the air removal system of the turbine's compressor; developing the burners; specifying the turbine's control system; and the supply of information and specifications allowing the purchase of the gas turbine package. GE finished its activities in the 2nd quarter of 1995.

### 0.3.2 Basic Plant Engineering

The basic process engineering was developed by BIOFLOW and by TPS while JPE carried out its complementation, auxiliary systems and infrastructure. As from 1995, as the gasification technology had been chosen, TPS and JPE began working together. The plant's complementary basic engineering project was completed in January 1997.

### 0.3.3 Choice of the Plant's Site

CHESF and JPE made a study to choose the exact site of the thermoelectric plant, evaluating the areas Entre Rios, Fazenda Quatis, Pivot Central and Fazenda Salgado. All those areas, with the exception of Entre Rios, are in areas belonging to COPENER which until the start of Phase II was considered a probable supplier of wood for the plant.

The exact site study concluded that the Fazenda Salgado and Fazenda Quatis areas should be viewed respectively as the first and second option for installing the project.

The Fazenda Salgado area also had the strategic advantage of allowing the plant to develop its own forest, if the "supply contract" with COPENER were not renewed.

However, negotiations between the Consortium and COPENER for signing a wood supply contract were not satisfactorily concluded. The Consortium was therefore obliged to look for alternative sites for the project, now in the south of Bahia state. It was also decided to change the supply strategy. A mixed scheme was chosen, where about 60% of the Demonstration Plant's requirements would be supplied by its own forests and the remainder, about 40% of the demand, through forestry residues to be supplied by the companies Aracruz and by Bahia Sul, which were already installed in the region.

Initially, an area of approximately 4,100 hectares was acquired in Mucuri municipality, in Southeast Bahia, to be used for growing its own forests and the supply of forestry residues was negotiated.

The Demonstration Plant will be installed on the Lagoa Bonita farm, alongside the road connecting the BR-101 highway to the town of Mucuri.

Considering the place's productivity and an average occupation rate of about 70%, the total area to be acquired is around 4,600 to 4,800 ha.

### 0.3.4 Preparation of the Fuel Supply Contract

The wood supply contract would have to be negotiated between the Management Council (CD) and the wood supplier. The main aspects of that contract included a guarantee of supply, cost of wood, weighted average (30 km) and maximum distances (45 km) for transporting the wood to the plant, validity period, renewal and wood quality parameter clauses.

The negotiations between the CD and COPENER were not however concluded. On the other hand, as the project's prior funding foresaw the acquisition of a forestry area for supplying the energy input, this option then began to be considered. Consequently, two projects began to coexist: the electric energy generation project and the project for acquiring an area for installing a forestry reserve. The wood coming from the area acquired in Mucuri municipality (BA) will supply about 60% of the plant's fuel.

The companies Aracruz and Bahia Sul were contracted to supply the forestry residues, in the quantity needed by the WBP/SIGAME Project. Among the principal aspects of those contracts were guaranteed supply, validity period, clauses renewing and defining the operating rules of the residue handling.

0.3.5 Preparation of Energy Sale Contract

The energy sale contract is the instrument that will regulate the sale of electric energy by the SER Consortium and its purchase by CHESF. That contract was negotiated by the companies involved and would later be submitted to the DNAEE, the national department responsible for water and electric resources, initially for approval and later, after it had been signed, for ratification. The contract defines the tariff basis of the energy negotiated and the reimbursement scheme to be used by CHESF.

The contract was entirely ready in June 1997. Its contents were analysed by the legal departments of the companies involved and by CHESF's commercial department. Initial approval of the tariff and of the transfer of the tariff differential was received from the DNAEE. After the internal approval process had been concluded by CHESF's management, the contract was sent to the DNAEE for approval.

In the meantime, the sector's legislation changed and the ANEEL, National Electric Energy Agency replaced the DNAEE. Under the new legislation ratification is no longer necessary and market rules will prevail. The new legislation, which is still being prepared, will include schemes for supporting development projects. The new atmosphere brought by the changes in the Brazilian electricity sector made it necessary to reappraise the contract already agreed. This reappraisal is in progress and should be concluded by May 1998.

The tariff basis, one of the contract's main points, was decided at US$ 60.00 per MWh.

0.3.6 Raising Funds for Phase III

The companies Ancer and Environmental Enterprises were contracted to obtain information that would provide the CD with a broad view of the possibilities of raising new funds for the project, through donations, financing or new partners.

As a result of those studies and of further negotiations with the provider bodies, it was agreed that the amount needed for carrying out Phase III would be divided between the World Bank, the GEF and the companies taking part in the consortium.

0.3.7 Institutional and Organisational Structure of Phase III

Studies made for incorporating Phase III resulted in the decision to form a Consortium comprising the present members of the Group of Participants of Phase II, which would have two separate phases of activity.

In the first phase their activity will put the interests of the Participants on a formal basis and begin negotiations with possible new partners and with the various bodies involved in the structuring of Phase III.

In the second phase their activity will be focused on unifying the results of the negotiations concluded in the initial phase and on implementing the operation of Phase III.

The legal formalities of the Consortium were concluded in December 1996. Its members were the companies CHESF, ELETROBRÁS and SHELL. As CVRD was unable to decide whether it would participate at that moment, it was granted the right to participate in the future. CIENTEC is legally precluded from participating in the Consortium.

The organisational structure of the Consortium included the following bodies:

- Management Council, formed of members indicated by the Consortium partners and by the MCT. This Council is the senior body of the consortium and is entrusted with defining policies and approving budgets, as well with appointing persons to occupy the various posts of the organisation and supervising executive level acts.

- a group of superintendencies, at an executive level, responsible for managing the Consortium and answering directly to the Management Council.

## 0.4 Economic Aspects

A model for the project's economic studies was developed and tested by ELETROBRÁS. Later on, it was improved by SHELL and approved by the project's participants as a basis for their financial evaluations.

Simulations of the venture's economic performance indicate that it will achieve a internal rate of return of 12.3%. This may be considered a very reasonable performance if compared with the parameters adopted by the Electric Sector for its ventures. The sensitivity study indicates values in the range of 8.8% to 13.2%, which are acceptable for a venture that is essentially intended for using a technology still being developed.

It is important to point out that the high level of donations is specifically for the 1$^{st}$ plant, that is, the demonstration plant of the WBP/SIGAME project. Any improvement of the profitability of the commercial plants will depend on reducing the investment costs and on whether acceptable rates of operating efficiency are achieved.

It is hoped, therefore, that subsequent plants will require a strongly decreasing ingress of subsidies (of the GEF donation type) and that the commercial maturity of the technology will be achieved with the construction of a relatively low number of new plants.

# 1 INTRODUCTION

The generation of electric energy in a combined cycle has been found to be one of the most suitable ways of producing thermoelectricity. These plants are extremely efficient in utilising the energy available in the fuel. They are also the cleanest way of producing electric energy when compared with conventional thermoelectric plants. Those characteristics result from the joint use of the Brayton (gas turbogenerator) and Rankine (heat recovery boiler and steam turbogenerator) thermodynamic cycles, while in conventional thermoelectric plants only the Rankine cycle is used.

As a limitation, plants in a combined cycle demand a fuel which is in an almost liquid or gaseous state, and which is already relative free of impurities, for it to be burned in the gas turbine.

The utilisation of solid fuels (coal, wood, sugar cane bagasse, etc.) in combined cycle plants, using gasification technologies appears to be the prevailing tendency in the world scenario. The largest investments in this area have been made in order to use coal, with emphasis on plants built under the American Clean Coal Technology Programme and others operating or under construction in Europe, such as the Buggenum plant (Holland) and the German KoBra project.

The BRAZILIAN WOOD BIG-GT DEMONSTRATION PROJECT/Integrated System of Wood Gasification for Producing Electricity (WBP/SIGAME), uses a renewable fuel which is neutral as regards the carbon cycle, its principal differential.

Both in the WBP/SIGAME project as in plants for using coal, the gasification equipment and gas purification systems are the critical points in terms of technological development. Except for modifications in the fuel and control systems, the gas turbine is almost conventional equipment. The plant's other equipment belongs to the group of those that have already proven technology and development.

At the end of this stage, Development of Equipment, Basic Engineering and Institutional Infrastructure (Phase II), all the conditions will be available for beginning Phase III, Installation of the Plant, that is, the construction of the thermoelectric plant. In practical terms, this will make it possible to show the commercial feasibility (technical, economic and financial) of this technological proposal.

## 1.1 Objective of the Final Report

The aim of this report is to describe the activities in Phase II of the WBP/SIGAME project. Those activities took place between April 1992 and October 1997. It also aims to analyse future activities foreseen for Phase III, and also to appraise the project's development until this moment.

## 1.2 The Project, its Objectives, Phases and Scope

The WBP/SIGAME project was conceived with the purpose of showing the technical, economic and financial feasibility of using wood as a primary source for generating electricity, through a demonstration plant that used BIG-GT technology (Biomass Integrated Gasification-Gas Turbine). If it is successful, it may be an example of the use of a new technology that is economically competitive with alternatives based on fossil fuels. It may also have a substantial influence in reducing global carbon emissions and, therefore, in controlling their presence in the atmosphere.

The BIG-GT technology, when it uses wood (biomass) efficiently, a renewable natural resources, produced through energy forests or plantations, has the environmental characteristic of being neutral as regards the carbon cycle. This way of producing electric energy allows the substitution of the energy that would be produced by burning non-renewable fossil fuels.

The demonstration plant, which has a nominal capacity of 32 MW, is being conceived as a model ?? of future commercial plants, able to generate between 60 and 100 MW, and which have an important impact on rural living standards, particularly in developing countries.

The WBP/SIGAME project was planned in the following five phases:

- Phase I Initial Studies (July 1991 to March 1992);

- Phase II Development of Equipment, Basic Engineering and Institutional Infrastructure (April 1992 to October 1997);

- Phase III Installation of Plant;

- Phase IV Demonstration Operation;

- Phase V Commercial Operation.

As a consequence of this project, extensions are planned which will be developed at the same time as its Phase III.

The first is for adapting the BIG-GT technology for use in the sugar-alcohol industry (co-generation), the second to make a broad appraisal of possible positive or negative environmental impacts, which could occur with the large-scale use of the BIG-GT technology. It is also stressed that the word environmental should be understood, in this case, in its broadest sense, applying not only to the physical and biotic aspects, but also to the social and economic-financial aspects.

The WBP/SIGAME and its extensions will make it possible not only to expand the field of utilisation of this technology but also, probably for the first time, introduce a new technology in a sustainable and environmentally healthy way.

## 1.3 Work Done

Phases I and II of the WBP/SIGAME project have been concluded.

In Phase I the foundations of the project were laid from the technical, economic-financial and managerial viewpoints, and the scope of work to be done in Phase II was consolidated. Among the results of Phase I were raising funds necessary for continuing the project; the development of the plant's conceptual engineering; preselection of companies qualified to develop technology (EDs); an initial analysis of the project's feasibility; planning of Phase II and a definition of assignments and responsibilities of the participants in the next Phase.

In April 1992, after the project had been approved by the GEF/UNDP/World Bank, Phase II was begun by contracting the companies chosen to develop the plant's equipment, process and basic engineering: TPS, BIOFLOW and GE. At the same time the following activities took place:

- choice of site;

- environmental impact and licensing studies of the project;

- complementation of basic engineering;

- fuel tests in the field;

- fuel supply contract;

- incorporation of Phase III;

- structuring of technology supplier selection procedure;

- energy sale contract.

Another important activity involved tests with the wood to be used as fuel, both in a laboratory and in pilot plants. Tests were also carried out with sugar cane bagasse in a laboratory and on a test stand.

### 1.4 Structure and Contents of Final Report

The final report was organised so as to give a brief idea of the work done in Phase I, to show in detail the activities carried out in Phase II and to provide an indication of the future activities of Phase III.

A critical analysis of the project's situation is also given, indicating crucial points or those that will require more attention.

The following chapters provide a brief background of the project, a description of the plant, the management structures adopted, the development philosophies chosen for the various phases, a concise environmental evaluation of the proposed technology, a description of the environmental studies made or to be made and a detailed description of the project's current stage of development.

Also described are the funds and infrastructure necessary for developing Phase III, an economic analysis, budget and expenditure, schedules and future activities, as well as conclusions and final recommendations.

## 2 BACKGROUND

The first steps in the WBP/SIGAME project were taken by a group of companies having different characteristics and objectives.

Companhia Hidro-Elétrica do São Francisco (CHESF), the company responsible for generating and transmitting electric energy in Brazil's north-east region, has been interested in developing the BIG-GT technology for a long time. At first, CHESF intended to develop an independent project but, due to its shortage of funds, it ended by associating with other companies that had similar interests, funds and credibility compatible with the project's requirements. CHESF's basic interest in the BIG-GT technology was to be able to use it for meeting future electric energy demand as from the early years of the next century, when low cost water resources for generating electricity will be entirely in use.

ELETROBRÁS, a holding company grouping together Brazil's leading companies of the electric energy generation, transmission and distribution sector, including CHESF, realised the importance of participating in the development of a new and promising generating technology, as well as the possibility of that technology leading to the decentralisation of energy production in a very large country.

Companhia Vale do Rio Doce (CVRD), one of Brazil's leading companies in the mining, transport and forestry products sector, and the holder of vast reforestation areas, has its participation linked to interests in new technologies that might offer it future business opportunities.

SHELL, essentially a company of the oil and natural gas sector, is interested in developing new environmentally beneficial technologies in the energy area. Adding this interest to its experience in development projects and particularly with the BIG-GT technology, it expects to contribute with its support to the success of the WBP project.

Finally, the Fundação de Ciência e Tecnologia (CIENTEC), a research and development foundation which has had considerable experience with gasification, is interested in absorbing this new technology as a way of expanding its area of activity.

That initial group of Participants (ELETROBRÁS, CHESF, CVRD, SHELL and CIENTEC) began to be organised in May 1991 and was consolidated in June 1991 when the then Secretariat of Science & Technology, now a government ministry, publicly endorsed the idea of implementing the project in Brazil. The Ministry of Science and Technology (MCT) performed the important task of co-ordinating the work of Phase II and was responsible to the World Bank/Global Environment Facility (financing the project) for presenting the project results.

Phase I had financial backing from the Rockefeller Foundation, Winrock Corporation, EPA and USAID and advisory services provided by Energy Enterprises.

## 2.1 Objectives of Phase I

The ultimate objective of this phase was to guarantee funds that would allow the project to go on to its Phase II, through careful planning of a group of actions necessary in the institutional and technical areas. The following partial objectives were defined for that purpose:

- the formation of the group of "Participants" through the Memorandum of Understanding (MOU) which defined the organisational structure, commitments and obligations of each participant for Phase II;

- development of the conceptual design of the demonstration plant;

- definition of the work Programme for Phase II and determination of the necessary funds;

- to provide the GEF with a commercial and technical data base for evaluating the potential of the BIG-GT technology and for allocating funds to the Project.

## 2.2 Participants of Phase I

The participants of Phase I were:

- CHESF (Companhia Hidro-Elétrica do São Francisco): acted as one of the main collaborators in developing this phase of the project, assuming the commitment of participating in Phase II, of analysing the acquisition of energy generated by the plant and of evaluating the alternatives for connecting the demonstration plant to the system.

- ELETROBRÁS (Centrais Elétricas Brasileiras S.A.): participated in that phase and due to the possible opening up of the energy generation area to private enterprise, is interested in developing technologies suited to Brazil's current situation.

- CVRD (Companhia Vale do Rio Doce): participated in that phase and is particularly interested in reforestation projects.

- CIENTEC (Fundação de Ciência e Tecnologia): took part in that phase, with its knowledge and experience in developing gasification projects.

- SHELL (Shell Brasil S.A.): with support from the Non-Traditional Business Division (NTB) in London, took part in Phase I and was responsible for supporting and preparing the Final Report of Phase I submitted to the GEF.

- BRASCEP (Brascep Engenharia Ltda.): took part as a consulting engineering company and in the administrative co-ordination of the work.

## 2.3 Achievements of Phase I

The achievements of the joint work done during that phase is summarised below:

- obtaining the GEF's approval of the project;

- developing the conceptual engineering of the demonstration plant;

- preselection of companies qualified to develop the technology and to supply process engineering;

- preselection of areas for installing the venture;

- preliminary economic analysis;

- definition of criteria for selling energy;

- creation of the management structure and of the work plan for Phase II.

## 2.4 Objectives of Phase II

Phase II of the project consisted of preparing the basis necessary for installing the demonstration plant. Its purpose was to develop the principal items of plant equipment, to choose the technology, to prepare its basic engineering, to analyse its economic and financial feasibility and to define the institutional and organisation infrastructure which will allow Phase III to be implemented (Installation of the Demonstration Plant).

The main activities of this phase of the project are listed below:

- selection of the engineering company to provide support to Phase II;
- development of equipment;
- basic plant engineering;
- choice of site for the plant;
- preparation of fuel supply contract;
- preparation of electric energy sales contract;
- fund raising for Phase III;
- analysis of the project's economic and financial feasibility;
- providing the institutional and organisation infrastructure for Phase III;
- preparation of the venture's economic and financial planning;
- preparation of the planning of Phase III.

## 2.5 Participants of Phase II

The participants of Phase II remained practically unchanged in relation to Phase I, with the exception of the companies entrusted with developing equipment and the consulting engineering company. The following companies were selected for these activities:

- BIOFLOW: a joint venture between Ahlstrom, a traditional Finnish supplier of equipment and Sydkraft, a Swedish supplier of electric and thermal energy. BIOFLOW is responsible for developing the plant based on pressurised gasification technology.

- TPS (Termiska Processer AB): a Swedish research and development company, responsible for developing the plant based on atmospheric gasification technology.

- GE (General Electric): leading American company supplying gas turbines and energy generation equipment, responsible for developing the gasification turbine.

- JPE (Jaakko Pöyry Engenharia): a Brazilian consulting engineering company having wide experience in the energy and forestry areas. JPE is responsible for accompanying the development of the equipment and for the project's complementary basic engineering.

## 2.6 Achievements of Phase II

Among the principal achievements of Phase II are:

- formal organisation of the Project by the MCT with the UNDP (United Nations Development Programme);

- contracting of engineering services;

- selection of technology suppliers (EDs);

- contracting of technology suppliers;

- development of gas turbine;

- development of atmospheric gasification technology;

- development of pressurised gasification technology;

- monitoring of activity of technology suppliers;

- selection of gasification technology;

- testing wood and dolomite in pilot plant;

- incorporation of Phase III;

- energy sales contract;

- selection of local equipment suppliers;

- complementary basic engineering;

- planning of Phase III;

- intermediate report on Phase II;

- selection of plant installation site;

- study of connection with electric system;

- wood drying test;

- acquisition of area for reforestation;

- forestry residues supply contract;

- start of plant licensing procedure;

- economic-financial analysis.

# 3 DESCRIPTION AND LOCATION OF PLANT

## 3.1 General Description of Plant

The Demonstration Plant of the WBP/SIGAME Project was conceived as a gasification plant integrated to a combined cycle for generating electric energy with an overall efficiency of 40%.

The Demonstration Plant will have a nominal capacity of 32 MW and will use wood chips as the principal fuel. Tests are also planned with sugar cane bagasse.

The thermoelectric plant was divided into principal systems and auxiliary systems. The main items of equipment are those that needed technical development, or adaptation for burning the fuel, while the auxiliary equipment is conventional. Table 3.1 shows the systems that form the Demonstration Plant, classifying each one as principal or auxiliary and indicating which company is responsible for developing it.

The plant will occupy an area of 80,000 m², which will house all the equipment and facilities necessary for it to function and to be interconnected with the electric system (principal substation). The area needed for biomass planting is not included. Table 3.2 shows an estimate of the required forestry area, for an occupation factor of 70%.

The plant's general layout is shown in drawing 4060-P03-R1-007 of Appendix I.

**Table 3.1 – Classification of the Plant's Component Systems**

| System | Classification | Responsible |
|---|---|---|
| Fuel handling and storage | Auxiliary | JPE |
| Fuel drying and feeding | Principal | TPS |
| Gasification and gas cleaning | Principal | TPS |
| Gas cooling | Principal | TPS |
| Gas turbine | Principal | GE |
| Heat recovery boiler | Auxiliary | TPS |
| Steam turbine and generators | Auxiliary | TPS |
| Steam condenser | Auxiliary | TPS |
| Cooling towers | Auxiliary | JPE |
| Water treatment | Auxiliary | JPE |
| Waste water treatment | Auxiliary | JPE |
| Substation and distribution system | Not classified | TPS/JPE |
| Auxiliary and safety systems | Not classified | TPS/JPE |
| Monitoring, control and acquisition of data | Not classified | TPS/JPE |
| Communication | Not classified | TPS/JPE |

Note: In the unclassified systems, concept TPS and basic design JPE.

The main technical parameters used for the plant are:

| | | |
|---|---|---|
| - plant's installed capacity | MW | 40.4 |
| - liquid generation | MW | 32.3 |
| - liquid thermal efficiency (LCP basis) | % | 40.7 |
| - conversion cycle | | combined |
| - capacity factor | % | 85 |
| - energy production | Mwh/y | 240,210 |
| - fuel consumption | $m^3$ solid/y | 236,515 |
| - specific consumption | $m^3$ solid/MWh | 0.985 |

**Table 3.2 - Required Forestry Area (occupation factor 70%)**

| Productivity | Planted Area | Total Area |
|---|---|---|

## 3.2 Simplified Description of Process

The energy generating process begins in the wood receiving area. Its ultimate objective is to produce chips of a size suitable for gasification.

The wood received in the form of logs is weighed and measured (volume). Part of it is sent directly to feed the chipping line while the remainder goes to the storage yard, where it is unloaded by mobile cranes. The wood is taken again from the stock to feed the chipping line by wagons pulled by diesel tractors or by trucks, which are loaded by mobile hydraulic cranes.

After the feeder table, the logs are taken by belt conveyors and rollers to the drum chipper for transformation into chips, first going through a washing and metal detection station. The chipper is the rotary drum type with gravity discharge.

The chips are carried by belt conveyors from the chipper to an open area where they are stored in piles. The chips are removed again from the pile by extractors (mobile screw feeder type or similar), and then go on to the chip dryer.

The dryer uses the combustion gases to reduce the biomass humidity from 35% to the range of 10% to 20%, thus increasing the plant's efficiency and allowing the gas generated in the gasification system to be burned in the gas turbine (suitable heating power).

The biomass is introduced into the dryer forming a bed and the hot gases coming from the heat recovery boiler (HRSG) enter the bottom of the dryer and pass through the biomass bed, drying the chips.

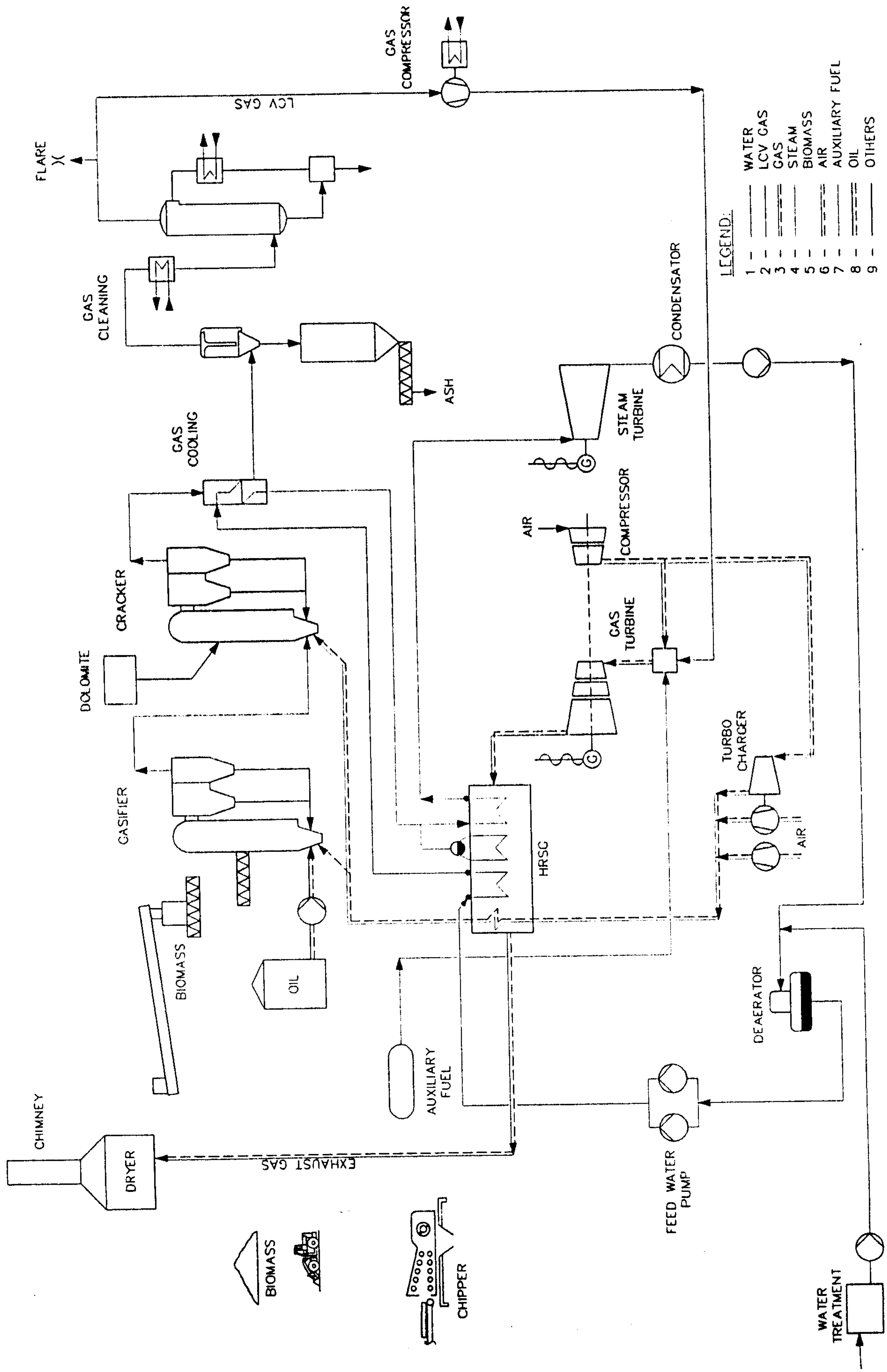
The dry chips feed the gasifier together with the combustion air, forming a mixture poor in oxygen, which is what generates the fuel gas.

The gas is cooled, purified and sent to the gas turbine where it is burned in the combustion chamber and later expanded, thus generating the mechanical energy necessary for driving the compressor and the electric generator coupled to the turbine. The exhaust gases pass through the heat recovery boiler where they generate the steam that feeds the steam turbogenerator.

A model LM-2500 aeroderivative gas turbine is used made by GE, modified for burning biogas. The main alterations lie in redimensioning the injector nozzles and in including bleeding for the air compressor.

The steam turbine discharges into a condenser cooled by water from the cooling tower. The condensate produced returns to the boiler's water feed system (HRSG), The electric energy is produced in independent generators, one for each turbine, which feed a bus-bar at a voltage of 13.8 kV. In the bus-bar, connected by switches, are the transformer that raises the voltage for the 13.8/69 kV (main substation) electric system and auxiliary transformers for feeding the plant which lower the voltage to 4.000 V and 440 V.

The transmission line and the main transformer are also interconnected by a switch. The process is shown in the simplified diagram of Figure 3.1.


GAS COMPRESSOR
LCV GAS
FLARE
GAS CLEANING
GAS COOLING
ASH
CRACKER
DOLOMITE
GASIFIER
BIOMASS
OIL
CONDENSATOR
STEAM TURBINE
AIR
COMPRESSOR
GAS TURBINE
TURBO CHARGER
AIR
HRSG
G
G
LEGEND:
1 - WATER
2 - LCV GAS
3 - GAS
4 - STEAM
5 - BIOMASS
6 - AIR
7 - AUXILIARY FUEL
8 - OIL
9 - OTHERS
DEAERATOR
AUXILIARY FUEL
FEED WATER PUMP
CHIMNEY
DRYER
EXHAUST GAS
BIOMASS
CHIPPER
WATER TREATMENT

## 3.3 Location of Plant

During Phase II, an analysis was made of areas that had forests capable of supplying biomass to the Demonstration Plant, contemplating the following aspects: location, accessibility, socio-economic characteristics and natural resources. Initially, the idea was to install the plant in the area of the Fazenda Salgado property, belonging to COPENER, 150 km north of Salvador (capital of Bahia state). However, it was not possible to reach an agreement on wood sales, resulting in the need to find new suppliers.

It was then decided to change the supply strategy and a mixed system was chosen, in which about 60% of the plant's requirements will be supplied by its own forests and the remainder, about 40% of the demand, by forestry residues to be supplied by Aracruz and by Bahia Sul.

Consequently, an area of about 4.100 ha, was acquired in Mucuri municipality, in the south of Bahia state, for planting its own forests. Negotiations were also concluded for supplying forestry residues. The Demonstration Plant will be installed on the Fazenda Lagoa Bonita property, alongside the road that links the BR-101 highway to Mucuri town.

Considering the place's productivity and an average occupation rate of about 70%, the total area to be acquired is approximately 4.600 to 4.800 ha.

## 3.4 Interconnection with the CHESF System (COELBA)

The preliminary study for interconnecting the plant with the electric energy transmission system was prepared taking into consideration, besides the costs, the load characteristics, system voltage and distances involved.

During the plant's installation phase, a study and detailed design of the interconnection with the system will be prepared.

# 4 MANAGEMENT AND ADMINISTRATIVE STRUCTURE

The basic idea of this chapter is to present clearly the management structures used for developing the Project until now, Phases I and II, as well as the structure proposed for Phase III.

It is also intended to show the evolution of the present and future management systems.

## 4.1 Structure of Phase I

Phase I was conducted by the group of companies through an informal agreement, without a defined institutional basis, or a signed legal contract. This phase was characterised by the preparation of specific studies for each of the companies and by technical and management meetings, where both the work done and the Project's next stages were evaluated.

Figure 4.1 shows the participants, gives an idea of how they operated, of the relationship between them and of each participant's contribution.

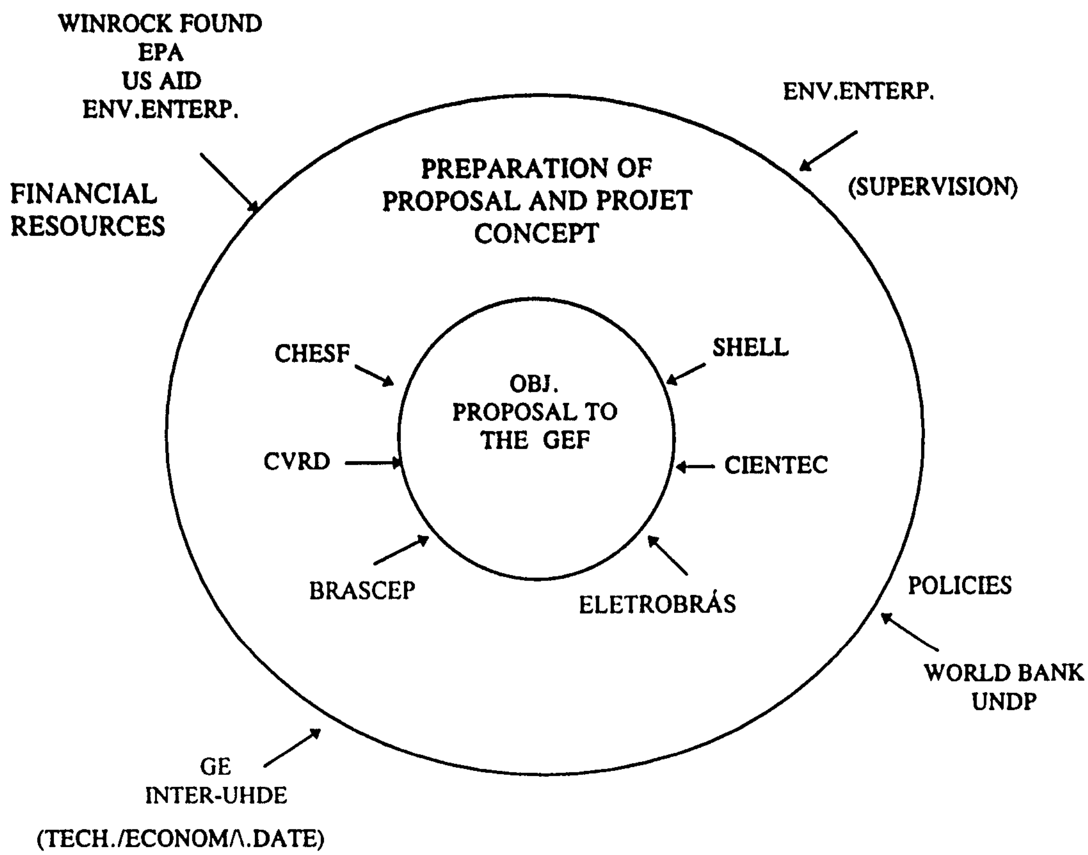



Figure 4.1 - Structure of Phase I

## 4.2 Structure of Phase II

The management structure of Phase II was described in a Memorandum of Understanding (MOU) signed by all the participants and by the MCT, and is shown in Figure 4.2. The same document also defines each participant's commitments and obligations.

The MCT assumed a formal commitment with the UNDP (United Nations Development Programme) to implement the Project, which it was agreed it would do through a Management Council (CD), presided by a ministry representative and composed of one representative of each Participating Company.

The CD works through a Project Management for which the CHESF representative is responsible, and Working Committees (GTs) appointed to carry out specific tasks and to follow up the work of the contracted companies (GE, TPS, BIOFLOW, JPE, etc.). The GT members are professionals allocated by the Participants and/or by their own representatives on the CD.

As a way of ensuring access to all the information necessary for evaluating the work done by BIOFLOW, GE and TPS, the Participant companies and the MCT signed with them a confidentiality agreement which allows the business interests involved to be preserved.

Under this agreement, all information considered confidential has its circulation controlled.

Such information is classified at two levels. Restricted information that BIOFLOW, GE or TPS considers vital for maintaining control of the technology used in the Plant's project is considered confidential.

Essas informações são classificadas em dois níveis, sendo consideradas confidenciais restritas aquelas que a BIOFLOW, GE ou TPS considerarem vitais para a manutenção do controle da tecnologia empregada no projeto da Usina.

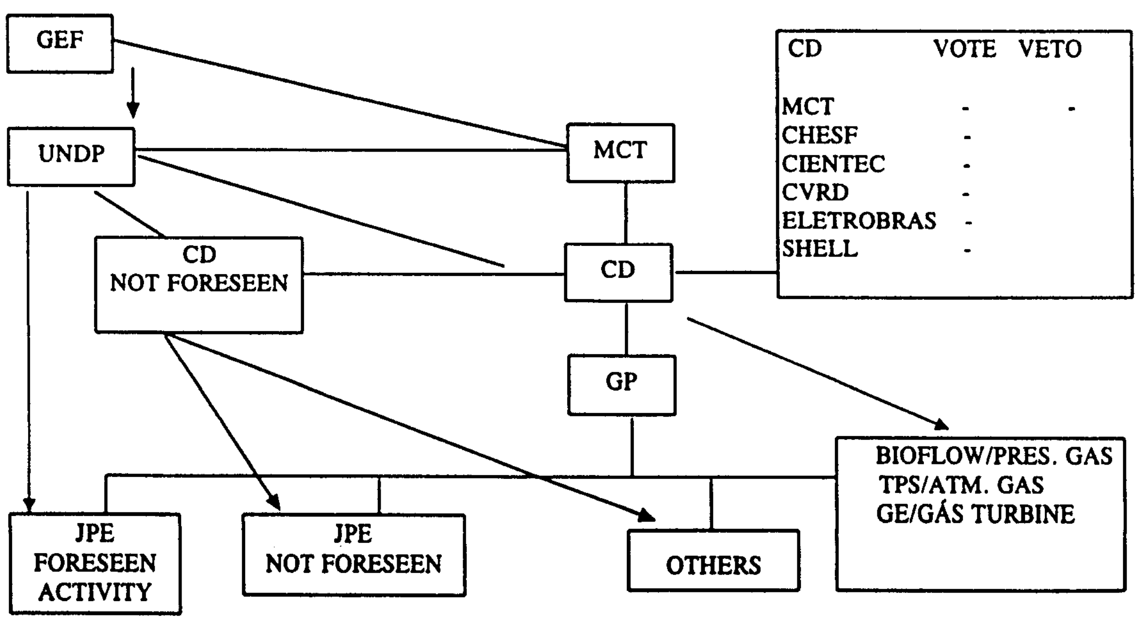


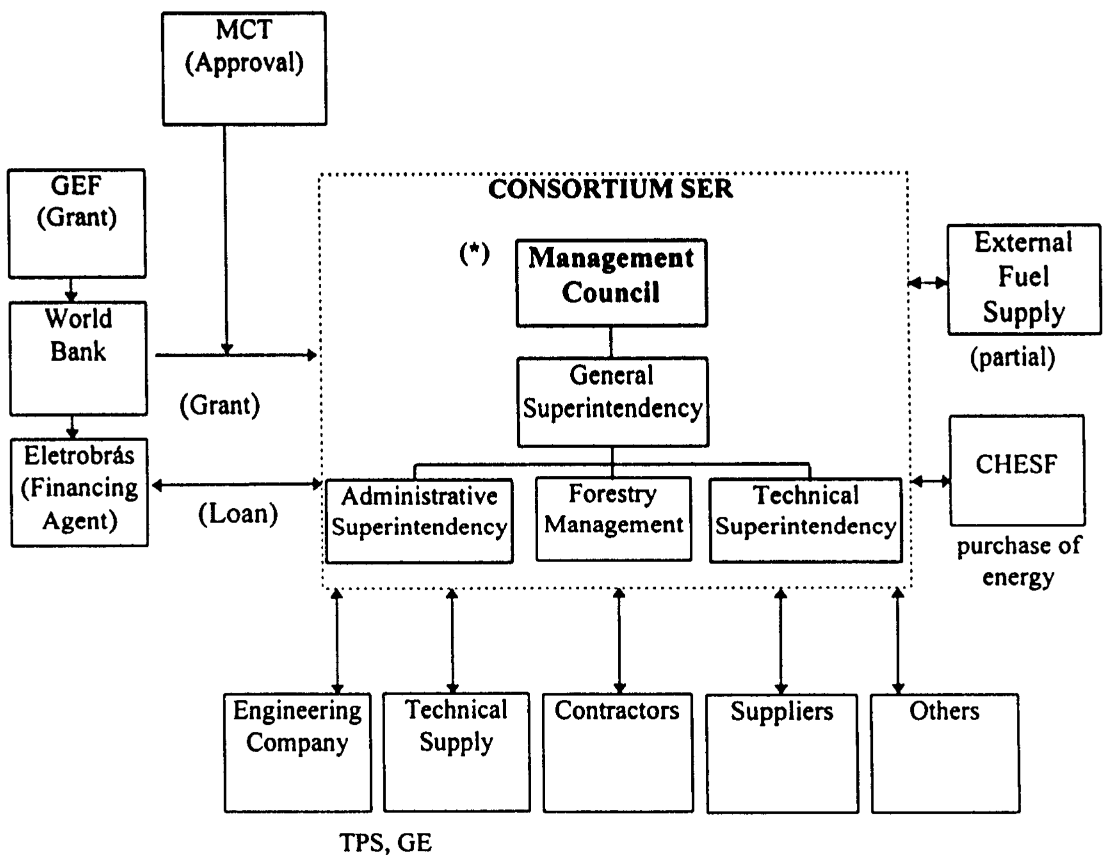

**Figure 4.2 - Phase II Structure**

## 4.3 Structure Proposed for Phase III

For performing Phase III, a group of Participants of Phase II (CHESF, ELETROBRÁS and SHELL) formed the "SER Consortium - Renewable Energies Systems".

This Consortium is organised to operate as shown in Figure 4.3. The Management Council is the senior body of the hierarchy. Its tasks include defining policies, approving budgets, and also indicating persons and supervising executive-level acts (Superintendencies) of the Consortium.

The superintendents, through the general superintendent, answer to the Management Council for the Consortium's administration.




* Representatives of the Companies (CHESF, ELETROBRÁS, SHELL) and of the MCT (without vote).

**Figure 4.3 - SER Consortium: Organisation and Relationships**

### 4.3.1 Assignments of the Management Council of the SER Consortium

The assignments of the Management Council may be summarised as follows:

- to define objectives, policies, general business guidance and basic guidelines of its organisation;
- to define a plan of action for installing and operating the Consortium;
- to approve an organisational structure and policy for human resources;
- to approve the disposal of assets of the Consortium whose value is above a certain ceiling;
- to approve the contracting of loans, financing and opening of credit;
- to approve commitments or contracts not foreseen in a budget;
- to approve expansion plans and investment programmes;
- to propose to the Consortium members amendments to the "Contract of Organisation of the Consortium";
- to choose the Chairman of the Management Council, the General Superintendent, the Technical Superintendent and the Administrative Superintendent;
- to approve the contracting and dismissal of independent auditors.

# 5 PROJECT DEVELOPMENT PHILOSOPHY

## 5.1 Phase I Development Philosophy

During Phase I, the work was performed through the contribution of all those involved and through decisions deriving from permanent negotiations among the representatives of the various companies, whose objective was to allocate specific responsibilities for carrying out the activities required by the Project at that moment.

That negotiation process took into consideration the available information, GEF guidelines, possibilities, availability and capability of persons representing the various participating bodies; it sought to allocate and distribute tasks to whoever could best perform them.

## 5.2 Phase II Development Philosophy

In order to get the best results with the available resources and to comply with the guidelines of the GEF/UNDP/World Bank, and also due to the fact that at the end of Phase I, no real superiority of either of the two technologies evaluated was clear, it was decided to introduce the concept of competitiveness in the work of Phase II.

The philosophy called the "Two Legged Approach" was therefore adopted. This consisted of simultaneous development of two Basic Projects, based on two competing gasification technologies, one pressurised and the other atmospheric. This philosophy is depicted in Figure 5.1.

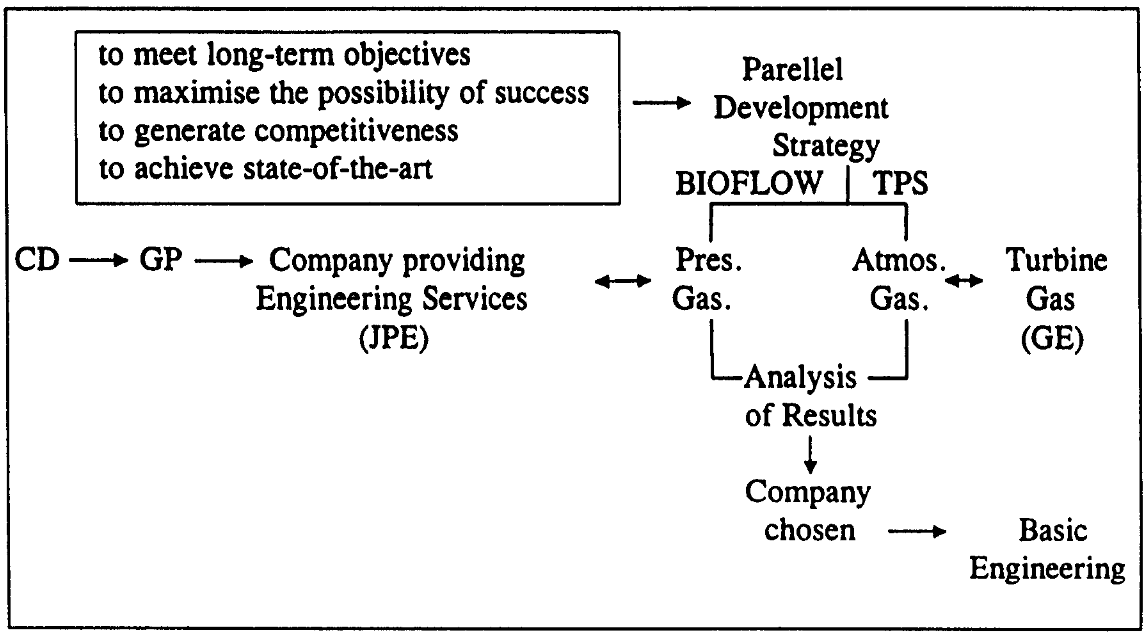



**Figure 5.1 - Phase II Development Philosophy**

In order to define the moment of decision, when one of the two technologies would be chosen, the Basic Project was subdivided into two stages, Preliminary and Final. The gasification technology was selected during the Preliminary stage.

At the same time, engineering was done necessary for modifying the gas turbine, which will be used by the two competing firms.

To complement the basic engineering entrusted to the Technology Supplier (ED), the engineering company JPE was contracted to carry out the following activities:

- absorption of technology;

- support given to EDs (Technology Suppliers);

- complementation of Basic Engineering;

- choice of Brazilian suppliers (preselection);

- support given to CD;

- technical-economic and financial evaluation;

- environmental studies and licensing;

- site studies.

## 5.3 Phase III Development Philosophy

So as to ensure that the financing agents' instructions are followed, the Consortium will opt for participating management. Among its advantages are less allocation of funds and a guarantee that the technology involved will be transferred.

Engineering, supply, construction and commissioning services will be contracted for implementing Phase III.

The Consortium will have a team that will accompany and supervise each of those services. Furthermore, in the supply and commissioning stages, the Consortium will co-ordinate the work.

Figure 5.2 illustrates this philosophy.

**ENGINEEERING COMPANIES**

Furnishing of drawings and documents for purchasing materials and equipment, construction and assembling; preparation of manuals for the commissioning, operation and maintenance for training and consultation; inspection and accompaniment of the manufacturing quality and progress.

**CONSORTIUM**

General project supervision; inspection and follow-up of engineering quality and progress, supply, construction, assembling and commissioning; recruiting and training for operation and maintenance; commissioning, operation and maintenance; supply of fuel; sale of production.

**CONSTRUCTION AND ASSEMBLING COMPANIES**

Construction and assembling; management of construction and assembling; supply of secondary components and of assembling materials; supply of infrastructure for construction and assembling, including lodgings, equipment for carrying out assembling, etc.

**Figure 5.2 - Implementation of Project during the Detailing, Construction and Commissioning Stages.**

# 6 THE PROJECT AND THE ENVIRONMENT

## 6.1 Environmental Potential of Technology

The environmental problem of $C0_2$ emission into the atmosphere occurs when petroleum, natural gas and mineral coal by-products are used, but has little to do with electricity generation in Brazil, which is predominantly hydroelectric. On the other hand, there is the matter of the environmental impacts of the hydroelectric plants, of their effects on the displaced communities and on the altered regimen of rivers.

The use of renewable energy sources as well as hydroelectricity, instead of fossil fuels, has the double advantage of avoiding the impacts of the hydroelectric plants and being neutral with regard to the balance of carbon dioxide ($CO_2$), when considering the forestry part (intake) and industrial part (emission) as a whole, thus contributing toward lessening the greenhouse effect.

In the specific case of Northeastern Brazil, the economically feasible hydroenergetic resources will have been entirely used up by about the year 2005, indicating the need to develop new sources of energy to supply the demand. The utilisation of energy produced from forestry biomass in a renewable and rational way is considered one of the best alternatives for this purpose.

Planted forests fix $CO_2$ during their growth period, removing it from the atmosphere. This, allied to the use of modern combustion technologies and biomass gasification, besides being a source of energy that may supply at least part of the Northeast's energy requirements, has the added advantage, as already mentioned, of not increasing the $CO_2$ content in the earth's atmosphere.

The pioneer project for generating electric energy from biomass gasification (BIG-GT), to be installed in Bahia State, aims to fulfil these objectives through a practical demonstration that will use a plant with a capacity to generate 32 MW of electric energy. It is being designed for use as a module of future commercial plants, whose output should be between 60 and 100 MW. The investment foreseen for the Demonstration Plant is US$ 113.5 million in current values, and should offer approximately 176 direct jobs (46 in the office and plant and 130 in the forestry area), as well as indirect jobs with forestry and services.

The Project's success may still represent, based on rationally planned reforestation, a means of achieving self-sustaining development, by fixing the population in the rural areas, eliminating the unchecked exploitation of natural resources.

The venture has support from the Ministry of Science and Technology, from the United Nations Development Programme - UNDP, and from the Global Environment Facility - GEF, a United Nations fund that supports the development of new technologies that are beneficial for the environment.

In addition to the above organisations, several foreign universities (among which are Princeton, Cornell and London Universities), Brazilian universities, Non-Governmental Organisations and Forestry Research Institutes, have been accompanying the project, both from the technological and environmental points of view. Perhaps it is the first time that a technology has aroused so much interest with respect to its environmental aspects.

## 6.2 Planned Environmental Studies

According to legislation of the CONAMA and of the State of Bahia, an Environmental Impact Study (EIA) and its related Environmental Impact Report (RIMA) will have to be prepared to obtain a Site License.

This study will also emphasise the Project's compliance with the GEF's instructions, namely:

- protection of the ozone layer;

- protection of biological diversity;

- protection of international waters;

- limitation of $C0_2$ accumulation in the atmosphere.

Other aspects that will be addressed in the study are the venture's favourable impacts, among which are: the jobs that will be offered, economic growth in rural areas and self-sustaining development.

Like any type of technology, the installation of a plant of this kind will affect the natural environment. Nevertheless, the study will seek to show that a well-prepared and properly managed venture will result in a positive global impact for the environment, when compared with other generation options.

The Environmental Impact Study - EIA, will not be restricted to the place where the plant will be installed. The foreseen scope covers both local and regional aspects.

The diagnosis will contemplate the characterisation of the physical, biological and man-altered environments, always seeking to identify the potentialities and uses of environmental resources, as well as the existing availabilities: water resources, atmospheric resources, utilisation of natural resources (renewable and non-renewable).

The diagnosis will include susceptible factors, that is, identifying the fragility or not of a particular environmental component, such as how a river, for example, directly or indirectly suffers significant effects of actions necessary to the project, like ground-levelling, for instance, in the phases of planning, installation, operation and, when necessary, the venture's deactivation. Cartographic information will be provided in which the area of influence will be duly described, using scales compatible with the level of detailing of the environmental factors studied.

The set of data to be presented in this Diagnosis will make it possible to establish the region's "vocation" in the right way and to reach conclusions that will be used when evaluating the impacts.

The impacts in their turn will be analysed from two angles, i.e.:

- an appraisal and discussion of all the project's environmental aspects, mostly involving those whose extent cannot be precisely determined and those whose quality only should be analysed;

- an evaluation of the extent or greater depth of the more significant impacts, whether because of the project or because of environmental susceptibility;

To reduce the adverse effects, mitigating measures will be suggested, classified according to:

- their nature: preventive or corrective;

- the project phase in which they should be taken;

- the environmental factor for which it is intended: physical, biological or socio-economic;

- how long will they apply: short, medium or long-term;

- responsibility for implementing them: entrepreneur, public authority or others;

Proposals will also be presented for programmes that monitor and control beneficial and adverse environmental impacts caused by the venture, including an indication and justification of parameters chosen for evaluating the impacts on each of the environmental factors considered, as well as emergency programmes to be activated in case of accidents.

After the EIA has been completed, a summarised version of the RIMA will be prepared for the public. The RIMA will reflect the conclusions of the Environmental Impact Study - EIA.

The technical information will be expressed in language the public will be able to understand, illustrated by maps on appropriate scales, tables, charts or other visual communication methods, so that the possible environmental consequences of the project and its alternatives may be clearly understood, comparing the pros and cons of each of them.

In addition to the studies required for the plant's licensing, the "Initial Terms of Reference" are being prepared of a study evaluating the beneficial and adverse environmental effects that may arise from the large-scale use in northeastern Brazil of the BIG-GT Technology.

This study will have a 25 to 30 year horizon and will evaluate the environmental impacts considering technical, economic, social and environmental aspects that would be involved when using that new generation technology.

## 6.3 Present Situation

The process was begun with the presentation of a Proposal of Terms of Reference to the Environmental Resources Centre (CRA) of Bahia. The proposal defines the scope and depth of the environmental impact study for the case in question.

This proposal was appraised by the CRA and, later, the final version of the Terms of Reference was prepared by mutual agreement between the Consortium and the CRA. Thus the process was begun for obtaining a license for installing the Demonstration Plant.

The EIA/RIMA studies will be concluded during Phase III of the project.

The area to be considered in the Environmental Impact Study is demarcated in the map in Figure 6.1.

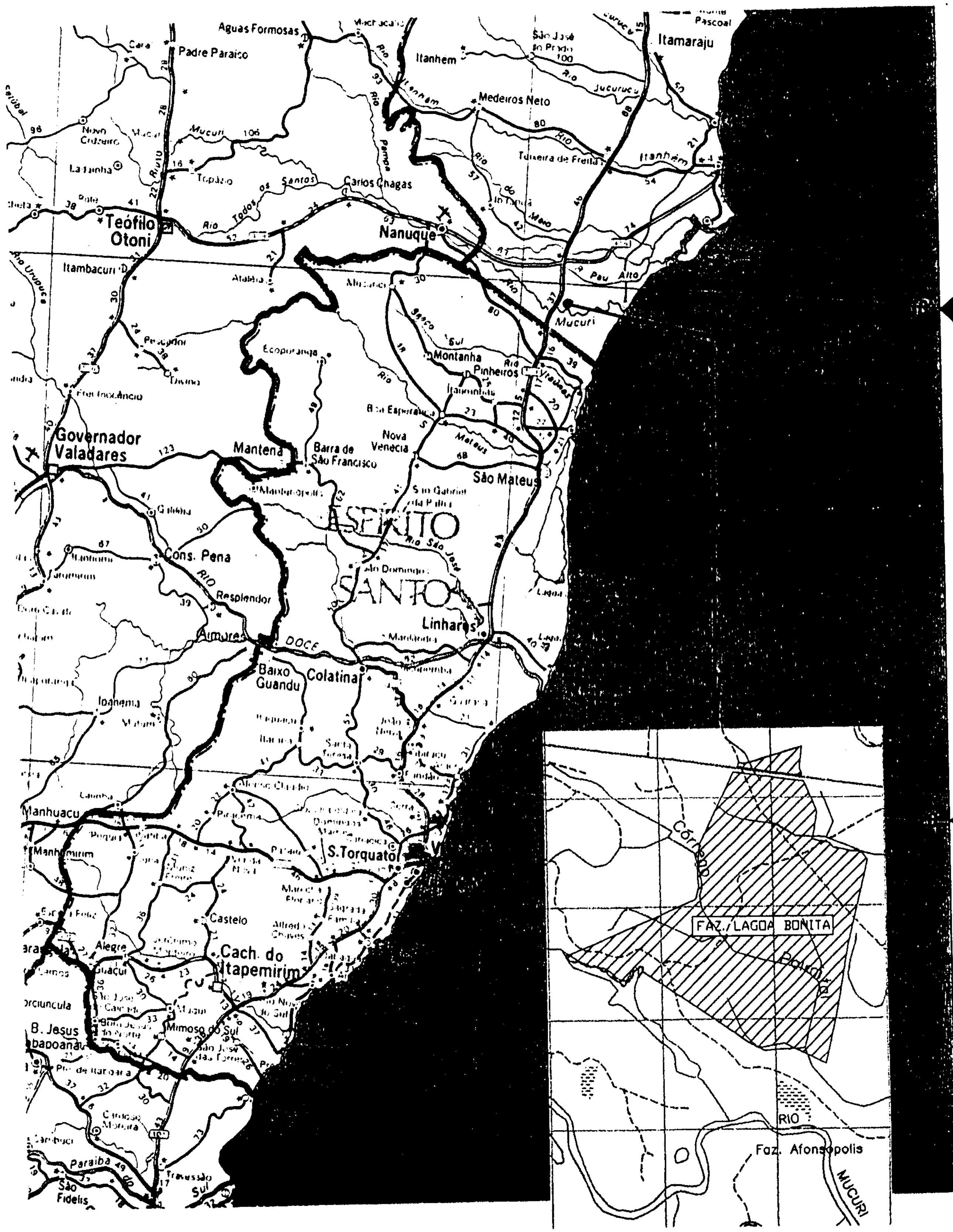



**Figure 6.1 – Demarcation of area where the Demonstration Plant will be built.**

# 7 PROJECT DEVELOPMENT

The purpose of this chapter is to offer a clear idea of the objective of the work done by BIOFLOW, TPS, GE, JPE and by the Project Management, and of the scope of work allocated to each of them.

## 7.1 Development of Pressurised Gasification

BIOFLOW's work was to develop, as far as the basic project, the engineering of a demonstration plant using BIG-GT technology based on a pressurised gasification plant.

BIOFLOW was also responsible for integrating all the plant's systems, including the gas turbine system.

By and large, BIOFLOW's activities followed the foreseen schedule, with the exception of the gasification tests.

After two successive delays due to commissioning problems at the Värnamo demonstration plant, the gasification tests were conducted in two stages.

In June 1995, Brazilian eucalyptus was gasified in four tests totalling 107 hours of equipment operation. In this stage the gas was burned in a free flame.

In October 1995 and September 1996 integration tests were conducted with the gas turbine, in a total of 149 hours of operation where eventually the generation of 3.7 MW was attained (100% of the turbine's capacity). In these tests, however, Brazilian eucalyptus was not used.

The preliminary basic engineering report was presented in January 1995, and then revised for final delivery in June 1995.

The scope of work, current stage of development, evaluation of progress and future activities are presented in Table 7.1.

### 7.1.1 Demonstration Plant

The plant used by BIOFLOW in the biomass gasification and catalyst tests is the same one that was built in 1991, also for the purpose of showing the potential of using biomass in an integrated combined cycle with a gasifier. That plant is in Värnamo, Sweden, and supplies both electric energy for the system and hot water (district heating) for the municipality. The equipment was developed by Sydkraft AB and by Foster Wheeler Energy International, Inc.

The plant's gasification process began with drying the biomass, for which exhaust gases were used. The fuel is fed through a system pressurised with inert gas.

The gasifier operates at 20 bar pressure (abs.) and a temperature in the rate of 950 to 1000 °C. It consists of a vertical pressure vessel which has a cyclone and the respective return piping installed in its outlet. Compressed air coming from the gas turbine extraction has its pressure increased by an auxiliary compressor and is injected into the bottom of the vessel, thus forming a recirculating fluidised bed. The gasifier, the cyclone and the return are lined with refractory material. The recirculating gas contains a certain amount of carbon, which is burned on the bed, thus maintaining the gasifier's temperature.

Due to the excess temperature, the generated gas is partly cooled in a steam generator, thus reaching a temperature in the range of 350 to 400 °C before it enters the cleaning system. This system basically consists of a ceramic filter. After cleaning, the gas feeds the single shaft gas turbine, in which 4 MW are generated.

The turbine's exhaust gases and the steam generated in the gas cooler feed a heat recovery boiler, which produces the superheated steam that drives a condensation steam turbine, with a 2 MW capacity. In addition to the total of 6 electric MW, the system also generates 9 thermal MW in the turbine's condenser, which supplies heat to the municipality. In the form of biomass, the system consumes 18 MW.

### 7.1.2 Gasification Tests

Four gasification tests were conducted for analysing the eucalyptus produced in Brazil. Those tests required 107 hours of gasification operation and in three of them the samples collected were analysed. Due to the difficulty of attaining a suitable biomass feed rate, the operating pressure was reduced and limited to the range of 15.5 to 18.5 bar (man.).

The need to improve the feeder's performance and, at the same time, to reduce the consumption of inert gas, meant that the system initially conceived (hopper with sealing and screw feeders) had to be substituted by a telescopic piston, which was installed and tested during the plant's commissioning, before the gasification tests.

The tests analysed the composition of the gas generated, its calorific power, the emission of particles, presence of alkalis, formation of ammonia, tar and chlorinated products and the composition of the ashes. The gasifier's behaviour was stable.

### 7.1.3 Integration of Gas Turbine

The fact that the Värnamo plant has a gas turbine made it possible to conduct tests integrating the gasification plant and the generating equipment. By and large, the behaviour of the gas turbine proved to be stable and the generating capacity was close to nominal. The efficiency was not measured.