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Fuel Substitution in Amazonia - Feasibility Study to Investigate Future Options for Joint Implementation Projects Between Brazil and Norway

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EXECUTIVE SUMMARY

The United Nations Framework Convention on Climate Change establishes no legal commitments for any of the Parties to reach specific targets of reduced greenhouse gas emissions. Although the Convention emphasizes the importance of immediate action by the industrialized countries, it is weak with respect to incentives for the industrialized countries to take the lead in fighting global warming. Through lowering the cost of reducing global greenhouse gas emissions, and in a beneficial way for all involved Parties, Joint Implementation under the Climate Convention may induce industrialized countries to increase their efforts to fight global warming.

The motives behind this study, financed by the Norwegian Ministry of Foreign Affairs, is to increase our experience and knowledge of possible future Joint Implementation projects. It is hoped that this feasibility study might add to the information on this issue and give all Parties to the Climate Convention further insight in this matter.

This study demonstrates some opportunities for fuel-switching from diesel to biomass in the power generation sector in Brazilian Amazonia as abatement measures to reduce emissions of carbon dioxide and nitrous oxide, and indicates the potential for such fuel substitution.

Our main conclusion is that many fuel-switching projects in Amazonia are both economically and environmentally interesting and that they, if implemented, will benefit both the local environment through reduced pollution, and the global environment through reduced emissions of greenhouse gases.

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CHAPTER 1
INTRODUCTION

1.1 JOINT IMPLEMENTATION

The basic argument behind Joint Implementation (JI) is straightforward; the country that pays for abatement abroad (investing country) will reduce its costs needed to fulfil a future legal commitment under the Climate Convention, while the country carrying out the emission reduction (host country) may gain from local environmental improvements, economic benefits and technological innovations in addition to reduced global warming.

JI may reduce the global costs of achieving a greenhouse gas (GHG) emissions reduction goal, but do not necessarily lead to lower global emissions. The global emission depends on the targets which are agreed upon under the Convention. By reducing costs, however, the obstacles for executing a global environmental policy become smaller, which again may have implications for the willingness of countries to participate.

1.2 THE STATUS OF JOINT IMPLEMENTATION

JI is a mechanism under the UN Framework Convention on Climate Change (FCCC). The mechanism is, however, not yet operational. This situation is caused by two main reasons. First, no countries have legally binding commitments under the Convention from which credits for reduced emissions in other countries may be deducted. Second, the criteria for the mechanism are yet to be decided upon by the Conference of the Parties (COP) to the Convention.[1]

Discussions in the Intergovernmental Negotiating Committee and in other fora seems to agree on the need for more experience on how JI may work under different rules and regulations. Many complicated issues related to the JI mechanism are under consideration. Some of these issues will probably be difficult to regulate into a strict set of rules and criteria. From our experience in the appraisal of demonstration projects on JI with the World Bank and the Global Environment Facility (GEF), it will be necessary to establish a few important criteria and leave other elements to the discretion of the countries, Parties to the FCCC, who on a voluntary basis choose to perform JI projects.[2]

Such an approach would give the COP an opportunity to learn from experiences with the mechanism and to adjust criteria as they see fit at a later stage. This project should be regarded as a step in the search for further information on how projects may be implemented under a JI arrangement.

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[1]Confer the discussion in Torvanger et al. (1994) and Matsuo (1994).

[2]One of these issues is the handling of 'no-regrets' projects, i.e. JI projects that are (or seem to be) profitable under ordinary market conditions. Since these projects should be undertaken anyway they should not be made applicable for credits under a JI arrangement. However, no-regrets JI projects may not be profitable in a broader sense if additional factors are considered, such as shortage of capital and institutional constraints, confer Selrod and Torvanger (1994).

1.3 FUEL-SWITCHING

The production and consumption of fossil fuels are the main sources of emissions of GHGs. The most important schemes for reducing emissions of GHGs are thus to reduce combustion of fossil fuels. Fuel-switching projects are projects in which the energy input is changing from a carbon-rich fuel to a carbon-poor fuel, or to a fuel without net emission of GHGs (such as biomass).

The practical way to estimate reduction in carbon dioxide emissions from reduced fossil fuel combustion in fuel-switching projects is to employ energy data from relevant generators, heaters, vehicles or other machinery. The carbon content of various fuels is well known, and provided that the availability of consumption data is satisfactory, the emission savings are easy to calculate. Estimation of nitrous oxide and methane emissions are more complicated as these are more technology-specific and varies with the combustion conditions.

1.4 THE SITUATION IN AMAZONIA[3]

The use of diesel for electricity production makes up about 1% of electricity production in Brazil. The main share of 95% is produced by hydropower while the remaining 4% is produced by coal and fuel oil combustion. Though diesel oil constitutes a very small fraction of total electricity consumption in Brazil, it takes a large share of electricity consumption in rural frontier regions, especially the North region. About 85% of national consumption of diesel for electricity production was consumed by isolated generator systems in the North Region in the 1980-85 period (Ponte (1992), p. 60). In 1985, diesel oil produced about 956 GWh of electrical energy, or about 21% of electrical energy in the region (Eletronorte cited by Ponte (1992), p. 65, table V). Electricity produced by diesel is especially important in remote states like Rondonia (92.5% in 1985), Acre (99.7% in 1985) and Roraima (99.9% in 1985) (IDESP cited from Ponte (1992), p. 65, table VI). By and large, the percentage of diesel in energy supply in the North region has remained stable over the last years, as the use of this fuel has expanded in pace with total energy consumption.

The demand for diesel for electricity production may be expected to increase rapidly in the future as rates of economic expansion and population growth are expected to continue to be well above the national average due to the process of frontier expansion.

Transports of diesel in this region are in themselves extremely energy-consuming. The Energy Company of Amazonas reports that diesel transports may require 50 days of travel of distances of up to 3.000 km to supply the most remote electricity producers (Ponte (1992), p. 60). High transportation costs is one reason for diesel oil being subsidized by around 15% in Amazonia.

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[3]The term 'Amazônia' as used in most texts usually has one of two meanings. One is the 'North-region' as defined by the Brazilian census agency IBGE, including the states of Para, Amazonas, Rondônia, Acre, Amapa, Tocantis and Roraima. The definition 'Legal Amazônia' that is used by the Brazilian planning agency for Amazônia, SUDAM, also includes Mato Grosso and large parts of Maranhão.

In addition to producing about 2.75 tonnes of carbon dioxide per m^3, combustion of diesel (especially in suboptimal plants) releases considerable amounts of carbon monoxide, both contributing to the greenhouse effect and local pollution. Furthermore about 0.6 kg nitrous oxide (N_2O) is released through combustion of one m^3 diesel. Nitrous oxide contributes to the greenhouse effect and in addition produces nitric oxide (NO) in the stratosphere, which contributes to the destruction of the ozone layer.

As the rural frontier in the North may be expected to expand well into the next century, there is a demand for more efficient and less environmentally harmful sources of electrical energy. In addition, as electricity production based on diesel oil is very common in rural regions all over the world, an analysis of more environmentally benign alternatives for Brazil may provide important background material for possible JI projects also in other countries.

This report does not address the interrelationship between the proposed projects and global and national problems connected to the expansion of the mining, logging and agricultural frontiers of Brazilian Amazonia. Especially important problems here are GHG emissions, biodiversity loss and destruction of indigenous reserves caused by uncontrolled large-scale deforestation and forest depletion. However, several of the main problems in Amazonia over the last thirty years have been connected not to regional economic development as such, but to the predatory and disordered mode of occupation of the region. The establishment of more reliable, less polluting and more labor-intensive systems of energy supply may contribute to a less chaotic and more manageable mode of regional development.

1.5 THE RATIONALE AND OBJECTIVES OF THIS STUDY

The global character of the challenge of man-induced climate change is also a challenge to traditional political solutions centered on problems within the nation-state. Effective responses to the problem of global warming in developing countries have to be identified and implemented at a national level in a way which also favors national development objectives. The FCCC charges the industrialized countries to take the lead to fight the threat of global warming and to commit themselves to reduce emissions of GHG either domestically or jointly with other parties. The Convention also charges the industrialized countries to assist developing countries financially and technologically in their endeavor to join in the fight against global climate change. This is the background for this joint study by BUN (Biomass Users Network) and CICERO (Center for International Climate and Energy Research, Oslo) to analyze the potential benefits of substituting biomass-generated electricity for diesel-generated electricity. If such projects are judged to be economically and environmentally interesting, they might be an option for future JI projects under the Convention.

The point of departure of this study is the fact that the combustion of diesel for electricity production in the rural areas of Brazil causes substantial emissions of carbon dioxide and other GHGs that also contribute to local pollution problems.

Biomass-related electricity production represents a feasible and cost-effective alternative which may recirculate carbon through burning and revegetation and thus eliminate net emissions of carbon dioxide and other gases. In addition it might contribute to economic development by providing employment. These opportunities are explored in further details in Chapter 2, which gives a discussion of various technological options and their corresponding cost per kW, optimal scale, potential of GHG emission savings, local development effects and adaptability to Brazilian Amazonia.

Two biomass-related alternatives suitable for Brazilian Amazonia are presented and analyzed in this study. The beneficial effects of these projects on the global climate and their cost-effectiveness is the background for the discussion of the second area in focus of this study, their relevance as JI projects. Among the tasks to be addressed in the study to clarify the potential of the projects as possible future JI projects are:

1. calculate a baseline of emissions in the absence of the project as a basis for the estimation of emission savings;
2. calculate total emission savings of CO_2 and N_2O by their Global Warming Potentials;
3. calculate the costs of projects;
4. evaluate other environmental and developmental benefits;
5. consider the total profitability of projects
6. give suggestions on how emission savings from possible future JI projects under the climate convention may be transformed to credits for the investing country.

CHAPTER 2
TECHNOLOGICAL OPTIONS

In this chapter, two main technological options are presented:
a) Conventional steam-turbine thermoelectric plant fueled with conventional biomass residues;
b) Internal combustion motors fueled with natural vegetable oil.

The greenhouse gases included in this study are given in Section 2.1. The selected projects of conventional steam-turbine thermoelectric plant fueled with conventional biomass residues are analyzed in Section 2.2. Just one project was identified to generate electricity through internal combustion motors fueled with natural vegetable oil; it is described in Section 2.3.

2.1 GREENHOUSE GASES CONSIDERED UNDER THIS PROJECT

The greenhouse gases considered under the present project are carbon dioxide (CO_2) and nitrous oxide (N_2O). Tables 2.1 and 2.2 below give a summary of the pertinent data collected for the Brazilian Northern Region, which includes the following states: Amazonas, Acre, Amapa, Para, Rondonia, Roraima and Tocantins. These data also include information concerning the use of diesel oil for electricity generation in that region, and specific emissions of GHGs associated to the use of this fuel.

TABLE 2.1 Data on diesel-based electricity generation in the Amazon region

Consumption of diesel for electricity generation in Amazonia in 1993 [1000m^3][4]	494.4
Total consumption of diesel oil in Brazil for all purposes in 1992 [1000 m^3][4]	25,450
Electricity generated in diesel-fueled engines in 1993 in Amazonia [GWh][4]	1,435
Carbon content in diesel oil[5]	85%
Nitrogen-to-carbon molar ratio in the diesel[6]	0.0002
Heating of N_2O relative to CO_2 per molecule[7]	320

[4]Ministerio da Infraestrutura (1993).

[5]Penner (1991).

[6]Badr and Probert (1992).

[7]Global Warming Potential based on a time horizon of 100 years, from IPCC (1994).

The carbon content of diesel oil is 85% and nitrogen content 0.017%. However, the greenhouse effect of nitrous oxide is 320 times that of carbon dioxide. For the Amazon region, diesel-based electricity produces on average 0.91 tonne of CO_2/MWh. The greenhouse net effect of nitrous oxide is thus 6.4% compared to CO_2, both produced from diesel-based electricity in Amazonia.

TABLE 2.2 Estimates of GHGs emissions from the diesel-based electricity generation in Amazonia

CO_2[million tonne/yr]	1.31
(0.85 x 494400 m^3 x 0.852 tonne/m^3 x 44/12)	
CO_2[tonne/MWh]	0.91
(1.31 x 10^6 tonne/yr / 1.435 x 10^6MWh/yr)	
N_2O [tonne/yr]	262
(0.0002 x 1.31 x 10^6)	
N_2O [million tonne/yr of CO_2 equivalent]	0.084
= (263 x 320 CO_2/N_2O)	
N_2O/CO_2 GHG net effect	6.4%
= (0.0002 x 320)	

Based on this data, the gross emissions of CO_2 and N_2O associated with burning of diesel oil used to generate electricity in that region was estimated. The amount of diesel used for electricity generation in the Northern region in 1992 corresponds to just 2.4% of all diesel consumed in Brazil for all purposes in 1992.

2.2 CONVENTIONAL STEAM-TURBINE THERMOELECTRIC PLANT FUELED WITH CONVENTIONAL BIOMASS RESIDUES

2.2.1 THE ARIQUEMES PROJECT

The Sathel company has a 14 MW thermoelectric biomass-fueled plant installed in Ariquemes, a city of 100,000 inhabitants located in the State of Rondonia. It intends to expand the installed capacity of this thermoelectric plant to 28 MW. The expansion will retain only a 6 MW unit from the existing system and add 22 MW of power. The new three units will be one with 12 MW and two other with 5 MW each. Since Ariquemes City is starting to receive its energy from a nearby hydro-electric power plant, Sathel intends to send electricity from its thermoelectric plant to Bom Futuro, a village 80 km from Ariquemes. The village has a population of 15,000 inhabitants. Cassiterite mineral extraction is the major activity. Currently, all electricity at Bom Futuro is generated through diesel units.

Environmental aspects
Since many farmers are clearing their land (they are allowed to clear up to 50% of each property), this wood is burned at the site and large fires can be seen all over the region. The Sathel project would make a better use of this wood and also reduce the local pollution caused by the many existing incinerators at the sawmills.

Social Aspects
As the present Sathel's contract with CERON (the local utility) is coming to an end, it will have to dismiss almost two hundred direct employees plus a similar amount of indirect employees if an alternate use for its thermal plant at the Ariquemes City is not found shortly.

Economic aspects
Table 2.3 gives a technical and economic summary for the Ariquemes project provided by SATHEL. The specific investment is about 1,600 USD/kW and the levelized electricity cost at the consumer door is 0.138 USD/kWh.

TABLE 2.3 Technical and economical summary for the Ariquemes project

Installed power [MW]	28
Gross energy generation [MWh/yr]	171,258
Specific fuel consumption [tonne/MWh]	2.50
Tradable energy [MWh/yr]	116,455
Investments [USD1000]	44,692
Operating & Maintenance costs [USD1000/yr]	3,279
Fuel costs [USD1000/yr]	6,208
Depreciation & amortization &	
return on investments [USD1000/yr]	6,562
Total annual cost [USD1000/YR]	16,049
Energy cost at the consumer door [USD/MWh]	138

Source: SATHEL

Baseline GHG emissions and carbon dioxide and N2O abatement effect
Assuming a mean GHGs emission from the Bom Futuro diesel generators of 0.91 tonne CO_2/MWh and 0.18 kg N_2O/MWh, and an average tradable energy during a 15-year period of 116,455 MWh/yr, then the baseline emission is 106 thousand tonnes of CO_2/yr and 21 tonnes of N_2O/yr during this period. From an average diesel consumption of 345 l/MWh this is equivalent

to a reduction in diesel oil use of 40,2 thousand m^3/yr. Considering that SATHEL gets a 15-year concession to distribute energy at Bom Futuro and an effective zero GHGs emission for the biomass cycle, then the CO_2 and N_2O abatement effects are equal to these baseline emissions.

Profitability and comparison between project alternatives
To compete with diesel-generated electricity at Bom Futuro, electricity should be sold for approximately 119 USD/MWh (diesel fuel plus O&M costs; see Table 2.4). As the energy cost at the consumer door for the biomass option is 138 USD/MWh, this project is not profitable. Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be 19 USD/MWh or 21 USD/tonne of CO_2. This cost might be paid per MWh generated or paid as an equivalent lump sum to be deducted from the investment in the Ariquemes plant. In this last case, the 19 USD/MWh means 14% of the energy cost at the consumer door of 138 USD/MWh, or 2.21 USD million/yr, which signifies 34% of the total investment, or USD 15.1 million, or yet 538 USD/kW-installed. Considering the GHG N_2O in the analysis would reduce the effective CO_2 abatement cost by about 6% (i.e. to 20 USD per tonne of CO_2 equivalent).

TABLE 2.4 Economics of diesel-generated electricity

Specific investment [USD/kW]	150
Capacity factor [%]	50
Interest rate [%/yr]	12
Useful life [yr]	15
Average diesel consumption [l/kWh]	0.345
Diesel cost [USD/l]	0.30
Operation & Maintenance costs [USD/MWh]	15
Fuel costs [USD/MWh]	104
Depreciation & amortization & return on investments [USD/MWh]	5
Total annual cost [USD/MWh]	124

2.2.2 THE AMAPA (SANTANA) PROJECT

The Santana Project is located at the city of Santana situated 30 km from the city of Macapa - the capital of the state of Amapa. The project consists of the construction, in two phases, of a 15.5 MW steam power plant capacity fueled by bark from Amapa Florestal e Celulose - AMCEL, a private wood-chip exporting factory owned by the CAEMI group.

Today, AMCEL is buying electricity from CEA (Electric Company of Amapa). Although all electricity is supplied by a 40 MW hydroplant during 9 months of the year, in the peak of the dry season, from October to November, the system requires thermal complementation (three gas engines, 18 MW each). The Amapa electricity market (52 MW) is growing with 7% per year, but is expected to grow at least 14% in the future since Santana was recently promoted to a free zone area. Eletronorte (Brazilian Northern Electric Centrals) is very interested in buying excess power from AMCEL. In this way, they hope to postpone some state investments in the area of electricity generation since they lack financial resources to execute all their expansion plans.

Fuel Supply

AMCEL has a 82,000-ha reforested area of pinus on a 180,000-ha farm. The company has 600 employees from which 500 are assigned to the farm and 74 to the factory. The installed production capacity of the factory is 900,000 t/yr. As 20% of the log weight corresponds to bark, the capacity of bark production is 180,000 t/yr.

Environmental Aspects

The potential impacts of the project include those associated with the fuel supply and the emissions from the generating station. As the bark from trees harvested must be disposed anyway, it will be used as fuel supply to the thermo-plant. Emissions from the generating plant itself should not be a problem. The most important is particulates.

Social Aspects

This project will generate about fifty jobs.

Economic Aspects

Assuming a 12% interest rate; a 15 year project life; a cost of 8.5 USD/tonne for the AMCEL bark residues; an annual O&M costs of 7.3% of the total investment; then the generating cost of electricity would be 87.9 USD/MWh, as may be seen in Table 2.5.

This value would be attractive to Eletronorte since even the fuel costs of its thermal-based units are in the order of 90 USD/MWh, or even more.

TABLE 2.5 Santana Project

Installed power [MW]	15.5
Planned energy generation [GWh/yr]	67.5
Specific bark consumption [tonne/MWh]	2.56
Specific Investment [USD/kW]	1,310
Useful life [yr]	15
Interest rate [%/yr]	12
Depreciation & Amortization	
& return on investment [USD million/yr]	2.98
Operation & Maintenance costs	
(at 7.3% of the investment) [USD million/yr]	1.48
Fuel costs (at 8.5 USD/tonne) [USD million/yr]	1.47
Total annual cost [USD million/yr]	5.93
Levelized energy annual cost [USD/MWh]	87.9

Baseline GHG emissions and CO_2 and N_2O abatement effect
Assuming as mean GHGs emission from the AMCEL diesel generators 0.91 tonne CO_2/MWh and 0.18 kg N_2O/MWh, and an average tradeable energy during a 15-year period of 67.5 GWh/yr, then the baseline emissions are 61 thousand tonnes of CO_2/yr and 12 tonnes of N_2O/yr during this period. Considering that SATHEL gets a 15-year contract to sell energy to Eletronorte and an effective zero GHGs emission for the biomass cycle, then the CO_2 and N_2O abatement effects are equal to these baseline emissions.

Profitability and comparison between project alternatives
According to Eletronorte officials, to compete with diesel-generated electricity at Macapa, electricity should be sold for at least 90 USD/MWh. The energy generation cost is 88 USD/MWh, hence the minimum profitability of this project is around 13%/yr (see Table 2.5), and the project seems to be no-regrets. Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be barely negative: -2 USD/MWh or -2.2 USD/tonne of CO_2. A more detailed feasibility study might get a smaller rate of return for this project which could possibly abort it. In this case, an external JI-funding might be needed for its execution.

2.2.3 BIOMASS-BASED ELECTRICITY GENERATION AT THE CITY OF SINOP

In 1985, a large ethanol plant was assembled at the outskirts of the SINOP city, located 400 km north of Cuiaba, the capital of the state of Mato Grosso. The ethanol plant which was designed to use cassava as a feedstock, operated for less than one year because enough feedstock was not available in the region at a competitive price. In 1993 the plant was acquired by 3 agricultural cooperatives headed by COMICEL (Cooperativa Agricola Mista Celeste).

The new owners are going to use millet as a feedstock for ethanol production and at this moment it has just started to operate. According to COMICEL, ethanol production from millet grain will not demand all the steam and electricity installed potential at the factory. One boiler and one turbine will be enough to produce all the energy services for the process. COMICEL is willing to generate and sell electricity to the Mato Grosso State utility (CEMAT), using steam produced in the reserve boiler.

SINOP, with a population of 100,000 inhabitants is planned to be connected to the grid up to the end of 1995. Presently its electricity is generated through the use of diesel motors connected to electric generators having a cost of about USD 100/MWh. Although in the near future, CEMAT will be able to purchase electricity from the national grid at prices between USD 30-40/MWh, there are arguments in favor of electricity acquisition from COMICEL: a) electricity acquisition will improve the city economy; b) it will increase the economic feasibility of the ethanol plant; c) increase of electric system stability; and d) reduction of energy losses.

The project

The generation system could make a better use of the high pressure boiler if one of the two single-stage back-pressure steam-turbines is replaced by a multistage condensing turbine. With the availability of 55 tonnes/h of steam it is possible to generate 9 MW of power. The fuel will be wood residues since SINOP is a major processing wood center on the region.

Environmental aspects

The plant will need 10,000 tonnes/month of biomass residues, a quantity well below the amount of wood residues available in the city. Thus no net increase in deforestation and CO_2 emission will occur.

At the short term, until SINOP is connected to the National Interconnected Grid, another advantage is the abatement of CO_2 produced from the combustion of diesel oil to generate 9 MW of electricity. Once connected to the Grid, the city will still rely on diesel generators to guarantee reliable supply. Connection through only one transmission line means that power supply interruption can occur. A statistical analysis foresees that 5% of the time electricity must be generated by diesel generators installed in the city. Also the National Connected Grid generates 3% of its electricity from coal plants which is another source of CO_2 emission that should be accounted for in the calculation.

Social Aspects

This project will generate about fifty direct jobs and help to make feasible the whole enterprise with a large direct economic and social impact on the local economy.

Economic Aspects

Incremental investments of USD 550/kW will increase power sales from 2 to 9 MW. Considering a similar cost composition as the Amapa Project (Section 2.2.2), to recover only the incremental investments being done on this project, the generated energy should be sold by about 62 USD/kWh (18 USD/kWh for depreciation & amortization & return on capital costs; 22 USD/kWh for O&M costs; and 22 USD/kWh for fuel costs).

Baseline GHG emissions and CO_2 and N_2O abatement effect
Considering all these factors, once connected to the grid, the following amount of CO_2 emission will be abated: 7,969 tonnes of CO_2/year and 1,576 kg of N_2O/year (see details in Annex 1).

Profitability and comparison between project alternatives
To be profitable (at 12% IRR), electricity should be sold for approximately 62 USD/MWh. It seems difficult that CEMAT pays more than 60 USD/MWh for this energy, consequently this project would barely be profitable. Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be 2 USD/MWh or 14 USD/tonne of CO_2. This calculation is based on 3% of electricity through the national grid from coal plants and 5% of local electricity production based on diesel generators. Considering N_2O in the analysis would reduce the effective CO_2 abatement cost by about 6%.

2.2.4 USE OF RESIDUES FROM PALM OIL INDUSTRIES TO PRODUCE ELECTRICITY FOR THE TAILANDIA CITY IN THE STATE OF PARA

In the state of Pará, 130 km west of the Brasilia-Belem highway there is a complex of 2 palm oil processing plants owned by Companhia Real de Crédito Agricola. The two plants are located 20 km north of the city of Tailandia.

These facilities process 36 tonnes/h each of fresh fruit bunches (FFB). For the processing of palm oil, it is necessary to produce steam and electricity. From the biomass residues available (11.5 tonnes/h of fibre; 4.3 tonnes/h of shell and 10.8 tonnes/h of empty bunch (dried to 40% moisture)) only the last one is not yet utilized as fuel. The empty bunches are presently returned to the soil to act as a soil nutrient.

The city of Tailandia has a population of 50,000 people and is electrified through diesel motors. It is not yet economically attractive to connect it to the grid in the near future. Due to the presence at modest distance of the palm oil industries, one potential possibility is to construct a thermoelectric biomass-based power station capable of utilizing the residues and power the city of Tailandia.

The Project
Two alternatives have been analyzed: alternative a) Steam turbine generation, and alternative b) Generation through biogas. Only the more economical option, the first one, is discussed in this section.

The moisture content of empty bunches is very high (about 60%) and needs to be reduced by a physical process (cutting and pressing, for instance) to allow combustion of the material as well as the operation of the boiler at high efficiency. Using 40%-moisture fuel, a boiler with efficiency as high as 85% and a condensing turbine it is possible to obtain a steam rate of 6 kg/kWh. The generation potential of the available empty bunches is 6 MW.

Environmental Aspects
The elimination of diesel use will lead to decreased local pollution in addition to the reduction of GHG emissions.

Social Aspects
Either project alternative would generate about fifty direct jobs.

Economic Aspects
Table 2.6 shows the economic evaluation of the use of empty bunches to generate electricity through steam turbine-based plant. The generation cost is approximately USD 78/MWh.

TABLE 2.6 - Alternative A

Boiler steam production:	35.7 tonnes/h at 21 kgf/cm^2 280^{0}C.
Multi-stage condensing turbine; Electr. capacity:	6 MWe
Fuel consumption = 100% of empty bunches (both factories).	
Total investments [USD 1,000]	8,609
Recovery of investments [USD 1,000/yr]	1,472
(in 15 years at a 15% rate of return)	
O&M costs [USD 1,000/yr]	689
Fuel transportation costs [USD 1,000/yr]	27
Revenue from recovered palm oil [USD 1,000/yr]	285
Revenue from recovered kernels [USD 1,000/yr]	69
Net annual cost [USD 1,000/yr]	1,834
Gross energy generation [MWh/yr]	29,800
Net energy generation [MWh/yr]	23,800
Energy delivery cost (before taxes) [USD/MWh]	78

Baseline GHG emissions and CO_2 and N_2O abatement effect
Assuming as mean GHGs emission from the CELPA diesel generators at Tailandia City of 0.91 tonne CO_2/MWh and 0.18 kg N_2O/MWh, and an average tradable energy during a 15-year period of 23,800 MWh/yr, then the baseline emissions are 22 thousand tonnes of CO_2/yr and 4 tonnes of N_2O/yr during this period. Considering an effective zero GHGs emission for the biomass cycle then the CO_2 and N_2O abatement effects are equal to these baseline emissions.

Profitability and comparison between project alternatives
To compete with diesel-generated electricity at Tailandia, electricity should be sold for approximately 119 USD/MWh (diesel fuel plus O&M costs). As the energy cost before taxes at

the consumer door for the biomass option is 78 USD/MWh this project is profitable.[8] Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be -41 USD/MWh or -45 USD/tonne of CO_2. Considering the GHG N_2O in the analysis would reduce the effective CO_2 abatement cost by about 6%.

2.2.5 STUDY OF A COGENERATING SYSTEM ON THE OIL PALM ESTATE 'DENPASA'

This section details one alternative to cogenerate electricity and process steam for DENPASA's palm oil factory located in the state of Pará. The Acaca unit has an installed capacity to process 10 tonnes of fresh fruit bunches (FFB) per hour, but it is planned to soon double this capacity. In Acara and its surroundings there is no electricity supply from the regional utility. At present the factory uses diesel generators as the main source of electricity. The proposed technology is based on biomass fired boilers coupled with steam turbines. From the biomass residues at the plant, composed of fibre, shells and empty bunches, only the first two will be used to satisfy current and future internal needs of steam and electricity.

Environmental Aspects
The elimination of diesel use will lead to decreased local pollution in addition to the reduction of GHG emissions.

Social Aspects
This project alternative would generate some tens of direct jobs.

Economic Aspects
Table 2.7 gives a summary of the technical and economical assumptions for the cogeneration alternative studied for the Acara unit. In this alternative, 488 kW of electric power plus 7.5 tonnes/h of process steam might be cogenerated with an investment of USD 1.04 million (2,130 USD/kWe).

Note that the cash flow is a net cash flow which compares the cogenerating alternative to its corresponding business as usual alternative. The main problem found is economic due to the very low IRR for the project (5.6%/yr) compared to local parameters (an acceptable IRR would be in the range 20-30%/yr). This low IRR fundamentally derive from three main factors:

a) the heavy subsidies given by the government to the diesel oil price due to lack of inclusion of the real transportation costs;
b) the small proposed-installed power capacities; and
c) the small expected-capacity factor for the installed power.

[8] BUN has not yet presented these calculations for the private group.

TABLE 2.7 Technical and economical summary for the Acara project

PREMISES	
Gross installed power [kW]	570
Capacity factor [%]	36.5
Net power demand [kW]	488
Process steam needs [tonne/h]	7.5
Factory energy consumption [MWh/yr]	1,560
Specific fuel consumption:	
Fibre [tonne/MWh]	4.08
+Shell [tonne/MWh]	1.53
Investments [USD 1000]	1,040
Operating & maintenance costs [USD1000/yr]	83
Avoided diesel oil costs [USD1000/yr]	122
Avoided existing boiler plus diesel sets	
O&M costs [USD 1000/yr]	65
Fuel (fibre & shell) costs (at 0 USD/tonne)	0
Total annual savings [USD 1000/yr]	104
Investment return (useful life of 15 yr) [%/yr]	5.6

Baseline GHG emissions and CO_2 and N_2O abatement effect
Assuming a mean GHGs emission from the DENPASA diesel generators of 0.62 tonne CO_2/MWh (diesel efficiency of 0.236 l/kWh versus 0.345 l/kWh for the average diesel set of utilities in Amazonia) and 0.12 kg N_2O/MWh, and an average energy production during a 15-year period of 1,560 MWh/yr, then the baseline emissions are 970 tonnes of CO_2/yr and 190 kg of N_2O/yr during this period. Considering an effective zero GHGs emission for the biomass cycle then the CO_2 and nitrous oxide abatement effects are equal to these baseline emissions.

Profitability and comparison between project alternatives
The total annual savings before taxes is USD 104 thousand/yr, which means that this project certainly will not be profitable after taxes (5.6% internal rate of return before taxes). As the total investment is USD 1.040 million, assuming a 15 year life and a 15%/yr interest rate, it is equivalent to an annual capital cost of USD 178 thousand/yr. The net annual cost is then USD 74 thousand/yr. Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be 47 USD/MWh or 76 USD/tonne of CO_2. Considering the GHG N_2O in the analysis would reduce the effective CO_2 abatement cost by about 6%.

2.2.6. ELECTRICITY GENERATION AT THE CITY OF GUAJARA MIRIM

The city of Guajara Mirim is located at the state of Rondonia near the border of Bolivia. On the other side of the Madeira River is the Bolivian city of Guayaramerin. Electricity is supplied respecitvely by CERON (Companhia de Eletricidade de Rondonia) and by Cooperativa Eletrica through diesel powered motors coupled to electric generators, in the two cities. Connection of Guajara-Mirim to the Grid is not expected to happen soon. Electricity demand in 93 was 4,300 kW with an average monthly consumption of 2,100 MWh at the city of Guajara-Mirim; there is a significant refrained demand. Biomass residues and cut trees are abundant in the region.

The project

The proposal is to install a thermoelectric plant of 8 MW capacity powered by biomass wastes and residues which will produce steam to drive turbines coupled to electric generators. Electricity can be sold to the city of Guajara-Mirim and to Guarayamerim in Bolivia. Presently the Bolivian city is supplied by 2.8 MW diesel powered motors and electricity is sold at a cost of USD 180/MWh. In the Brazilian city, electricity is sold at an average price of USD 80/MWh, but internal sector subsidies of the National Electric System to the amount of USD 50/MWh are added. The economic evaluation is shown in Table 2.8.

Environmental Aspects

The substitution of biomass residues for diesel fuel will decrease the emission of pollutants not only from diesel use, but also at the stacks of the sawmill incinerators.

Social Aspects

This project would generate some tenths of jobs since wood-fueled thermal units are more labor intensive than diesel sets.

Baseline GHG emissions and CO2 and N2O abatement effect

Assuming as mean GHGs emission from the Guajara-Mirim diesel generators of 0.91 tonne CO_2/MWh and 0.18 kg N_2O/MWh, and an average tradable energy during a 15-year period of 42,000 MWh/yr, then the baseline emissions are 38 thousand tonnes of CO_2/yr and 7.6 tonnes of N_2O/yr during this period. Considering that the project gets a 15-year concession to distribute energy at Guajara-Mirim and an effective zero GHGs emission for the biomass cycle, then the CO_2 and N_2O abatement effects are equal to these baseline emissions.

Profitability and comparison between project alternatives

To compete with diesel-generated electricity at Bom Futuro, electricity should be sold for approximately 150 USD/MWh (average price at the two cities). As the energy cost at the consumer door for the biomass option is 200 USD/MWh this project is not profitable. Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be 50 USD/MWh or 55 USD/tonne of CO_2. Considering the GHG N_2O in the analysis would reduce the effective CO_2 abatement cost by about 6%.

TABLE 2.8 Technical and economical summary for the Guajara-Mirim project

Installed power [MW]	8
Gross energy generation [MWh/yr]	50,500
Specific fuel consumption [tonne/MWh]	2.50
Tradable energy [MWh/yr]	42,000
Investments [USD1000]	10,400
Operating & Maintenance Costs [USD1000/yr]	830
Fuel Costs [USD 1000/yr]	5,800
Acquisition and manipulation (at 40 USD/tonne)	5,040
IBAMA tax (at 6.0 USD/tonne)	760
Investments return (15 yr at 15%/yr)	
[USD1000/yr]	1,780
Total annual cost [USD1000/yr]	8,410
Energy cost at the consumer door [USD/MWh]	200

2.3 INTERNAL COMBUSTION MOTORS FUELED WITH NATURAL VEGETABLE OIL

2.3.1 ELECTRICITY GENERATION FOR THE MOGNO FARM

The Mogno farm is located in the extreme north of Mato Grosso state, at 100 km from the border with the state of Pará, and 60 km away from the city of Alta Floresta. With a total land area of 300,000 ha, of which 93% is still native, cocoa and coffee agriculture and cattle-ranching are practiced in an extensive way. The owner of the farm is considering to construct a meat storage facility in Alta Floresta city.

Alta Floresta is electrically supplied by diesel motors and a link with the National Grid will possibly be postponed to after the year 2000. The existing diesel-based electric system serving Alta Floresta is barely able to supply power in the off peak hours. Under these circumstances, to power the storage meat facility, a preliminary proposal quotes the following requirements:

	Power demand (kW)	Energy (kWh/month)
Peak hours (kW)	500	25,000
Off peak hours (kWh/month)	1,000	400,000

Electricity may be acquired from the electric grid of Alta Floresta but without any guarantee that electricity will be available, mainly during the peak-hours, which requires the installation of diesel based electric generators. Table 9 gives a summary of this alternative.

TABLE 2.9 Option 1) Acquisition of electricity from the electric grid of Alta Floresta

Investment {I} (USD/kW)	250
Installed diesel power (kW)	1,000
O&M annual costs (% of I)	20
Fuel cost (USD/m^3)	300
Thermal efficiency of generation (%)	40
High heating value of fuel (Mcal/m^3)	9,160
Useful life (years)	15
Interest rate(% per year)	15
Annual electricity consumption (MWh)	
self-produced	780
Acquired from CEMAT	4,320
Electricity costs (USD/MWh)	
self-produced	189
Acquired from CEMAT	81
Average	98

The project

With the commercial availability of diesel type engines powered by vegetable oil 'in natura', a new alternative can be proposed. It is a variant of the first one but, instead of using diesel fuel, it will use vegetable oil.

Vegetable oil can be produced in the farm through, for example, rice, corn or mamona crops. Rice is planted, in general, as a subsistence crop for the employees, and corn is an auxiliary foodstuff to the cattle. Mamona is a nonedible fast-growing plant. Here, only the corn oil option to supply all electricity needs is detailed, whereas Annex 1 details also the mamona option as well as part power production.

Vegetable oil from Corn

Under this option, total electricity produced (5,100 MWh/yr) will require 1,200 tonnes of vegetable oil (for an specific consumption of 235 g/kWh). This amount of oil can be obtained in 11,100 ha of corn plantation (108 kg/ha). The motivation to grow corn in the farm is the synergism between energy and concentrate. To feed animals, it is important to provide as much as 1.8 tonnes/head per year of concentrate. With 11,100 ha of corn plantation, as much as 19,000 tonnes of concentrate might be produced. With the installation of an oil extracting facility, it becomes possible to avoid long distance transportation of the grain and back transportation of the fodder, as well as the payment of taxes which is charged for the products commercialization. Consequently, the effective fuel cost becomes zero (see Table 8 in Annex).

Environmental Aspects
Besides reducing local use of diesel oil, the project will reduce emissions from trucks used in the transportation of corn and its derivatives.

Social Aspects
With full power generation, this project would generate a few hundred jobs if we account for the agroindustrial activity.

Economic Aspects
Corn production cost is assumed to be USD 120/ha. A simple oil extracting facility can be installed for USD 100,000, including equipment and building. Concentrate has a market price of USD 83/tonne before tax. Assuming that 1 tonne of grain produces 60 kg of oil and 900 kg of concentrate (and an average yield of 1.8 tonnes of grain/ha), the following economic analysis can be performed.

TABLE 2. 10 Option 2) Only self-generated electricity

Investment on diesel motor and	
generator {I} (USD 300/kW)	300,000
O&M equipment costs (%)	30
O&M equipment depreciation (years)	5
Interest rate (% year)	15
O&M equipment (USD/year)	90,000
Investment return (USD/year)	89,500
Annual electricity	
self produced (MWh/year)	5,100
investment return (USD/MWh)	17
O&M costs (USD/MWh)	18
fuel cost {at 0 USD/tonne} (USD/MWh)	0
Final electricity cost (USD/MWh)	35

The vegetable oil option creates new employment at the farm, can improve cattle revenue, which is not considered in our evaluation, and has environmental benign consequences. With near zero fuel costs, the electricity would cost only USD 35/MWh.

Baseline GHG emissions and CO2 and N2O abatement effect
Assuming a mean GHGs emission from the Alta Floresta diesel generators of 0.91 tonne CO2/MWh and 0.18 kg N_2O/MWh), and an average generation during a 15-year period of 5,100 MWh/yr, then the baseline emissions are 4.6 thousand tonnes of CO_2/yr and 0.92 tonnes of N_2O/yr during this period. Considering a 15-year period and an effective zero GHGs emission for the biomass cycle, then the CO_2 and nitrous oxide abatement effects are equal to these baseline emissions.

Profitability and comparison between project alternatives
To compete with diesel-generated electricity at Alta Floresta, electricity should be produced for approximately 81 USD/MWh. As the energy cost at the consumer door for the corn oil option is only 35 USD/MWh, hence this project seems to be highly profitable. Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be -46 USD/MWh or -51 USD/tonnes of CO_2. Considering the GHG N_2O in the analysis would reduce the effective CO_2 abatement cost by about 6%.

2.4 SUMMARY OF FUEL-SWITCHING ALTERNATIVES

Table 11 gives a short summary of the alternatives. Some alternatives present a negative GHG abatement cost and a low likelihood of realization. This contradiction may be explained: the Tailandia project was proposed by BUN to the owners of the palm oil factories; and the Mogno Project needs large investments on the corn plantation and an oil mill installation which are not accounted for in the preliminary investment estimates.

TABLE 2.11A - Summary of fuel-switching alternatives

	Ariquemes	Amapa	Sinop	Tailandia
Power Capacity [MW]	28	15.5	9	6
Average delivered energy [GWh/yr]	116	67.5	55.2	23.8
Diesel replaced [1,000 m^3/yr]	40.2	23.3	[a]	8.2
CO2 abated [1,000 tonne/yr]	106	61	8	22
N2O abated [tonne/yr]	21	12	1.6	4
Investment [USD million]	44.7	20.3	5	8.61
Capital costs [USD million/yr]	6.56	2.98	0.99	1.47
O&M costs [USD million/yr]	3.28	1.48	1.21	0.69
Fuel costs [USD million/yr]	6.21	1.47	1.21	0.027
Added revenues [USD million/yr]				0.36
Avoided costs [USD million/yr]				
Additional investment [USD million]	44.7	20.3	5	8.61
Internal rate of return [%/yr]				
Discount rate [%/yr]	12	12	12	15
Energy levelized cost [USD/MWh]	138	87.9	62	78
Likelihood of realization without JI	Medium	Medium	Medium	Low
Abatement cost [USD/tonne of CO_2]	21	-2.2	14	-45
Abatement cost [USD/tonne of CO_2 equivalents][b]	20	-2.1	13	-42

[a] 1.66 thousand tonnes of coal plus 0.95 thousand m^3 of diesel oil.
[b] Includes the greenhouse effect of nitrous oxide.

TABLE 2.11 B - Summary of fuel-switching alternatives

	Denpasa	Guajara	Mogno
Power Capacity [MW]	0.57	8	1
Average delivered energy [GWh/yr]	1.56	42	5.1
Diesel replaced [1,000 m^3/yr]	0.54	14.5	1.76
CO2 abated [1,000 tonne/yr]	0.97	38	4.6
N_2O abated [tonne/yr]	0.19	7.6	0.92
Investment [USD million]	1.04	10.4	0.4
Capital costs [USD million/yr]		1.78	0.09
O&M costs [USD million/yr]	0.083	0.83	0.09
Fuel costs [USD million/yr]	0	5.8	0
Added revenues [USD million/yr]			
Avoided costs [USD million/yr]	0.187		
Additional investment [USD million]	1.04		
Internal rate of return [%/yr]	5.6		
Discount rate [%/yr]	15	15	15
Energy levelized cost [USD/MWh]		200	35
Likelihood of realization without JI	Low	Low	Low
Abatement cost [USD/tonne of CO_2]	76	55	-51
Abatement cost [USD/tonne of CO_2 equivalents]	72	52	-48

2.5 CONCLUSIONS

In this section the various aspects are summed up across the fuel-switching projects.

Local environmental aspects
Substituting biomass fueled electricity generation for diesel based electricity generation means reduced local emissions to air of carbon monoxide, sulfur oxides, nitrogen oxides, polynuclear aromatic hydrocarbons (PAH), and some heavy metals from diesel.[9] However, some particulates, nitrogen oxides, PAH and other hydrocarbons, and carbon monoxide are released to the atmosphere from combustion of biomass. The net effect on local air quality will depend on the relative contribution of air pollutants from the two energy sources and the application of purification technologies. The net effect is likely to be positive in terms of an improved local air quality.

Social aspects
Most of the projects will each generate some tenths of jobs since biomass fueled electricity generators are more labor intensive than diesel units. Some projects can generate around fifty jobs, whereas the Mogno project can generate up to a few hundreds jobs.

Economic aspects
Including investment costs, fuel costs, and O&M costs, the energy levelized cost of the fuel-switching projects varies according to Table 2.11 between 35 and 200 USD per MWh.

Baseline and GHGs emissions abatement effect
The baseline definition employed in this report relates to present emissions of GHGs at the micro level. Thus the baseline is defined as GHG emissions from existing diesel fueled electricity generators that may be replaced with biomass fueled generators. GHG emissions abatement is then calculated as the reduction in GHG emissions due to the reduction of diesel consumption replaced by consumption of biomass. Combustion of biomass is not assumed to generate net emissions of CO_2 to the atmosphere since the released carbon should be sequestered in new biomass through regrowth of plants and reforestation.

For some projects, in particular Sinop, the local municipality may be connected to the National Grid in the near future. Since electricity from the National Grid is mainly based on hydropower (95%), replacing the diesel generators for such deliveries will have almost the same GHGs abatement effect as biomass fueled generators. However, some local generators may be kept to increase the electricity supply stability of the system. Assuming that connection to the National Grid in the near future is profitable, the GHGs abatement effect from biomass generators should only be calculated in the period until the Grid connection. Even if some emissions are abated due to the 5% share of fossil fuels from the National Grid, and through some periods of delivery problems from the National Grid, the cost of new biomass generators compared to the relative small GHG abatement effect is not likely to make this an attractive JI project. Considering these factors the annual CO_2 abatement effect of Sinop is equal to 8,000 tonnes, whereas the annual N_2O abatement effect is equal to 1.6 tonne.

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[9]Confer Torvanger (1993).

For the other fuel-switching projects the annual CO_2 abatement effect ranges from 970 tonnes to 106,000 tonnes. The annual N_2O abatement effect of the projects ranges from 0.19 to 21 tonnes.

Profitability and comparison between project alternatives
There is a large variation in the profitability of the fuel-switching projects, not including environmental benefits and social benefits for the local communities. The Mogno, Tailandia and Amapa projects seems to be profitable and should be undertaken without any external JI funding, These projects would consequently be problematic with respect to GHG emission credits for any JI investor. The Denpasa, Guajara, Ariquemes and Sinop projects are not profitable given the premises of the calculations, and could thus be considered for external JI funding. The abatement cost of the latter projects varies between 14 and 76 USD per tonne of CO_2, and between 13 and 72 USD per tonne of CO_2 equivalent (i.e. including both CO_2 and N_2O). Considering a 15% subsidy on the diesel oil price at present, the abatement cost per ton of carbon dioxide could be further reduced if this subsidy was to be reduced or removed, or eventually, more fuel-switching projects could be made profitable without external funding.

CHAPTER 3
FORMULATING THE FUEL-SWITCHING PROJECTS IN A JOINT IMPLEMENTATION SETTING

The most promising projects in terms of unit abatement cost and small likelihood of realization without external funding could be chosen for a more elaborate study based on the present feasibility study of future options for JI fuel-switching projects in Amazonia. One possibility is to prepare one of the projects as a pilot project. This project should demonstrate the most important elements in a JI project realization (*inter alia* involving unknown barriers to implementation, negotiations on credits, the definition of control and verification systems, etc.) Apart from the credits, not being claimed, this might give valuable information on the much discussed issue of the size of transaction costs. Transaction costs are for the most part due to barriers in host countries and investing countries. Host country barriers may *inter alia* be lack of capital, lack of private interest, legislation, regulations and permits, and import duties. Investing country barriers may *inter alia* be project risk, Climate Convention rules and regulations, ownership issues, the negotiation of contracts between the Parties and implementing institutions. For the purpose of choosing pilot projects a few of the projects in this feasibility study should be considered more closely. In such a case the most representative projects should be chosen to learn as much as possible about this category of projects in Brazil and possibly also in other countries.

An additional possibility is to employ the new elaborate studies of the most promising projects in this study to develop further projects, which at a later stage can be forwarded as JI project candidates for interested hosts to gain GHG credits. Before such JI projects can be forwarded, the COP must develop criteria that make the mechanism of JI operational, and potential host countries must have legally binding commitments to curb their GHG emissions.

CHAPTER 4
RECOMMENDATIONS

The recommendations from this study with respect to preliminary qualification as JI projects are formulated as a priority list based on increasing abatement cost per unit of GHGs: 1. Sinop, 2. Ariquemes, 3. Guajara, and 4. Denpasa.

Further analysis of these projects may lead to changes in the priority list due to uncertainty related to economic data and various non-economic barriers to implementation of projects.

The Amapa,Tailandia and Mogno projects are less attractive projects in terms of JI due to being profitable without JI funding.

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ANNEX

Report 1995:1

Fuel Substitution in Amazonia - Feasibility Study to Investigate Future Options for Joint Implementation Projects Between Brazil and Norway

by

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January 1995

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ANNEX
TECHNOLOGICAL OPTIONS

Index to annex

SECTION A1 - TECHNOLOGICAL OPTIONS TO BE EVALUATED

In this section, two main technological options to be further investigated in the pre-project are presented:

a) Conventional steam-turbine thermoelectric plant fueled with conventional biomass residues;
b) Internal combustion motors fueled with natural vegetable oil.

The greenhouse gases included in this study are given in Section A1.1. The selected projects of conventional steam-turbine thermoelectric plant fueled with conventional biomass residues are analyzed in Section A1.2. Just one project was identified to generate electricity through internal combustion motors fueled with natural vegetable oil; it is described in Section A1.3.

A1.1 Greenhouse gases (GHG) considered under this project

The greenhouse gases considered under the present project are the following:

* CO_2 (carbon dioxide)
* N_2O (nitrous oxide)

Table 1 gives a summary of the pertinent data collected for the Brazilian Northern Region (which includes the following states: Amazonas, Acre, Amapa, Para, Rondonia, Roraima and Tocantins). These data include information concerning the use of diesel oil for electricity generation in that region and specific emissions of GHGs associated to the use of this fuel.

Based on this data, it was estimated the gross emissions of the GHGs CO_2 and N_2O associated with the burning of diesel oil used to generate electricity in that region (see Table 2). It is worth to point out that the amount of diesel used for electricity generation in the Northern region in 1992 corresponds to just 2.4 percent of all diesel consumed in Brazil for all purposes in 1992.

TABLE 1 - Data about diesel-based electricity generation in the Amazon region and associated greenhouse gases emissions.

[1]	Consumption of diesel for electricity generation in Amazonia in 1992 [1000m^3]	599.7
[1]	Consumption of diesel for electricity generation in Amazonia in 1993 [1000m^3]	494.4
[2]	Total consumption of diesel oil in Brazil for all purposes in 1992 [1000 m^3]	2.5450
[1]	Electricity generated on diesel-fueled engines in 1993 in Amazonia [GWhr]	1.435
[3]	Carbon contents in diesel oil	85 percent
[4]	Nitrogen-to-carbon molar ratio in the diesel	0,0002
[5]	Heating of N_2O relative to CO_2 per molecule	206

TABLE 2 - Estimates of GHGs emissions from diesel fueled power plants in Amazonia:

CO_2 [million tons/yr] = (0.85 x 494400 m3 x 0.852 tons/m^3 x 44/12)	1.31
CO_2 [tons/MWh] = (1.31 x 106 tons/yr / 1.435 x 106MWh/yr)	0.91
N_2O [tons/yr] = (0.0002 x 1.31 x 106)	263
N_2O [million tons/yr of CO_2 equivalent] = (263 x 206 CO_2/N_2O)	0.054
N_2O/CO_2 GH net effect = (0.0002 x 206)	4.1 percent

A1.2 CONVENTIONAL STEAM-TURBINE THERMOELECTRIC PLANT FUELED WITH CONVENTIONAL BIOMASS RESIDUES.

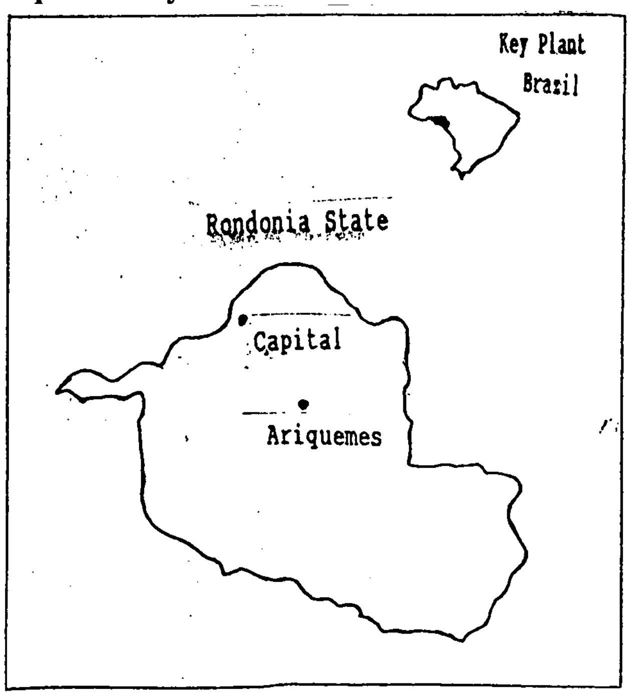
The company Sathel, Usinas Termo e Hidroeletricas S.A., has two potential thermoelectric projects planned in the Amazon region: Ariquemes (28 MW) and Santana (15.5 MW). As the Ariquemes project is in the most advanced project stage, more details regarding this project are provided in the present section.

A1.2.1 The Ariquemes project

Project description

Sathel has a 14-MWe thermoelectric biomass-fueled plant installed in Ariquemes, a city of 100,000 inhabitants located in the State of Rondonia, Brazil (see Figure 1). This plant provides electric power to the isolated electric system of Ariquemes in parallel with a diesel-based 10-MW electric plant of the utility Centrais Eletricas de Rondonia (CERON), the Rondonia State-public utility.

Figure 1 - Localization of Ariquemes City



SATHEL intends to expand the installed capacity of this thermoelectric plant to 28 MW. The current installed capacity at Ariquemes is 14 MW and another unit of 5 MW is being installed. However, from the 14 MW installed, only one unit of 6 MW will be kept as the three other units totalling 8 MW are being retired. The expansion will add 17 MW of power (two units: one with 12 MW and another with 5 MW) to the existing plant. Thus, the final installed capacity at Ariquemes will be 28 MW (a 12 MW unit; a 6 MW unit; and two 5 MW units).

Market size

The 28 MW capacity should be used to produce electricity to be sold to the ELETRONORTE future integrated Acre/Rondônia System and to several mining users at the BOM FUTURO mine.

Bom Futuro[6]

BOM FUTURO is a village 80 km distant of Ariquemes with large mining activities. The village has a population of 15,000 inhabitants (according to the City Mayor, the peak population was 50,000 some years ago) and is not served by CERON. Cassiterite is the major mineral extracted and the mine is owned by Empresa Brasileira de Estanho S.A. - EBESA. Present production of cassiterite is 14.000 tons/year and the mine should be able to produce for another 8 years if no further resources will be located. EBESA initially planned to exploit alone the mine, requiring 14 mobile generators, 1000 kW each.

Nowadays the exploration is carried by EBESA and by several independent producers which use together, according to EBESA evaluation, 1,3 million liters of diesel oil per month. Assuming all this diesel is used to generate electricity, at an efficiency of 2,9 kWh/l, then the maximum electricity generation would be 3,77 million kWh/month, or 45,3 million kWh/yr, which is much less then the value projected by SATHEL: 116 million kWh/yr (see Table 5). If only 50 percent of this diesel is used to generate electricity, then the discrepancy with SATHEL's forecast grows to a 5-fold factor.

According to these estimations, the expected electricity demand might be 10,3 MW in the first case or 5,2 MW in the second case (assuming a 50 percent capacity factor). Considering uncertainties on diesel consumption to generate electricity and on the average capacity factor, the conclusion is that something between 4.000 and 14.000 kW is required for the Bom Futuro mining activities.

The Future Acre-Rondônia System[7]

What is available today of the future Acre-Rondonia system is small isolated centers supplied by electricity, as: Porto Velho, Rio Branco, Ariquemes, Ji-Paraná, Ouro Preto, Jari, Presidente Médici, Guajará-Mirim, and other even smaller sites which are being understood as the first phase of the formation of such a system. Porto Velho has been supplied by the hydro plant of Samuel since 1989. Ariquemes has just been connected to the same plant on August 94 and Ji-Parana is forecasted to be connected to the same network by the end of 94 if money for investment will be available (see Figure 1).

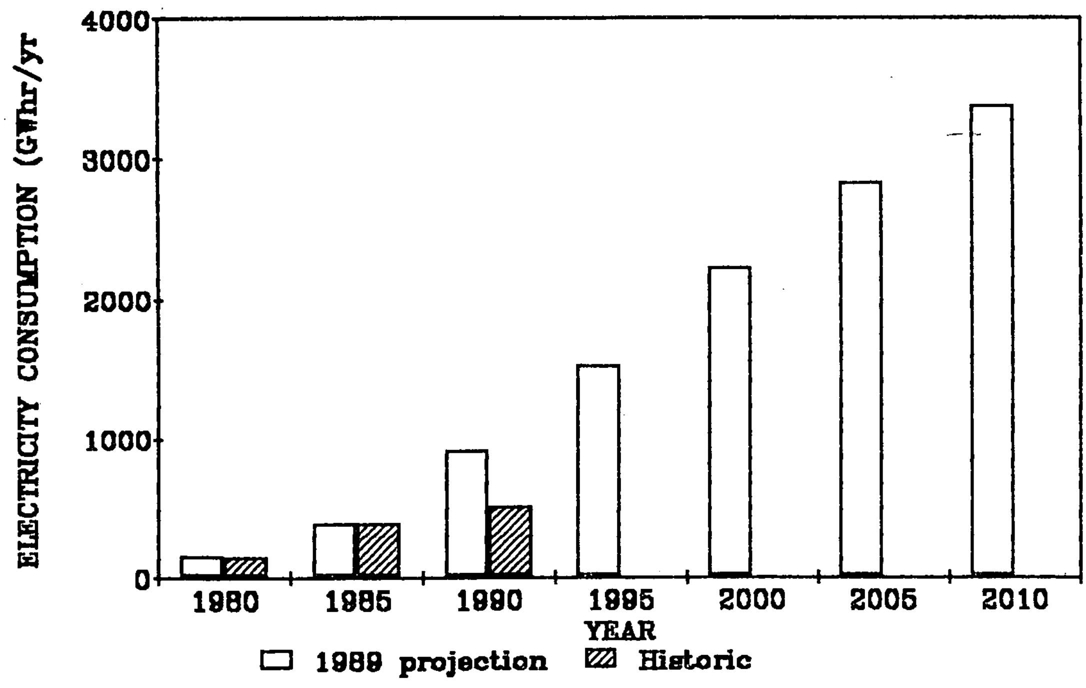
It is further expected that major centers at the Southeast of Rondônia will be tied to the major line from Samuel and by the end of the century a small inter connection with the national electric grid, through the State of Mato Grosso will exist. By the year 2010, it is almost sure that all Rio Branco/Porto Velho corridor will be part of the national electric grid, with the help of a large hydro plant located at the high part of the Tapajós river (Teles Pires or Juruena rivers) or at the Madeira river, near Porto Velho.

The Acre State economy is growing slower than in Rondônia. Approximately 80 percent of the electric consumption occurs at the capital (Rio Branco) and the service is quite poor. Future economic and electric development of Acre is hard to forecast. There are considerable extensions of land with reasonable agricultural capability (as compared with typical land pattern of the Amazon region) but it is the place where the most significant debate about deforestation is taking place.

Energy consumption in Rondônia increased at very high rate during the early 80's due to demographic and economic growth. In less than 10 years, 80 new villages have been constructed. Most of the growth occurred outside of the capital Porto Velho which is responsible today for only 50 percent of total electricity demand. To attend the market is a big challenge and at the beginning of the 80's self-generation, by private enterprises, was a significant share of total generation, but is declining since them. Service quality is still very poor and there is significant refrained demand as high as 50-60 percent of the served market. Lack of funds to increase the supply is so huge that the State Government has asked to Federal authorities permission to apply an overprice in the electric tariff set homogeneously at the national level.

In the long run, future market behavior is of growth at a lower rate than the one occurred in the 80's, intercalated with short periods of stable consumption. For instance, Figure 2 shows two different economic scenarios projections forecasted in 1989[8]. One is high growth with significant agricultural activities and the other a moderate growth with emphasis on cattle-ranching. Figure 2 also shows the historical consumption up to 1993 demonstrating the unanticipated gross failure of the mentioned macro-predictions.

FIG. 2 – ELECTRICITY CONSUMPTION AT THE RONDONIA STATE



Until recently, all electricity was supplied by isolated thermoelectric plants. With the partial operation of the Samuel hydro plant Porto Velho received this energy. According to ELETROBRAS' plans, a transmission line connecting Samuel to Ji- Paraná (320 km) and Rio Branco (495 km), should start operations in mid 2001 establishing the Acre-Rondônia system[9].

Samuel hydro plant (see Table 3) will have an installed capacity of 217 MW (5 X 43.4 MW), an average capacity factor of 38.8 percent and a firm energy of only 53.1 MW. Up to now, only 2 of the 5 turbines are installed, and the next unit of 43.4 MW will be operational only in 1997[8].

The original next option is to construct the Ji-Paraná hydroelectric plant (see Table 4). This unit will impact the environment and the native Indian population and, thus it should be more expensive after the inclusion of measures to minimize the impacts. Natural gas from Urucú field (in the Amazon State) called the attention of electricity planners since Petrobrás (the State owned monopoly oil company) has shown interest in finding a market for its product and a thermoelectric plant can be quickly built avoiding the shortage crises.

TABLE 3 - Characteristics of the SAMUEL Hydroelectric[6]

Federation Unit:	Rondonia State
River:	Jamari
Basin:	Madeira
Installed capacity:	217 MW
Number of units:	5 X 43.4 MW
Turbine type:	Kaplan
Reference waterfall:	28.5 m
Maximum reservoir level:	87.5 m
Minimum reservoir level:	80.0 m
Average escape channel:	56.8 m
Maximum operation depletion:	7.0 m
Maximum volume:	3500 hm^3
Minimum volume:	994 hm^3
Maximum area:	585 km^2
Firm energy:	53.1 MW (avg)
Average generated energy:	83.3 MW (avg)
Critical period:	Jun/80 to Dec/84

TABLE 4 - Characteristics of the JI-PARANA Hydroelectric[6]

Federation Unit	Rondonia State
River:	Jiparana
Basin:	Madeira
Installed capacity:	512 MW
Number of units:	4 X 128 MW
Turbine type:	Kaplan
Reference waterfall:	35.0 m
Maximum reservoir level:	137.0 m
Minimum reservoir level:	122.7 m
Average escape channel:	94.2 m
Maximum operation depletion:	14.3 m
Maximum volume:	12.138 hm^3
Minimum volume:	2.894 hm^3
Maximum area:	960 km^2
Firm energy:	217 MW (avg)
Average generated energy:	264.8 MW (avg)
Critical period:	May/45 a Dec/46

The initial plans of ELETROBRAS were not accepted by PETROBRAS since Ji-Paraná was delayed for only 4 years, becoming operational in 1998. This would have a negative impact on the demand of natural gas from Urucú, in the period 1997-2000, with some recovery occurring in 2001 due to market increase. A new agreement was established between both companies and Ji-Paraná postponed to 2001.
Thus, presently, ELETROBRAS, delayed the construction of Ji-Paraná in favor of a thermoelectric plant in Urucú, which will uses gas available at the well with electricity transmission up to Porto Velho where a connection with the Acre-Rondônia system will occur.

The integrated Acre-Rondonia system is planned to be completed by the end of the century. What is presently installed is the line which connects the Samuel hydro plant to Porto Velho and Ariquemes and the planned extension of this line up to Ji- Parana, which is supposed to occur at the end of 1994, if financial constraints will not set a delay.

Even with the conclusion of the line in 1994, it is expected that Samuel will not be able to supply electricity continuously to the city of Ariquemes, due to its small capacity (see Table 3) and mainly because 3 of the 5 turbines will not be operational up to 1997. The situation will be even more critical when the line will supply electricity to the city of Ji-Parana. According to CERON this should occur in 1995.

Peak demand at the Ariquemes city is 11.0 MW with an average consumption of 8.000 MWh/month and a refrained demand of 3 to 4 MW. Until recently, this peak demand was served through the operation of 7 diesel generators owned by CERON, totaling 10 MW and the 14 MW thermoelectric plant owned by SATHEL. Samuel with 2 installed hydrogenerators will be able to attend 2 X 43 MW= 86 MW of peak power but a firm energy of only 53 MW.

In September 93, CERON sold 47 GWh to its consumers, with an average demand of 65 MW, and a peak demand of 117 MW. Assuming that 20 percent of this electricity is consumed in sites which will not be soon connected with the grid (Ouro Preto, Jaru and Guajara-Mirim require a peak demand of 15 MW), average demand on the grid would be 52 MW. Thus, Samuel alone is barely able to supply electricity to the grid, requiring the operation of thermoelectric plants in Ariquemes and/or Porto Velho.

Thus, the expectation of SATHEL as a potential candidate to sell electricity to ELETRONORTE makes sense, as soon as the line interconnection with Ji-Parana is complete. Typical sales potential should be around 10 MW already in 1995 (assuming that some growth will occur and mainly refrained demand will be partially attended; this should be the behavior for an average rain fall year but SATHEL's market can be even larger for years with a rain fall below the average). Obviously, SATHEL must be able to provide electricity at a cost lower than electricity produced by the large size diesel machines already installed in Porto Velho, to guarantee the sale.

Considering together the ELETRONORTE grid and BOM FUTURO village there is a space to sell immediately, at least, 14 MW of power. The installed capacity of 28 MW should operate with modest capacity factor at least for the first years until refrained demand and economic growth will push up electric demand significantly. Bom Futuro requires high capacity factor but the ELETRONORTE grid can be fed for most of the year through Samuel alone.

Installation of 28 MW to supply close to 14 MW is a pattern of thermoelectric supply in the Amazon region. For instance, the forecasts made on Reference 7, the average capacity factors assumed for auto-producers is only 35 percent. Equipments are old, poorly maintained and manpower has low qualification. For instance, the existent 14 MW installed by SATHEL is composed of used equipments which have been recovered.

The biomass fuel supply

According to SATHEL, the efficiency of the Ariquemes plant is around 14 percent or 3.0 kg of biomass residues per kWh and the average lower heating value of the wood residues is 2,000 kcal/kg.

The fuel is a mixture of wood and agricultural residues from sawmills and farms located in the region. The residues may be in the form of sawdust, bark and larger wood pieces in a variety of forms, rice husk etc. Because the local State environmental agency requires that sawmills get rid of their residues, they give for free all their residues to SATHEL. Otherwise, sawmills are required to have a furnace to fire their residues. Visually, these furnaces pollute more than the boilers of SATHEL's plant, where burning is better controlled.

SATHEL then pays to local part time workers 1,50 USD/ton to fill containers (they call the larger biomass residues at the saw mills as "refill"), which are transported to the storage area of the SATHEL plant by means of SATHEL's own special trucks. Although the majority of sawmills are easily accessed even in the rainy season, a large stock of residues is kept on the storage area to prevent eventual difficulties to obtain fuel.

According to the local sawmills association and environmental agencies, sawmills located within a 50-km radius will have enough wood residues to feed SATHEL plant for the next 15 years. This interval will be probably stretched if the new rules of reforestation, which obligate sawmills to reforest part of the wood they consume are enforced (20 percent in 1994; 50 percent in 1995 and 100 percent from 1996 on).

Presently, SATHEL consumes only half the wood residues generated by sawmills located in a 15-km radius of its plant at Ariquemes city (4.200 m^3/month = 2.800 tons of biomass residues according to the local sawmills association). Currently operators feed the boilers with biomass by hand, but, as a first step to automatize fuel feeding into all its boilers, Sathel is instaling two wood shredders to standardize the size of the wood residues it receives .

The available 2.800 tons/month of wood residues from sawmills might generate only 933 MWh/month which is insufficient to feed even present SATHEL plant electricity generation of 1.624 MWh/month. The alternative is that Sathel purchases soft wood that is not used by the sawmills and otherwise would be burned by land owners. According to IBAMA (The Brazilian Institute of the Environment), there are only 18-22 m^3/ha (18-22 tons/ha) of commercial wood from 210-280 m^3/ha (140-180 tons/ha) of native forest. Since the available residues from commercial residues are only 5—7 tons/ha, then non-commercial wood has a potential twenty- five times greater than the available residues from the local sawmills. Consequently, Sathel has more than enough non-commercial wood to feed its planned plant expansion and a possible increase in its capacity factor.

Environmental aspects

Today SATHEL should pay USD 3,1 to IBAMA per each cubic meter of softwood it consumes or reforest three trees at a commercial cost of 1 USD/tree; they are not doing this. SATHEL says that they intend to fulfill the new legislation and pay old debts to IBAMA as soon as CERON pays old debts to SATHEL (SATHEL is considering to buy shares of some reforestation programs which are being performed in the region). The same rule is applied to the non- commercial wood eventually consumed by Sathel. It is worth to emphasize that according to SEDAN (Secretariat of Environmental Development) each farm cannot be divided and may clean or deforest up to 50 percent of its total area. Since present electricity production of Sathel plant is not enough to buy all available non-commercial wood, and many farmers are clearing the land, this wood is burned at the site and large fires can be seen all over that region. Sathel project would make a better use of this wood and also reduce the local pollution caused by the many existing incinerators at the sawmills.

Economic aspects

According to CERON staff at Ariquemes, the average tariff today to consumers is 60 USD/MWh. Its own cost of generation is about 93 USD/MWh and the price paid to SATHEL is about 95 USD/MWh. Present inflation rates in Brazil reduce the real cost of electricity due to the time the account is presented and money is collected.

CERON also informed us that it will pay only 35—38 USD/MWh to ELETRONORTE for the electricity from Samuel hydroelectric plant. In reality, electricity will be less costly to CERON, but the difference is not as big as the above figures show (95 and 38) since today costs are partially paid by the Brazilian electric system through the CCC (fuel consumption account). As soon as electricity will be generated from hydro, CCC payments stop.

Table 5 gives an updated technical and economical summary for the Ariquemes project provided by SATHEL. The specific investment is about 1600 USD/kW and the levelized electricity cost at the consumer door is 0.138 USD/kwh. It is impressive the weight of the IBAMA tax on the total fuel cost: 41 percent.

TABLE 5 - Technical and economical summary for the Ariquemes project (Source: SATHEL).

PREMISES	
Installed power [MW]	28
Capacity factor [percent]	70
Average power [MW]	19,55
Gross energy generation [MWhr/yr]	171.258
Specific fuel consumption [tons/MWhr]	2.50
Fuel consumption [tons/yr]	428.145
Avg. self consumption [MW]	2,54
Avg. maintenance losses [MW]	1,37
Avg. transmission & distribution losses [MW]	2,35
Net avg. power [MW]	13,3
Tradable energy [MWhr/yr]	116.455
INVESTMENTS [USD 1000]	44.692
Power house	35.962
Lifting substation	1.500
Transmission line	1.800
Lowering substation	1.500
Distribution network	200
Complementary equipments	991
Support installations	156
Strategic stock	1.290
Working capital	1.293
OPERATION & MAINTENANCE COSTS [USD1000/yr]	3.279
Labor	1.966
Technical audit	44
Support office	11
Expedient materials	2
Communications materials	24
Medical and juridic assistance	16
Maintenance of machines and equipments	1.024
Maintenance for the feet	99
Fuel for the fleet	92
FUEL COSTS [USD1000/yr]	6.208
Acquisition and manipulation (at 8,5 USD/tons)	3.639
IBAMA tax (at 6,0 USD/tons)	2.569
DEPRECIATION & AMORTIZATION & RETURN ON INVESTMENTS [USD1000/yr]	6.562
TOTAL ANNUAL COST [USD1000/YR]	16.049
Energy cost at the consumer door [USD/MWhr]	138

Social Aspects

As the present Sathel's contract with CERON is finishing, it will have to dismiss almost two hundred direct employees plus a similar amount of indirect employees if it does not quickly find an alternate use for its thermal plant located at the Ariquemes City.

CO2 Abatement Cost

Baseline GHGs emission and CO_2 and N_2O abatement effect

Assuming as mean GHGs emission from the Bom Futuro diesel generators of 0,91 tons—CO_2/MWh and 0.18 kg—N_2O/MWh (see Table 2), and an average tradable energy during a 15-year period of 116.455 MWh/yr, then the baseline emission are 0.11 million tons of CO_2/yr and 21 thousand tons of N_2O/yr during this period. Considering that SATHEL gets a 15-year concession to distribute energy at Bom Futuro and an effective zero GHGs emission for the biomass cycle then the carbon dioxide and nitrous oxide abatement effects are equal to these baseline emission.

Profitability and comparison between project alternatives

To compete with diesel-generated electricity at Bom Futuro, electricity should be sold for approximately 119 USD/MWh (diesel fuel plus O&M costs; see Table 6). As the energy cost at the consumer door for the biomass option is 138 USD/MWh, hence this project is not profitable. Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be 19 USD/MWh or 21 USD/tons of CO_2. This cost might be paid per MWh generated or paid as an equivalent lump sum to be deducted from the investment in the Ariquemes plant. In this last case, the 19 USD/MWh means 14 percent of the energy cost at the consumer door of 138 USD/MWh, or 2,21 USD million/yr, which signifies 34 percent of the total investment, or USD 15,1 million, or yet 538 USD/kW- installed. Considering the GHG N_2O in the analysis would reduce the effective CO_2 abatement cost by about 4 percent (see Table 2).

Table 6 - Technical and economical summary for diesel-generated electricity.

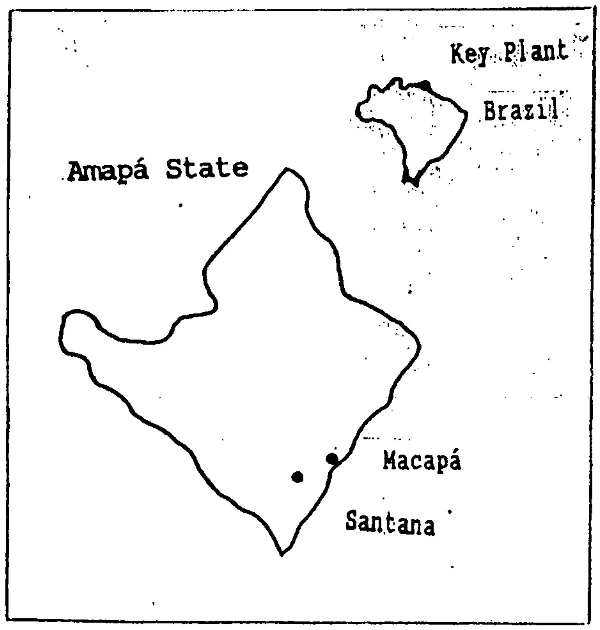
PREMISES	
Specific investment [USD/kW]	150
Capacity factor [percent]	50
Interest rate [percent/yr]	12
Useful life [yr]	15
Average diesel consumption [l/kWh]	0,345
Diesel cost [USD/l]	0,30
OPERATING & MAINTENANCE COSTS [USD/MWh] 15	
Filters & lubricating oil	5
Manpower	5
Maintenance	5
FUEL COSTS [USD/MWh]	104
DEPRECIATION & AMORTIZATION & RETURN ON INVESTMENTS [USD/MWh]	5
TOTAL ENERGY COST [USD/MWh]	124

A1.2.2 THE AMAPA PROJECT

Project Description - SANTANA PROJECT

The Santana Project is located at the city of Santana situated 30 km apart from the city of Macapa - the capital of Amapa State, Brazil (see Figure 3). The project analyses the construction, in two phases, of a 15,5 MWe steam power—plant fueled by bark from Amapa Florestal e Celulose - AMCEL, a private wood-chip exporting factory owned by the CAEMI group.

Figure 3 - Localization of Santana City



Next to the factory, AMCEL has an old 1,5-MW wood-fueled thermoelectric unit which is being partially recuperated by SATHEL. The unit has served 25 years for a wood-compensate factory which is now inactive.

Right now, SATHEL has a signed contract with AMCEL to refurbish the existing 1,5-MW plant. SATHEL is retrofitting one of the three existing boilers, each one having a capacity of 10 t/h, which means 1.050 kW, and a steam pressure of 28 kgf/cm^2. Sathel is also installing one superheater and recovering the turbine, electric wiring, a 6,6-kV / 13,8-kV transformer and controls. The net generating capacity of the plant, after this initial refurbishment, will be 850-900 kW. The plant will be connected to AMCEL and ELETRONORTE grid and will operate in the base. In the final refurbishment, SATHEL is proposing to enlarge the capacity of the boilers and increase their efficiency.

Today, AMCEL is buying electricity from CEA, Companhia Elétrica do Amapá, and has two 1.366 kW diesel generators set, which belong to SATHEL, to supply backup power. These units have supplied all the demand of the chip factory from its initial operation, in January 1993, up to June, 1993, when the factory was connected to CEA´s grid.

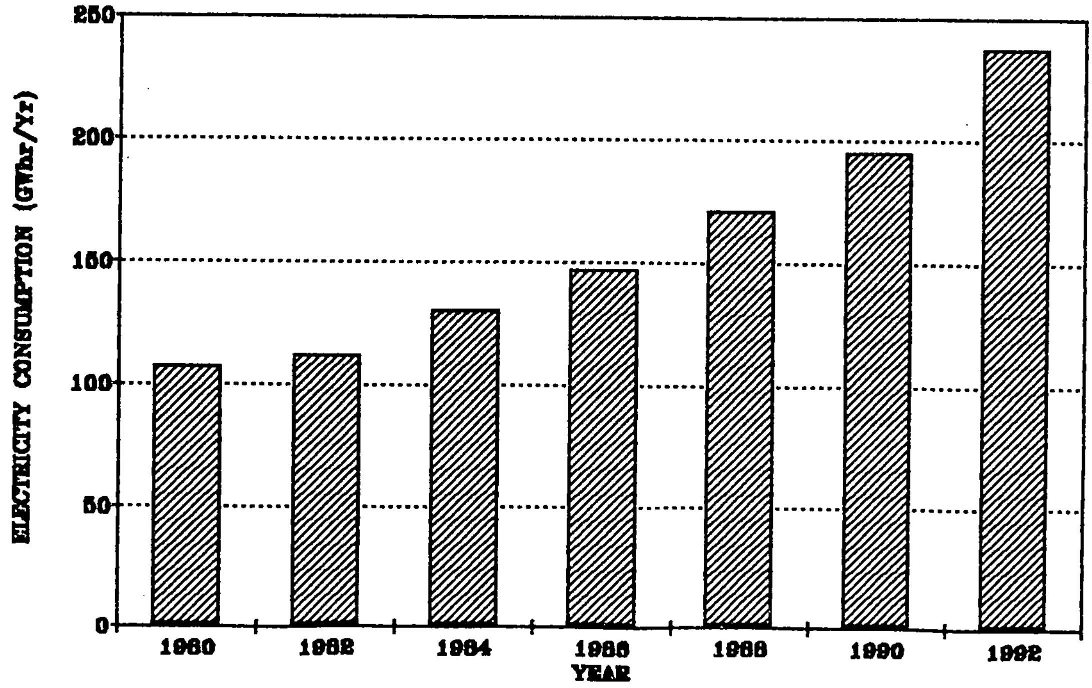
According to the local staff of Eletronorte, the Amapá electric system has the Coaracy Nunes hydroelectric which has two 20-MW installed turbines and it is foreseen a third 30-MW turbine. During 9 months of the year, all electricity is supplied by this plant. But in the peak of dry season, from October to November, the system requires complementation. Three 18-MW gas turbines which operate with diesel oil are being installed and already initiated operation in November, 1993. These units will also be used in the peak interval from 7:00 pm to 11:00 pm to attend the maximum demand of 52 MW. CEA has another set of five 2.5-MW Russian gas turbines which are very noisy and because of this are kept in stand by position.

Market Size

The main clients will be Centrais Eletricas do Norte do Brazil S.A - ELETRONORTE, the regional public-electric concessionary, and AMCEL. AMCEL has a large reforested area with pines and has started industrial operations in the beginning of 1993. It basically produces wood chips which are exported to cellulose industries. In its process, large amounts of bark and other wood residues are generated: about 120 thousand metric tons per year.

Amapa electricity market is growing 7 percent per year, but it is expected to grow from now on at least 14 percent because the city of Santana was recently promoted to a free zone area (Figure 4). Eletronorte local officials informed us that the utility is very interested to buy excess power from AMCEL. In this way, they hope to postpone some state investments in the area of electricity generation since they lack sources of financial resources to execute all their expansion plans.

FIG.4 ELECTRICITY CONSUMPTION AT THE AMAPA STATE



The Biomass Fuel Supply

AMCEL has a 82.000 ha reforested area of pinus on a 180.000 ha farm. It started reforestation in August of 1976 with incentives of Superintendencia de Desenvolvimento da Amazonia (SUDAM), and implemented it with loans from the International Fund Commission (IFC), obtained in 1986/87. Investments already amount to USD 31 million in reforestation and USD 22 million in the wood chip factory and in administrative offices. AMCEL has 600 employees from which approximately 500 are assigned to the farm and 74 to the factory.

AMCEL plans to produce 600.000 t/yr of chips "in natura" (with 37 percent to 47 percent humidity). The installed production capacity of the factory is 900,000 t/yr, working in three turns; right now they are working with only two turns. The factory started to operate in January, 1993. The accumulated production up to September 30 was 200.000 t of chips; as 20 percent of the log weight, or 25 percent of the chips, correspond to bark, the accumulated bark production was 50.000 t.

Environmental Aspects

The potential impacts of the project include those associated with the fuel supply and the emissions from the generating station. As the bark from trees harvested must be disposed anyway, it will be used as fuel supply for the thermoplant.

The soil at AMCEL's farm is a scrub-land, of the "cerrado" type, which is very poor. Besides, the fertile soil layer is thin and hard. Pinus reforestation improves soil properties a little, making the second sowing better than the first one. Hondurian pinus was chosen because is the best adapted to this type of soil. According to the local IBAMA office, AMCEL has the largest among the few reforested areas in the state of Amapá. Also, according to the local IBAMA staff, AMCEL has complied with IBAMA's forest legislation.

IBAMA is trying to change legislation such that reforestations made on scrub-lands may use up to 80 percent, instead of 50 percent, of the total farm area. This is the standard in the "cerrado" region of Brazil. This change is of limited relevance to the electricity generation project itself. The use of other residues may be more problematic. More detailed analyses of technical/economic viability have not yet been made.

Emissions from the generating plant itself should not be a problem. The most important is particulates. However the project is not detailed enough to give informations on the combustion gas , equipments and on problems of CO.

According to the local state environmental-agency, CEMA, Coordenaçao Estadual do Meio Ambiente, all activities of AMCEL industry have been licensed except the disposal of the wood bark. For this item, AMCEL needs to prepare an acceptable plan of disposal. The chosen strategy is electricity generation as reviewed here. According to CEMA, legislation requires a full environmental impact assessment for thermoelectric plants with an installed capacity larger than 10 MW. SATHEL insists that the operating capacity of the projected plant will be lower than 10 MW being the rest cold reserve. In this case, SATHEL will try to negotiate the contents of this assessment with CEMA since a full assessment is very expensive.

Economic Aspects

Assuming a 12 percent interest rate; a 15 year project life; a cost of 8,5 USD/ton for the AMCEL bark residues; an annual O&M costs of 7,3 percent of the total investment; then the generating cost of electricity would be 87,9 USD/MWhr, as may be seen in Table 7.

This value would be attractive to ELETRONORTE since only the fuel costs of its thermal-based units are on the order of 90 USD/MWh or even more. The same thing might not hold for AMCEL since the electricity in the North region, when sold to final users, is subsidized at a value near the Sathel's project busbar- cost.

TABLE 7 - Santana Project phases:

1st. Phase:

Reform of an existing 1,5-MW plant and expansion to 6,5 MW with the installation of a turbine of 5,0 MW.

Installed power [MW] 6,	5
Planned energy generation [GWhr/yr]	39
Specific bark consumption [tons/MWhr]	2,93
Bark consumption (from AMCEL) [tons/yr]	114.270
Investment [USD million]	8,1

2nd. Phase:

Plant expansion to 15,5 MW with the installation of three 3,0 MW- each units.

Installed power [MW]	15,5
Planned energy generation [GWhr/yr]	67,5
Specific bark consumption [tons/MWhr]	2,56
Bark consumption (from AMCEL) [tons/yr]	172.800
Investment [USD million]	12,2
Total Investment [USD million]	20,3
Specific Investment [USD/kW]	1.310
Useful life [yr]	15
Interest rate [percent/yr]	12
Depreciation & Amortization & return on investment [USD million/yr]	2,98
Operation & Maintenance costs (at 7,3 percent of the investment) [USD million/yr]	1,48
Fuel costs (at 8,5 USD/tons) [USD/yr]	1,47
Total annual cost [USD million/yr]	5,93
Levelized energy annual cost [USD/MWhr]	87,9

Social Aspects

This project will generate about fifty direct jobs.

CO2 Abatement Cost

Baseline GHGs emission and CO2 and N2O abatement effect

Assuming as mean GHGs emission from the AMCEL diesel generators 0,91 tons of CO_2/MWh and 0,18 kg—N_2O/MWh (see Table 2), and an average tradable energy during a 15-year period of 67,5 GWh/yr, then the baseline emissions are 61 thousand tons of CO_2/yr and 12 tons of N_2O/yr during this period. Considering that SATHEL gets a 15-year contract to sell energy to Eletronorte and an effective zero GHGs emission for the biomass cycle then the carbon dioxide and nitrous oxide abatement effects are equal to this baseline emission.

Profitability and comparison between project alternatives

Accordingly to Eletronorte officials, to compete with diesel- generated electricity at Macapa, electricity should be sold for at least 90 USD/MWh. As the energy generation cost is 88 USD/MWh, hence the minimum profitability of this project is around 13 percent/yr (see Table 7). Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be barely negative: -2 USD/MWh or -2.2 USD/tons of CO_2. A deeper feasibility study might get a smaller rate of return for this project which could possibly abort it. In this case, an external JI-funding might be needed for its consecution.

Institutional aspects

The institutional aspects here referred are related to the regulatory process regarding authorization of construction and operation of thermoelectric plants. In Brazil, the regulatory responsibility is carried out by DNAEE (National Department of Water and Electric Energy) a department of MME (Ministry of Mines and Energy), located in Brasilia-DF.

DNAEE establishes rules and demands for approval of studies and projects, as well as for the implantation of thermoelectric plants, owned by the concessionaires of public and private services.

The regulations about this matter are written in Edict n° 187 of October 21, 1988, in force since November 15, 1988, and which consist of 4 specific Norms:

DNAEE N° 10: Norm for presentation of studies and projects of thermoelectric plants;

DNAEE N° 11: Norm for approval of studies and projects of thermoelectric plants, with capacity above 10 MW, for concessionaires of public services;

DNAEE N° 12: Norm for the approval of projects of thermoelectric plants with capacity equal or inferior to 10 MW, for concessionaires;

DNAEE N° 13 Norm for the approval of studies and projects of thermoelectric plants for self producers.

According to the document which presents these norms, DNAEE confirms, based on the long run studies of ELETROBRAS - Plano 2010 - that the expansion of the electric sector needs an increased participation of thermoelectricity, and the revision of the regulations intends to agile the approval of new plants. In any case, the DNAEE demands that the construction be started only after the approval of the final project.

Considering the general informations exposed above, it is convenient to analyses the proposed SATHEL plants in Ariquemes/Rondonia and in Santana/Amapa.

Thermoelectric Plant - ARIQUEMES/RONDONIA

This proposal refers to the enlargement of an operating SATHEL thermoelectric plant at Ariquemes, which energy was, up to recently, being sold to CERON - the electric utility of Rondonia which directly supplies the consumers of this state.

From the institutional point of view, SATHEL should present the study and project of plant enlargement according to DNAEE rules. Since SATHEL intends to supply Bom Futuro City located 80 km far from Ariquemes, the project must also include the subtransmission project to Bom Futuro.

SATHEL already presented a formal request to DNAEE having in view the approval of its proposal to enlarge its generating capacity at Ariquemes and supply Bom Futuro. This request has the legal proceedings number 29000.003659/91-56. DNAEE has already approved the technical aspects of the project and currently is working on the tariff evaluation which must be defined by an official authorization. It is expected that the DNAEE approves SATHEL request of becoming a concessionary of public electric services in a precarious fashion. The issue of full permission is constrained by the fact that the Congress must approve a new law which will govern all sorts of permission to use and exploit public services

Thermoelectric Plant - SANTANA/AMAPA

This proposal refers to the expansion of an inoperative 1,5 MW thermoelectric plant at Santana, belonging to AMCEL - a wood-chip exporting company.

The goal is to supply electricity to AMCEL and export the excess to ELETRONORTE - the regional generating utility - which, by its turn, shall sell this energy to CEA - the State utility which directly supplies the end consumers.

SATHEL has already signed a contract with AMCEL to refurbish the existing plant to bring it to an operating 900 kW level. SATHEL is negotiating with AMCEL the next steps to go on with the project to increase the instaled capacity to a 15,5 MW level.

Consequently, SATHEL did not make any formal request to DNAEE; just an informal lobbying. Considering the several aspects of this project, it seems that there will be any problem for DNAEE give its approval.

It is worth to say that this project and the Ariquemes/Rondonia one will be able to apply for the compensation for the operating fuel expenses through specific quotes of CCC, according to Decree 774, of March 18, 1993, which regulated the Law 8631, of April 3, 1993.

Fuel consumption account - CCC

CCC essentially recognizes that thermal generation which compliments the hydro system is more expensive and, accordingly, the sector compensates the utilities that have to operate thermal units in linked systems. This arrangement,which is coordinated by GCOs (Coordinator Groups of Interconnected Operations), works well both technically and financially for the linked systems of regions South, Southeast and, more recently, North.

The CCC - account of fuel consumption - is a financial reserve to cover the costs of fuels used in thermal generation by the Brazilian electric system. This reserve works as a fund, whose contributors include all the electric utilities of the country which attend end consumers.

This fund operates through shares, which are defined in the Fuel Annual Plans, up to October of the previous year and authorized by DNAEE (Department of Water and Electric Energy). The plans are elaborated by three coordinator groups of interconnected operations in three sub accounts by regions. Thus, the GCON establishes the CCC of the North and Northeast regions; the GCOI establishes the CCC for the South, Southeast and Centerwest regions; and the GTON defines the CCC for the isolated systems.

The DNAEE defines the values of the EHE - Equivalent Hydraulic Energy - for each concessionary of the isolated systems to be discounted from the expenditures with fuels and reimbursed by the CCC. The EHE is the energy which might substitute the total thermal generation if the systems where completely linked.

For the case of SATHEL, this understanding is very important, because if SATHEL gets the permission to generate in Ariquemes and distribute in Bom Futuro, according to a request submitted to DNAEE, it could be considered as an isolated system.

The monthly refund of the expenses with the acquisition of fuels is paid by ELETROBRAS (the major holding of the electric companies in Brazil) to the concessionaires and debited from the CCC account. In the case of CCC-ISOL, ELETROBRAS will refund only the expenses with fuels which exceed the corresponding amounts of the respective EHE.

The CCC is an old precept in the electric sector in Brazil and received a recent addition through the regulations of the Decree 774, of March 18, 1993, and according to the Law 8631, of March 4, 1993. The decree mentioned deals with the fixation of the tariff levels for the public service of electric energy and the forms of readjustments.

The CCC is a component of tariffs, according to Article 2nd., letters m, n, and o, which treats of CCC shares for the respective connected systems; for the CCC shares of the isolated systems; and, finally, of the fuels utilized in the thermal generation, not refunded by CCC.

The amplification of the CCC fund to the isolated systems suggests the Government's intention in promoting the existence of a thermal capacity, complementary to the hydro system, with greater representativity in the energy matrix. This view is seen also in the edition of the DNAEE rules which are speeding the approval of new thermal plants, since 1988.

Conclusions

SATHEL company is proposing to implement two biomass-based thermoelectric projects for the Amazon region to compete with diesel-based electricity generation, most common in that region. SATHEL has a large experience in biomass-based electricity in Amazonia. Despite working with recovered used equipments and having had serious financial problems attributable to continuous delays on payments from the local utility, SATHEL plant at Ariquemes City has succeeded to generate reasonably well. One project will be an expansion of 17 MW to this thermoelectric plant, located at Ariquemes City in Rondonia State; the final installed capacity will amount to 28 MW. The second project, located at Santana City in Amapa State, will also be an expansion of a small existing 1,5 MW plant, which is being refurbished, to 15,5 MW.

The investments add to USD 44,7 millions for the Ariquemes project and to USD 20,3 millions for the Santana project; freing the local state utilities which are having problems to equate their plans to expand the grid. Based on the present installations of SATHEL in Ariquemes, the total number of jobs to be created will be about 400. The electricity delivered at the consumer door will cost 138 USD/MWh for Ariquemes and 88 USD/MWh for Santana. The projects are also environmentally safe and have the advantage that they will abate greenhouse gases CO_2 and N_2O since they will substitute diesel-based electricity.

The CO_2 abatement cost is negative for the Santana project and 21 USD/ton of CO_2 for the Ariquemes project. In this last case, the abatement cost might be deducted from the total investment cost in the plant as a lump sum of 34 percent of the total investment, or USD 15,1 million, or yet 538 USD/kW. The net effect of also considering N_2O savings is to lower these figures by about 4 percent.

A1.2.3 BIOMASS-BASED ELECTRICITY GENERATION IN THE CITY OF SINOP.

In the city of SINOP, located 400 km north of Cuiaba, the capital of the state of Mato Grosso, there is a potential possibility for electricity generation based on biomass residues. As early as 1984, a large ethanol plant was assembled at the outskirts of the SINOP city and this agro-industrial activity was an important part of the colonization effort on the area, which started in 1979.

The ethanol plant was designed to use cassava as a feedstock, considering that soil quality in the region would be a serious limitation to the development of high yield sugarcane plantation. On the other side, cassava crop can be developed in low quality soils with reasonable success. The agroindustry was totally installed in 1985 and includes steam and electricity production facilities, designed to attend the processing requirements at the plant.

Steam is produced in two boilers with a capacity of 55 tons/h each and at a pressure of 50 atm. To operate at this pressure a water treatment station is installed. Steam from the boiler, at full pressure drives two back-pressure single-stage Toshiba-steam turbines. Steam exits the turbines at a pressure of 9 atm since it has to be used to cook cassava at temperature near 140°C, to carry out starch hydrolysis.

The agro-industry operated with cassava as a feedstock for less than one year, because it became clear that enough feedstock was not available in the region at a price low enough to allow competition with ethanol produced in other parts of the country using sugarcane. Since then, several attempts were performed to use the agroindustrial installation for some purpose. In 1993 the plant was acquired by 3 agricultural cooperatives headed by COMICEL (Cooperativa Agricola Mista Celeste) by USD 30 million.

The new owners are planning to use millet as a feedstock for ethanol production and at this moment already distributed seeds to be planted on 50.000 ha of land. The operation has started on August of 1994 after several minor restoration work has been performed at the plant. In particular, both boilers are receiving an external treatment since corrosion due to rain fall has unpaired some of the installations.

According to the opinion of Mr. Jorge Kamitani, president of COMICEL, ethanol production from millet grain will not demand all the steam and electricity installed potential at the factory. One boiler and one turbine will be enough to produce all the energy services for the process. Mr. Kamitani is in contact with the Mato Grosso State utility (CEMAT) and is willing to generate and sell electricity to them, using steam produced in the reserve boiler.

SINOP, with a population of 100.000 inhabitants is not yet connected to the National Integrated Grid which serves the South/Southeast/Centerwest of Brazil, but a 230 kV transmission line is being constructed with that purpose. The 400 km long line will transport electricity from Cuiabá up to SINOP and is an important political achievement of the present state governor.

Most of the towers are already installed and, according to the schedule, the line should be completed by the end of 1994. Even considering that shortage of funds can delay the line installation, we have to note that: a) SINOP is a well developed city that can not wait much longer for a reliable electricity service; and b) the project is politically important. Under these circumstances, probably the interconnection will be completed no latter than 1996.

Presently SINOP electricity is generated through the use of diesel motors coupled to electric generators. The service is quite poor and demand surpasses production, requiring continuous load sharing in the city. Refrained demand is considerable. On the other hand, SINOP is a major processing wood center on the region. More than 50 sawmills operate in the city as well as several plywood industries. An estimate claims that 35.000 m^3/month of wood is consumed for plywood manufacture and near 100,000 m^3/month is consumed at the sawmills. Woody biomass residues are abundant and they are burned in very simple ovens, producing particulates and smoke at high levels, in the city.

One possibility analyzed by COMICEL is to use these residues as a feedstock for the boilers installed at the ethanol plant. One of the boilers must operate to provide energy services to the process and the second is being operated to sell electricity to the CEMAT grid. As discussed above, presently electricity is produced from diesel oil and its weight on the electricity cost composition is high, corresponding to about USD 100/MWh.

In the near future, electricity will be provided through the national grid and will mostly be from hydro origin. Its marginal cost to the final user is estimated as USD 64/MWh but the real price is around USD 50/MWh. CEMAT will be able to purchase electricity from the national grid at prices between USD 30 and 40/MWh. Under these scenarios, it is difficult to make a long term agreement with CEMAT to acquire electricity from Independent Power Producers or from Cogenerators by a price which will attract private investors.

From a conversation with Dr. LaRossa from the DNAEE (the federal electricity regulatory authority), we learned that political and technical arguments exist in favour of electricity acquisition by CEMAT in SINOP. The political arguments are: a) electricity acquisition improves the city economy keeping the money received in the town; and b) it increases the economic feasibility of the ethanol plant. The technical arguments are: a) increase of electric system stability; and b) reduction of energy losses.

Cuiabá city receives electricity from the National Interconnected Grid through a line which has 900 km of extension from the nearest supply plant and the SINOP transmission line will increase this distance to 1.300 km. Under this circumstance, it is necessary the installation of a large reactive load to increase stability or/and the inclusion of a generation station at the line extreme. Transmission losses are also significant and some estimates quote losses as high as 30 percent of the total transmitted energy.

By the way, CEMAT made recently other agreements to buy electricity in the west area of the state, in places where the National Interconnected Grid will be installed very soon. This is the case of a 80 MW from hydroplant, owned by the Itamaraty Group.

Under all this framework, it makes sense to propose another project to use the agroindustrial facility in SINOP in a better way.

The project

As discussed earlier, if a real market to generate electricity to the grid in SINOP is confirmed, the most cost effective option seems to be the conversion, to this end, of part of the generation plant located at the Agroindustrial plant owned by COMICEL and others.

The generation system could make a better use of the high pressure boiler if one of the two single-stage back-pressure Toshiba steam-turbines is replaced by a multistage condensing turbine. Improvement in power availability is very high. The present installed turbine requires 20 kg of steam to generate 1 kWh and the proposed one uses only 6 kg of steam. With the availability of 55 tons/h of steam it is possible to generate 9 MW of power, which can improve the overall economy of the project.

With the new turbine, biomass feedstock can be converted in electricity with an efficiency of 22 percent, instead of 5 percent which is obtained on the present installation. This means that 9 MW of electricity will be generated with the same amount of biomass today required to generate 2 MW. Another economic gain will show up when considering the costs of equipments which are necessary to install to perform with minimum protection requirements to attach the power plant to the grid and the cost of the connection itself.

Economic Aspects

Investment in the new turbine can be estimated as USD 500/kW or USD 4,5 million. Overcost due to further equipments for grid connection will be around USD 50/kW or USD 350.000. Thus a total incremental investment of approximately USD 5 million will increase power sales from 2 to 9 MW. Considering a similar cost composition as the Amapa Project (Section A1.2.2), to recover only the incremental investments being done on this project (550 USD/kW), then the generated energy should be sold by about 62 USD/kWh (18 USD/kWh for depreciation & amortization & return on capital costs; 22 USD/kWh for O&M costs; and 22 USD/kWh for fuel costs).

Social Aspects

This project will generate on the order of fifty direct jobs and help to make feasible the whole enterprise with a large direct economic an social impact on the local economy.

CO2 Abatement Cost

Environmental aspects

The environmental advantage is large. Presently and for the forecasted future, biomass residues have no commercial market at the region and, as such, are incinerated in the city. With the generation of 9 MW of electricity, 20 tons of biomass residues per hour (2,2 kg/kWh) will be consumed in the boiler, yielding a monthly demand of 10.000 tons. This quantity is well below wood residues available in the city, thus no net increase in deforestation and CO_2 emission will occur.

At the short term, until SINOP is connected to the National Interconnected Grid, another advantage is the abatement of CO_2 produced from the combustion of diesel oil to generate 9 MW of electricity. Once connected to the Grid, the city will still rely on diesel generators to guarantee reliable supply. Connection through only one transmission line means that power supply interruption can occur. Power shortage estimate can be carried out based in other sites where similar supply occur; typical results show that 5 percent of the time electricity must be generated by diesel generators installed in the city. Also the National Interconnected Grid generates 3 percent of its electricity from coal plants which is another source of CO_2 emission that should be accounted for in the calculation.

Baseline GHGs emission and CO_2 and N_2O abatement effect

Considering all these factors, once connected to the grid, the following amount of CO2 emission will be abated.

BOX 1 - CO2 emissions abated for the SINOP project.

a) from coal - 3 percent of the electricity generated at the National Grid and necessary to deliver 9 MW of power in the city with 70 percent capacity factor.

9 MW X 1,3 X 8.760 X 0,7 = 71.744 MWh/year, from which 3 percent is from coal, that is: 2.152 MWh/year.

The average efficiency of coal plants is 28 percent and coal energy content is 4.000 kcal/kg, which means that: 1 kg of coal generates 1,30 kWh and emits 0,9 kg of C, thus C emission is 0.692 kg/kWhe generated. To generate 2.152 MWh/year total CO_2 emission is 5.460 tons.

b) from diesel oil - For 5 percent of the time electricity must be generated through the use of diesel engines. Assuming 28 percent efficiency of the equipment and 0,85 kg of C/kg of diesel oil we have:

5 percent X 9 MW X 8.760 X 0,7 = 2.759 MWh/year from diesel.

1 kg of diesel oil has 10.500 kcal and is converted to electricity with an efficiency of 28 percent.

1 kg of diesel generates 3,42 kWh and emits 0,85 kg of C.

Thus 0,248 kg of C/kWhe yielding 2.509 tons of CO_2/year.

Adding a) and b) contributions the project will abate only 7.969 tons of CO_2/year. Assuming the emission of N_2O as 0,20 kg/tons of CO_2, then total N2O abatement is 1,576 kg/yr.

Profitability and comparison between project alternatives

To be profitable (12 percent IRR), electricity should be sold for approximately 62 USD/MWh. It seems difficult that CEMAT pays more than 60 USD/MWh for this energy, consequently this project would barely be profitable. Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be 2 USD/MWh or 14 USD/ton of CO_2. Considering the GHG N_2O in the analysis would reduce the effective CO_2 abatement cost by about 4 percent.

A1.2.4. USE OF RESIDUES FROM PALM OIL INDUSTRIES TO PRODUCE ELECTRICITY FOR THE TAILANDIA CITY IN THE STATE OF PARÁ

In the state of Pará, 130 km west of the Brasilia-Belem highway there is a complex of 2 palm oil processing plants owned by Companhia Real de Crédito Agricola. The two plants (known as CRAI and Agropalma) are located 20 km north of the city of Tailandia.

These facilities process 36 tons each of fresh fruit bunches (FFB) per hour. Total amount of biomass residues and the energy content are given in Box 2.

BOX 2 - Total amount of biomass residues and the energy content at the two factories together.

	Production (kg/h)	LHV (kcal/kg)	Total energy (kcal/h)
Fibre	11.5220	2.368	27.280.000
Shell	4.320	3.968	17.140.000
Empty bunch (*)	10.800	2.278	24.600.000
			69.020.000

(*) Dried to 40 percent moisture.

For the processing of palm oil it is necessary to produce steam and electricity. Total steam and electricity consumption, including processing of palmist oil and oil refining is near 31 tons/h and 3.300 kW, respectively. Energy is produced in the two different factories, since geographical distance prevents steam distribution from a centralized facility and the plants were assembled at different times.

To produce all steam and electricity requirements using the traditional low-pressure steam boilers (21 atm) and back pressure- steam turbine, almost all of the fibers and shell are burned. The only residue which is in excess is the empty bunches which are presently returned to the soil to degrade under aerobic fermentation and act as a soil nutrient. This operation is time consuming and it is not clear if they provide any net financial benefit. It is then possible to propose one potential energy use of this material, with the objective to improve overall economics of the plants.

The city of Tailandia has a population of 50.000 people and is electrified through diesel motors. In the near future, Companhia Eletrica do Pará (CELPA), which is responsible for the electricity supply to Tailandia, is planning to connect this city to the National Electric Grid (North/Northeast system) through the construction of a 230 kV transmission line starting in Vila do Conde. The project requires investments of USD 50 million and will only be executed if, through public bidding, an entrepreneur will be able to finance it. This is a quite remote possibility and CELPA interest in the project is modest since economic return will never occur through the sale of electricity.

Due to the presence at modest distance of the palm oil industries, one potential possibility is to construct a thermoelectric biomass-based power station capable to utilize the residues and power the city of Tailandia.

The project

Alternative A: Steam Turbine Generation

Since the tradition in the vegetable oil processing plants is to use fiber and shell as a feedstock to the boiler, this is an indication that it is not so easy to handle and burn empty bunches. Its moisture content is very high (about 60 percent) and needs to be reduced by physical processes (cutting and pressing, for instance) to allow combustion of the material as well as the operation of the boiler at high efficiency.

Figure 5 shows a sketch of a type of an empty bunch press and circular saw. The empty fuel bunches (EFB) are removed manually from the EFB conveyor and dropped through the chute on the circular saw, which cuts them into smaller sections before dropping them on to the screw press. As the empty bunches are squeezed from a moisture content of 60 percent to 40 percent, around 2/3 of its palm oil content is recuperated; also some of the unstrapped fruitiest are exposed and ready for removal.

Using 40 percent-moisture fuel, a boiler with efficiency as high as 85 percent is not difficult to find. If the objective is high efficiency in the use of steam for mechanical power production, a super heater and a condensing steam turbine should be used. Obviously steam pressure should be pushed up to the maximum restricted only for economical reason. But even a 21 kgf/cm2 pressure boiler with super heated steam at 280° C is an equipment which can be found at the internal and external markets. Using this steam in a condensing turbine it is possible to obtain a steam rate of 6 kg/kWh. This means that through the utilization of 24,6 X 106 kcal at 85 percent efficiency it is possible to produce 6 MWe.

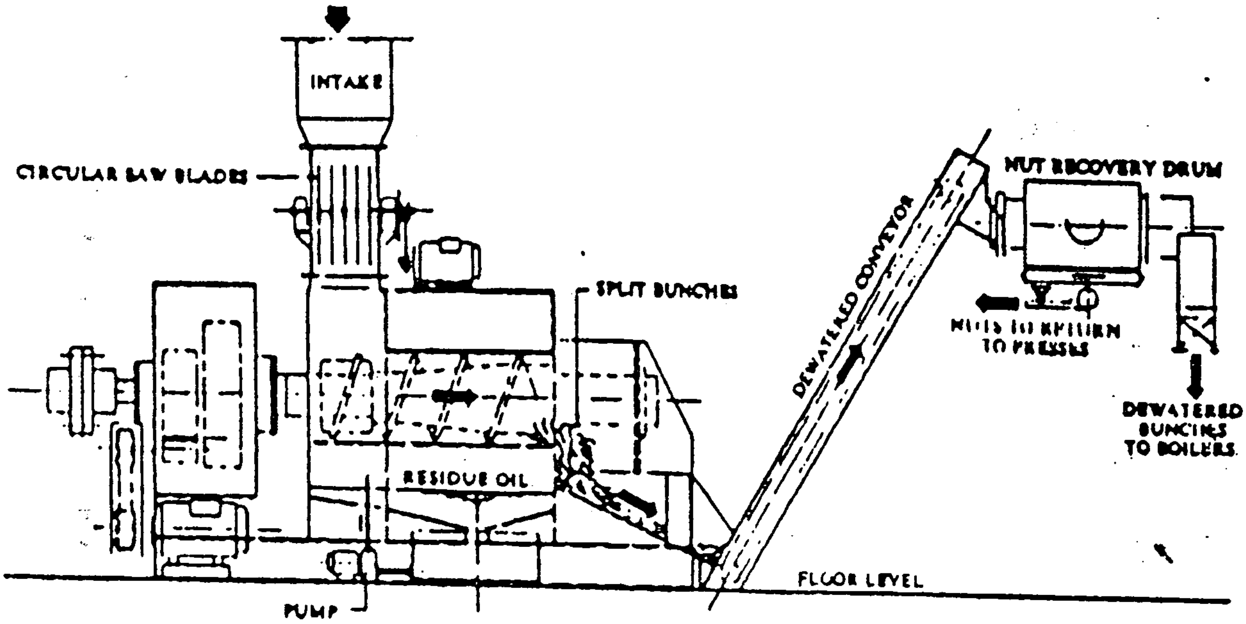
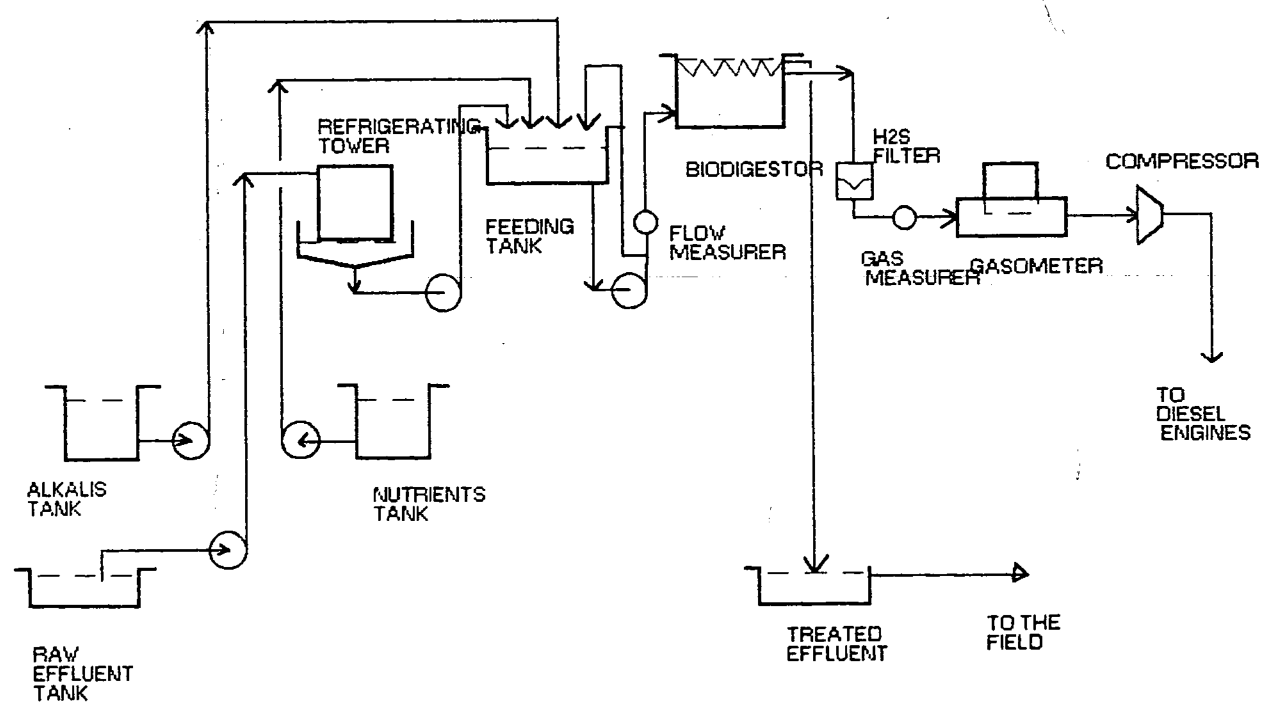


Figure 5 Sketch of UPB Empty Bunch Press C/W Circular Saw

Alternative B: Generation through Biogas

The COD (chemical oxygen demand) of the liquid waste derived from palm oil processing is 60.000 ppm and the BOD (biological oxygen demand), 20.000 mg/l (or ppm). Typical production of biogas in a biodigestor using liquid effluents from a palm oil plant is between 20 Nm^3 to 40 Nm^3 of biogas (60 percent of CH_4 plus 40 percent of CO_2 and other small components) per m^3 of effluent (see Figure 6 and Box 3) . This compares reasonable well with results from the anaerobic fermentation of sugarcane stillage which has a COD of 40,000 mg/l and produces 16 Nm^3 of biogas /m^3 of effluent (Source: Ref. 12). Considering the production of liquid wastes as equivalent to 43 percent of the FFB plant capacity, then the production of liquid wastes is 31.0 m^3/h and the potential biogas production is then 620-1240 Nm^3/h.

FIGURE 6 - Process flowsheet for biogas production (UASB)



BOX 3 A rough estimate of the biogas production
Solids/m^3 of effluent = 4 percent Oil/m^3 of effluent = 1 percent Assuming 4.000 kcal/kg of solid, and 8.800 kcal/kg of oil, then if 90 percent of this energy is transformed in biogas of 5.500 kcal/kg, it will be produced: 0,90 x (40 kg x 4.000 kcal/kg + 10 kg x 8.800 kcal/kg) / 5.500 kcal/kg = 40,6 Nm^3/m^3 of effluent. FFB capacity = 72 tons/h Liquid effluent production = 43 percent x 72 tFFB/h = 31,0 m^3/h Biogas production = 40,6 Nm^3/h x 31,0 m^3/h =1.257 Nm^3/h

This biogas without any treatment can be used as a fuel for Otto engines which coupled to electric generators can produce electricity and, with a heat recovery system, can produce low pressure steam. Electric generators driven by Otto engines can achieve efficiency around 30 percent, which guarantees the production of 1.190-2.380 kWe of power (assuming a lower heat value of 5.500 kcal/Nm^3 for the biogas).

It is then obvious that such system deserves to be investigated if there is interest in the production of electricity, since the values we arrived are enough to attend half of the electricity demand at the city of Tailandia. A factor of 2 improvement on the amount of electricity is not impossible since precise tests about the liquid effluent fermentation were never performed.

In the peak season, the maximum volume of digested material is about 1.300 m^3/day, requiring a total volume of biodigestors on the order of 13.000 m^3 considering a 10-day residence time. (As it is seen below, biomass solid wastes from the plant might, eventually, be mixed to liquid effluents to increase gas production; in this case, the needed volume of biodigestors could be higher).

Major by-product is liquid effluent which should be returned to the field or further cleaned before returning to rivers. The liquid effluent also can be used as an organic fertilizer.

This alternative do not use the FFB and the amount of electricity produced is quite small, something between 1.190—2.380 kW. It is possible to add the FFB to the liquid effluent and the mixture be fermented in the biodigestor. At least the hemicellulose part of the biomass will be hydrolysed and partially fermented. This will be more efficient the smaller are the solid particulates added to the mixture.

Considering that solid biomass can be successfully fermented in biodigestor up to 20 percent solid matter, it is possible to evaluate the maximum amount of FFB that can be used as a source of biogas. Typical effluent production is 31,0 m^3/h and total production of empty bunches is 16,2 tons/h (at a 60 percent moisture from process). Mixing all effluent with all empty bunches allows to achieve a maximum of 16,4 percent solid matter on a total mixture flow of 47,2 m^3/h.

Assuming that 30 percent of the added material (6,5 tons/h of dried material) is hemicellulose and that 50 percent of it will be biodigested, the following amount of energy will be presented as biogas (Box 4).

BOX 4 Amount of energy presented as biogas due to the FFB mixed to the liquid effluents.
Heating value of dry biomass - 5.000 kcal/kg Energy contend of hemicellulose in 30 percent of the biomass 6.500 kg X 0,30 X 5.000 kcal/kg = 9.750 Mcal/h, from which 50 percent is transformed in energy = 4.900 Mcal/h (which means an additional biogas flow of 890 Nm^3/h), which if converted to electricity with 30 percent efficiency provides 1.460 Mcal/h or approx 1.700 kW.

Consequently, the total energy collected from the biodigestor (considering the energy content of the original effluent) will allow the generation of 2.900 - 4.100 kW of electricity. The wastes of the biodigestor could be applied to the palm oil plantation as nutrient.

Investments in a 10 km duct plus pumps will also be required to transport the liquid effluent mixed with the empty bunches from one factory to the other, where the biodigestor plant would be located. The wastes from the biodigestor follow the opposite way.

The biodigestor and Otto type engines would be installed near CRAI or Agropalma and a transmission line of 20 km, probably at 13.6 kV, would be necessary to bring up to 5 MW to the city of Tailandia.

Economic Evaluation of the Project

Alternative A
Box 5 shows the economic evaluation of the use of empty bunches to generate electricity through steam turbine-based plant. The electricity generation cost is on the order of USD 78/MWh.

BOX 5 - Alternative A

Boiler steam production: 35,7 tons/h at 21 kgf/cm^2 2.800C.

Multi-stage condensing turbine; Electr. capacity: 6 MWe.

Fuel consumption = 100 percent of empty bunches (both factories).

		[USD 1.000]	[USD 1.000]
A)	Screw presses & depericarpers		1.550
B)	Belt conveyors complementation		336
	Equipments	286	
	Transport	20	
	Erection	30	
C)	Steam generator		1.832
	Boiler	1.063	
	Deaerator	66	
	Piping	133	
	Water treatment	35	
	Transport	166	
	Erection	319	
	Civil works	50	
D)	Turbogenerator		3.528
	Turbine, gearbox, generator & controls	2.380	
	Steam piping	105	
	Transport	157	
	Linkage to the external grid	322	
	Refrigerating system	26	
	Erection (10 percent (B1+B2)	201	
	Civil works and rolling bridge	337	
E)	Engineering costs (8 percent{A+B+C+D})		580
F)	Unexpected costs (10 percent{A+..+E})		783
G)	Total (A+..+F)		8.609

			[USD 1.000/yr]
H)	Recovery of investments (in 15 years at a 15 percent rate of return)		1.472
I)	O&M costs (Estimate: 8 percent G/yr)		689
J)	Fuel transportation costs (20 km; 5.4 tons/h; 5,000h/yr; 0.05 $/{tons.km})		27
K)	Revenue from recovered palm oil (0.22 percent of FFB; 72 tons/h FFB; 5,000 h/yr; 360$/t oil)	285	
L)	Revenue from recovered kernels (0.12 percent of FFB; 160 USD/tons of kernel)		69
M)	Net annual cost (H+I+J-K-L)	1.834	
			[MWh/yr]
N)	Energy generation	29.800	
O)	Generation & transmission losses		6.000
P)	Net energy generation	23.800	
			[USD/MWh]
Q)	Energy delivery cost (before taxes)		78

Alternative B
Box 6 shows the economic evaluation of the use of empty bunches to generate electricity through biogas-fueled Otto-cycle engines. The electricity generation cost is on the order of USD 120- 127/MWh.

BOX 6 - Alternative B

Electricity generation using biogas in Otto cycle engines

Fuel consumption = 100 percent of all biogas produced using as feed all empty bunches mixed to all liquid effluents produced.

	Capacity [MW]	2.900-4.100
	Gas consumption [Nm³/h]	1.510-2.140
1.	Installation investment (USD 1.000)	5.374- 7.358
1.1	Biogas generator12	2.474-3.265
	Equipments	1.140-1.504
	Civil works	575-759
	Erection + Electr. Inst.	490-646
	Mud treatment	39-52
	Initial operation	23-31
	Unexpected costs	207-273
1.2	Otto generator sets	2.900-4.100
2.	Annual costs (USD 1.000/yr)	1.469-1.967
2.1	O&M costs	430-589
2.2	Transportation of effluents by truck	120
2.3	Investments return	919-1.258
		[MWh/yr]
M)	Energy generation	14.500-20.500
N)	Generation & transmission losses	2.900-4.100
O)	Net energy generation	11.600-16.400
		[USD/MWh]
P)	Energy delivery cost (before taxes)	127-120

Social Aspects

Either project alternative would generate on the order of fifty direct jobs.

CO2 Abatement Cost

As Alternative A is economically the best, then we analyze below only the CO_2 abatement cost for it.

Baseline GHGs emission and CO_2 and N_2O abatement effect

Assuming as mean GHGs emission from the CELPA diesel generators at Tailandia City of 0.91 tons CO_2/MWh and 0.18 kg N_2O/MWh (see Table 2), and an average tradable energy during a 15-year period of 23.800 MWh/yr, then the baseline emissions are 22 thousand tons of CO_2/yr and 4 tons of N_2O/yr during this period. Considering an effective zero GHGs emission for the biomass cycle then the carbon dioxide and nitrous oxide abatement effects are equal to these baseline emissions.

Profitability and comparison between project alternatives

To compete with diesel-generated electricity at Tailandia, electricity should be sold for approximately 119 USD/MWh (diesel fuel plus O&M costs; see Table 6). As the before—taxes energy cost at the consumer door for the biomass option is 78 USD/MWh, hence this project is profitable. Assuming no net emission of CO2 by the biomass cycle, the CO_2 abatement cost would be -41 USD/MWh or 45 USD/tons of CO_2. Considering the GHG N_2O in the analysis would reduce the effective CO_2 abatement cost by about 4 percent (see Table 2).

A1.2.5 STUDY OF A COGENERATING SYSTEM ON THE OIL PALM ESTATE "DENPASA"

SUMMARY

This section details one alternative to cogenerate electricity and process steam for a DENPASA's palm oil factory located in the state of Pará in the Brazilian Amazon region. The Acara unit has an installed capacity to process 10 tons of fresh fruit bunches (FFB) per hour, but it is planned to soon double this capacity. The proposed technology is based on biomass fired boilers coupled with steam turbines. From the biomass residues at the plant, composed of fibre, shells and empty bunches, only the first two will be used to satisfy current and future internal needs of steam and electricity.

The study has shown that 488 kW of electric power plus 7,5 tons/h of process steam might be cogenerated with an investment of USD 1,04 million (2.130 USD/kWe). If DENPASA makes all the required investments without any financing, the internal rate of return (IRR), before taxes, is on the order of only 5,6 percent per year. Unfortunately, due to the very high interest rates prevailing in Brazil, these IRRs are uninteresting to private investors which require IRRs on the order of 20 percent to 30 percent per year.

Thus, to go forward with the implementation of this alternatives, a grant must be looked for from an entity similar to the Global Environment Facility (GEF). This action might be an incentive to the implementation of similar projects in the Amazon region, helping the country to better use its renewable energy resources with the added benefits of replacing diesel generated electricity and, consequently, reducing local emissions of greenhouse gas CO_2.

Description of Acara unit

The Acara factory has a capacity to process 10 tons of FFB/hr and started commercial operation on Dec. 20, 1993. In the near future, the factory capacity will be increased to 20 tons of FFB/hr.

This unit has a 9 year-old boiler with a steam production capacity of 8.000 kg/hr with a pressure of 13,8 kgf/cm^2 and a 85 percent—efficiency, which might supply steam even when Acara's capacity is doubled to 20 tons of FFB/hr. Nevertheless, the steam temperature and pressure are too low for electricity generation. This boiler is scheduled to be replaced in 2013. At this unit, the process will need just 7.500 kg/h of 3,4 kgf/cm^2 steam beginning in 1996.

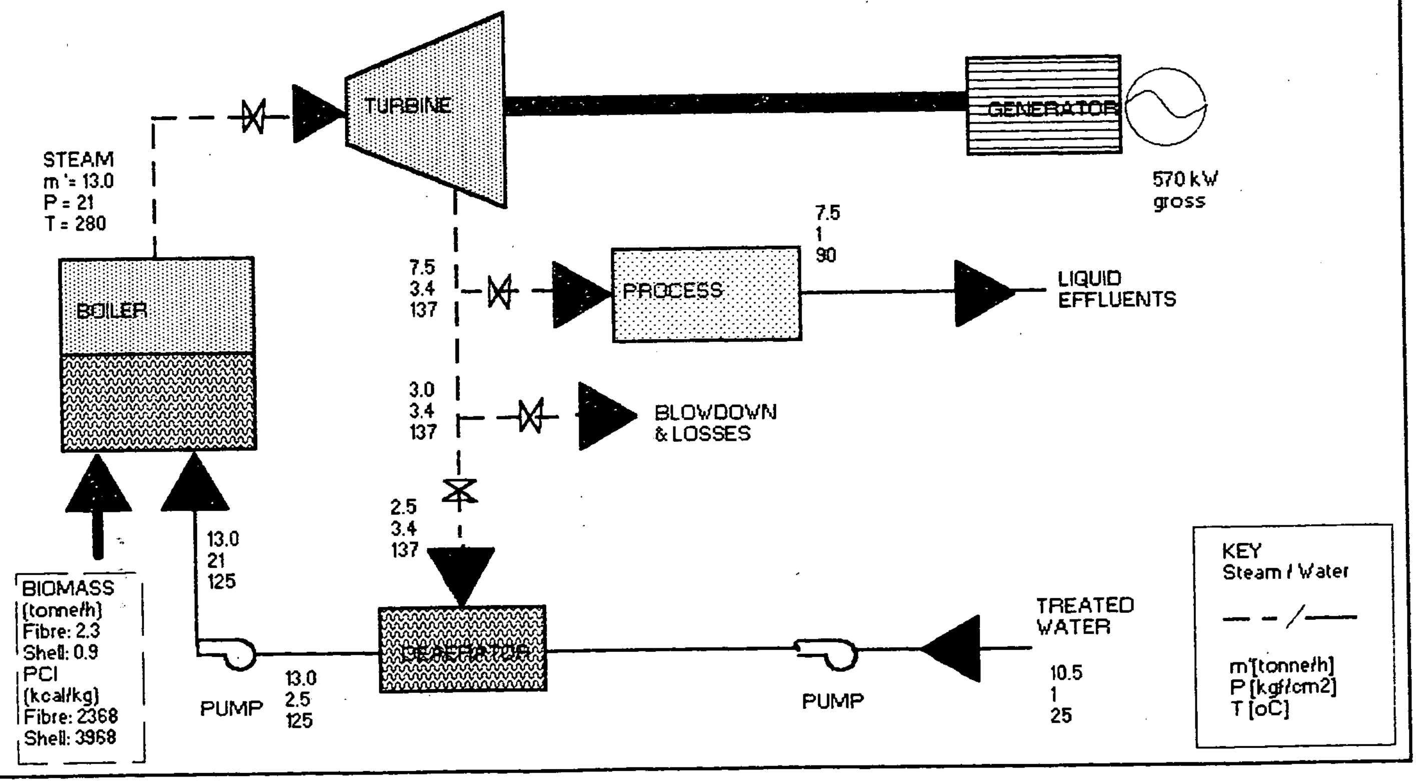
Since in Acara and its surrounding there is no electricity supply from the regional utility, the factory uses today a 355 kVA diesel generator as the main source of electricity. Another generator with 180 kVA is in stand-by for the factory. There are three more generators: two 44,5 kVA units that supply electricity to the workshop and village and another of 30 kVA for other uses. Diesel oil is fully available in the region.

With the production increasing to 20 tons of FFB/hr in 1996, the power demand will increase as the load of installed motors grows to 488 kW. Starting in 1996, the monthly consumption is estimated in 130.000 kWh/month. Assuming a consumption of diesel oil of 0,236 l/kWh, as suggested by the manufacturer, and considering the current price of diesel fuel at Acara of 0,33 USD/l, the annual fuel cost to generate electricity at Acara beginning in 1996 will be 122.000 USD/yr.

The current O&M costs of the diesel units were estimated in 17.000 USD/yr by DENPASA. For the boiler, the current O&M cost is 48.000 USD/yr.

In the cogeneration option, a 13 tons/h boiler is needed to supply the process and turbine steam needs as shown in Figure 7. The gross power capacity of the cogenerating capacity is 570 kW to give a certain margin to account for steam, temperature and pressure losses and electricity distribution losses. Although there is no fuel constraint to supply this power (Box 1), even using an inefficient, but cheap, single-stage steam turbine, a deaerator was added to the cogenerating system mainly to decrease the required boiler capacity and the load on the water treatment system (Fig.7). There is no fuel supply restriction as seen in Box 7.

FIGURE 7 - Cogeneration system-process flowsheet
(Acara - Alternative 1 - 488 kW net)



BOX 7 Available energy from fibre and shell biomass residues at the Acara unit.

	Production (kg/hr)	LHV (kcal/kg)	Total energy (kcal/hr)
Fibre	3.200	2.368	7.577.600
Shell	1.200	3.968	4.761.600
Total			12.339.200

Steam that might be generated by a new 85 percent-efficient water- tube boiler using all fibre and shell residues available using 125°C-feed water= (12.339.200 kcal/hr) / (586 kcal/kg of steam) x 0,85 = 17.898 kg/hr.

Economical and financial analysis of the alternatives

Table 8 gives a summary of the technical and economical assumptions for the cogeneration alternative studied for the Acara unit. Investment data are based on Ref. 10 and on quoted equipment prices from some specific manufacturers. In this alternative, 488 kW of electric power plus 7,5 tons/h of process steam might be cogenerated with an investment of USD 1,04 million (2.130 USD/kWe).

Note that the cash flow is a net cash flow which compares the cogenerating alternative to its corresponding business as usual alternative. The main problem found is economic due to the very low IRR for the project (5,6 percent/yr) compared to local parameters (an acceptable IRR would be in the range 20-30 percent/yr). This low IRR fundamentally derive from three main factors: a) the heavy subsidies given by the government to the diesel oil price which not covers transportation costs to far away sites; b) the small proposed-installed power capacities; and c) the small expected-capacity factor for the installed power.

TABLE 8 - Technical and economical summary for the Acara project.

PREMISES	
Gross installed power [kW]	570
Capacity factor [percent]	36,5
Net power demand [kW]	488
Process steam needs [tons/h]	7,5
Factory energy consumption [MWhr/yr]	1.560
Specific fuel consumption:	
Fibre [tons/MWhr]	4,08
+ Shell [tons/MWhr]	1,53
INVESTMENTS [USD 1000]	1.040
OPERATING & MAINTENANCE COSTS [USD 1000/yr]	83
AVOIDED DIESEL OIL COSTS [USD1000/yr]	122
AVOIDED EXISTING BOILER PLUS DIESEL SETS O&M COSTS [USD1000/yr]	65
FUEL (Fibre & shell) COSTS (at 0 USD/tons)	0
TOTAL ANNUAL SAVINGS [USD1000/YR]	104
INVESTMENT RETURN (Useful life of 15 yr) [percent/yr]	5,6

Social Aspects

This project alternative would generate some tens of direct jobs.

CO2 Abatement Cost

Baseline GHGs emission and CO_2 and N_2O abatement effect

Assuming as mean GHGs emission from the DENPASA diesel generators of 0,62 tons CO_2/MWh (diesel efficiency of 0,236 l/kWh versus 0,345 l/kWh for the average diesel set of utilities in Amazonia) and 0,12 kg—N_2O/MWh (see Table 2), and an average energy production during a 15-year period of 1.560 MWh/yr, then the baseline emission are 970 tons of CO_2/yr and 190 kg of N_2O/yr during this period. Considering an effective zero GHGs emission for the biomass cycle, then the carbon dioxide and nitrous oxide abatement effects are equal to these baseline emission.

Profitability and comparison between project alternatives

The total annual savings before taxes is USD 104 thousand/yr, which means that this project certainly will not be profitable after taxes (5,6 percent internal rate of return before taxes). As the total investment is USD 1.040 million, assuming a 15 year life and a 15 percent/yr interest rate, it is equivalent to an annual capital cost of USD 178 thousand/yr. The net annual cost is then USD 74 thousand/yr. Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be 47 USD/MWh or 76 USD/tons of CO_2. Considering the GHG N_2O in the analysis would reduce the effective CO_2 abatement cost by about 4 percent (see Table 2).

Conclusions

In order to obtain an acceptable IRR for the project alternatives, a grant from an entity like the GEF must be searched for. This donation might be totally justified since biomass fuel replaces diesel oil in the generation of electricity, decreasing locally greenhouse gas-CO_2 emissions. The accomplishment of this alternative would be a practical demonstration of how to link global environment objectives with engineering/economic solutions for small private plants.

A1.2.6. ELECTRICITY GENERATION AT THE CITY OF GUAJARA MIRIM.

The city of Guajara Mirim is located at the state of Rondonia near the border of Bolivia. On the other side of the Madeira River, there is the Bolivian city of Guayaramerin. Electricity is supplied by CERON (Companhia de Eletricidade de Rondonia) and by Cooperativa Eletrica though diesel powered motors coupled to electric generators, in the two cities.

The cities are 300 km west of BR-364 highway which crosses the major cities of the Rondonia state - Porto Velho - the capital, Ariquemes, Ji-Parana and Vilhena.

According to the new 10 years electric expansion plan issued in 1994 by Eletrobras, it is anticipated that a local grid will be extended from Porto Velho to the south of the Rondonia state, reaching cities at the south of Ji-Parana city. Eletronorte, the electricity supply utility, will complete the 230 kV transmission line from Porto Velho to Ji-Parana by 1995 (there is reasonable chance that this will be postponed for a few more years) and CERON, the utility responsible for electricity distribution, will extend 69 kV lines to further south of Ji-Parana.

According with contacts with Dr. LaRossa from DNAEE the interest to extend the grid up to Vilhena in the extreme south of the state exists but there is no reason to execute a link with the National Interconnected Grid (South/Southeast/Centerwest system) since the major electric supply plant are at more than 2.000 km of distance.

As already described in item A1.2.1. the local Rondonia grid is supplied by one medium size hydro plant (Samuel) which will be unable to attend even present demand of the already listed cities. Several alternatives exist to solve the supply problem but there is no prevision in the official planning report for the next 10 years.

Furthermore there is no possibility of providing a significant connection of Guajara-Mirim to the Grid for more than 10 years, since it is too far (300 km). Electricity demand in 93 was 4.300 kW with an average monthly consumption of 2.100 MWh at the city of Guajara-Mirim. This yields a utilization factor of 67 percent which is high and explained by significant refrained demand.

The region around Guajara-Mirim have experienced large land use changes due to significant increase in the population promoted by colonization efforts implemented since 1980. Biomass residues and cut tress are abundant in the region.

The project

The proposal is to install a thermoeletric plant with 8 MW capacity powered by biomass wastes and residues which will produce steam to drive steam turbines coupled to electric generators.

Electricity can be sold to the city of Guajara-Mirim and to Guarayamerim in Bolivia. Presently the Bolivian city is supplied by 2,8 MW diesel powered motors with an average generation of 2 MW. Diesel oil consumption is 300.000 l/month and is sold with a subsidy of 0,19 USD/l. Even so electricity is sold at a cost of USD 180/MWh.

In the Brazilian city, electricity is sold at an average price of USD 80/MWh but internal sector subsidies of the National Electric System are added, to the amount of USD 50/Mwh, yielding a final revenue to the supplier of USD 130/MWh. Even at this sale price, the Rondonia state provides financial support to CERON, since this value is not enough to cover all costs.

A preliminary evaluation of the project has been performed with the help of many contacts with Asea Brown Bovery of Brazil, Companhia Brasileira de Caldeiras and Dedini, potential turbine sellers, in November 1993.

Other contacts were carried out with CERON in December 1993, through mr. Jorge de Lima (president) and mr. Antonio Marrocos (director of distribution), and with Mr. Isaac Bennesby (Guajara- Mirim city mayor). According with them, the project is extremely welcomed since shortage of electricity is a serious problem and there is no political obstacle to be overcome for the installation of a private power supply plant.

The same travel was used to contact mr. Antonio de Padua, assistant of the director of operation of CERON, which confirmed that the Samuel hydro plant will not be enough to provide a reliable supply to the local grid and, as such, before a supply solution is found there is no reason to connect Guajara-Mirim to the grid.

Another contact was performed with IBAMA in Porto Velho, with mr. Luiz Voss. According with him, the project must be submitted to IBAMA for environmental appreciation as soon as possible.

Further contacts were performed with Embrapa (Brazilian Enterprise of Agricultural Research) in Porto Velho, with Cooperativa de Servicos Eletricos Guayaramerin Ltda, Bolivia, with SUFRAMA (Duties and Taxes Authority in Amazonia) at the Guajara-Mirim city were it was learned from Mr. Celmo Alencar, its director, that all commercial transactions in the city are tax- free as far as Federal and State tax are concerned.

Contacts were also maintained with BNDES (Bank for National Economic Development) through Mr. Ariel M. de Oliveira e Silva and Carlos Alberto Alves from the credit department. According with them, the bank has interest in financing a private entrepreneurship for Guajara-Mirim city, supposing guarantees are provided by the taker. Between 65 to 75 percent can be financed at long term and at low interest rates. It is necessary authorizations issued by DNAEE and IBAMA and a permission issued by CERON for a preliminary consult.

Our initial estimate is for an investment of USD 1.300/kW installed, a little below the average cost evaluated in A1.2.1 since several Federal and State taxes are waived. This requires a total investments of USD 10,4 million.

The economic evaluation is shown at Table 9. The electricity cost is USD 200/MWh, which is a higher price than today (USD 130 in Brazil and USD 180 in Bolivia). Biomass residues for fuel can be acquired at prices around USD 20/ton plus transportation and handling cost (USD 20/ton).

TABLE 9 - Technical and economical summary for the Guajara-Mirim project.

PREMISES	
Installed power [MW]	8
Capacity factor [percent]	72
Average power [MW]	5,8
Gross energy generation [MWhr/yr]	50.500
Specific fuel consumption [tons/MWhr]	2,50
Fuel consumption [tons/yr]	126.000
Avg. self consumption [MW]	0,5
Avg. transmission & distribution losses [MW]	0,5
Net avg. power [MW]	4,8
Tradable energy [MWhr/yr]	42.000
INVESTMENTS [USD 1000]	10.400
OPERATING & MAINTENANCE COSTS [USD 1000/yr]	830
FUEL COSTS [USD 1000/yr]	5.800
Acquisition and manipulation (at 40 USD/tons)	5.040
IBAMA tax (at 6,0 USD/tons)	760
INVESTMENTS RETURN (15 yr at 15 percent/yr) [USD1000/yr]	1.780
TOTAL ANNUAL COST [USD 1000/YR]	8.410
Energy cost at the consumer door [USD/MWhr]	200

Social Aspects

This project would generate some tenths of jobs since wood-fueled thermal units are more labor intensive than diesel sets.

CO2 Abatement Cost

Baseline GHGs emission and CO_2 and N_2O abatement effect

Assuming as mean GHGs emission from the Guajara-Mirim diesel generators of 0.91 tons CO_2/MWh and 0.18 kg N_2O/MWh (see Table 2), and an average tradable energy during a 15-year period of 42.000 MWh/yr, then the baseline emission are 38 thousand tons of CO_2/yr and 7,6 tons of N_2O/yr during this period. Considering that the project gets a 15-year concession to distribute energy at Guajara-Mirim and an effective zero GHGs emission for the biomass cycle then the carbon dioxide and nitrous oxide abatement effects are equal to these baseline emission.

Profitability and comparison between project alternatives

To compete with diesel-generated electricity at Bom Futuro, electricity should be sold for approximately 150 USD/MWh (average price at the two cities). As the energy cost at the consumer door for the biomass option is 200 USD/MWh, hence this project is not profitable. Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be 50 USD/MWh or 55 USD/ton of CO_2. Considering the GHG N_2O in the analysis would reduce the effective CO_2 abatement cost by about 4 percent (see Table 2).

A1.3 INTERNAL COMBUSTION MOTORS FUELED WITH NATURAL VEGETABLE OIL.

Just one project was identified to generate electricity through internal combustion motors fueled with natural vegetable oil, the Mogno Farm project; it is described in Section A1.3.1.

A1.3.1 ELECTRICITY GENERATION FOR THE MOGNO FARM.

Mogno farm is located in the extreme north of Mato Grosso state, at 100 km from the border of the state of Pará, and 60 km away from the city of Alta Floresta. With a total land area of 300.000 ha, from which 93 percent is still native, cocoa and coffee agriculture and extensive cattle-ranching are practiced. The owner of the farm is considering to construct a meat storage facility in the city of Alta Floresta.

Alta Floresta is electrically supplied by diesel motors and a 138 kV transmission line is planned to extend the National Interconnected Grid (South/Southeast/Centerwest system) up to there through a connection in the cities of SINOP and Colider, located 200 km North from SINOP. It is also necessary to upgrade the existing 69 kV transmission line from Colider to Alta Floresta. This kind of entrepreneurship is forecasted for the next 4 years but the extreme shortage of funds can possibly postpone it to after the year 2000.

The existing diesel-based electric system serving Alta Floresta is barely able to supply power in the off peak hours. Even with the installation of such grid, technical difficulties will be present. The distance of Alta Floresta from the nearest hydroplant of 1.700 km poses stability problems and significant energy losses.

Under these circumstances, to power the storage meat facility, a preliminary proposal quotes the following requirements:

	Power demand (kW)	Energy (kWh/month)
Peak hours	500	25.000
Off peak hours	1.000	400.000

and the following option of supply.

1) Acquisition of electricity from the electric grid of Alta Floresta.

This can be performed with no guarantee that electricity will be available, mainly during the peak-hours. The alternative then requires the installation of diesel based electric generators.

Under the assumption that 100 percent of all electricity will be generated by diesel motors during peak-hours and that 10 percent of all the electricity consumed out off-peak hours will be generated by diesel motor the following economic evaluation was performed (BOX 8).

BOX 8	
Option 1) Acquisition of electricity from the electric grid of Alta Floresta.	
Investment {I} (USD/kW)	250
Installed diesel power (kW)	1.000
O&M annual costs (percent of I)	20
Fuel cost (USD/m^3)	300
Thermal efficiency	
of generation (percent)	40
High heating value of fuel	
(Mcal/m^3)	9.160
Useful life (years)	15
Interest rate(percent per year)	15
Annual electricity consumption (MWh)	
self - produced	780
Acquired from CEMAT	4.320
Electricity costs (USD/MWh)	
self - produced	189
Acquired from CEMAT	81
Average	98

2) Another alternative considered is the installation of a biomass based thermoelectric plant to generate electricity through a steam turbine (Box 9). Since the investment is now much higher than the earlier solution the idea is to sell surplus electricity to CEMAT at a price of USD 65/MWh. To guarantee reliable supply, at the meat storage facility, it is necessary to add a stand-by diesel generator with 500 kW of power.

BOX 9

Option 2) Installation of a biomass based thermoelectric plant to generate electricity through a steam turbine.

	Steam	Diesel
Installed power (kW)	1.000	500
Investment {I} (USD/kW)	2.000	250
O&M annual costs (percent of I)	10	20
Fuel cost (USD/unit*)	15	300
Thermal efficiency (percent)	16	40
High heating value of fuel (Mcal/unit)	3.300	9.160
Useful life (years)	15	15
Interest rate (percent year)	15	15
Electric energy (MWh)		
self-produced	6.130	30
consumed	4.590	30
sold to CEMAT	1.540	0
acquired from CEMAT	--	480
Cost/Price of electricity(USD/MWh)		
self-produced	113	1.616
acquired from CEMAT	--	81
sold to CEMAT	65	--
average	133	
(for a total consumption of 5100 kWh/yr)		

* Units - diesel: cubic meter; woodfuel: metric ton.

The project

With the commercial availability of diesel type engines powered by vegetable oil "in natura", a new alternative can be proposed. It is a variant of the first one but, instead of using diesel fuel, it will use vegetable oil.

Vegetable oil is more expensive than diesel fuel when both are acquired at market prices, respectively USD 400/m^3 and USD 300/m^3. In reality, the prices can be totally different if we consider the following issues:

a) vegetable oil can be produced at the farm and used in its rawest form to feed diesel engines;

b) future price of diesel fuel will be significantly higher since an internal subsidy exists to cover transportation costs of fuel derivatives. These subsidies are under severe criticism and, in the near future, the real cost of transport will probably be charged in the final price and paid by the user.

Vegetable oil can be produced in the farm through, for example, rice, corn or mamona crops. Rice is planted, in general, as a subsistence crop for the employees and corn is an auxiliary foodstuff to the cattle. Mamona is a nonedible fast-growing plant which can produce near 1.500 kg/ha of seeds per harvesting period.

Under the first option above, total electricity produced (780 MWh/yr) will require 183 tons of vegetable oil (for an specific consumption of 235 g/kWh).

Option A - Vegetable oil from Corn

The above mentioned amount of oil can be obtained in 1700 ha of corn plantation (108 kg/ha).

The motivation to grow corn in the farm is the synergism between energy and concentrate. To feed animals, it is important to provide as much as 1,8 tons/head per year of concentrate. With 1.700 ha of corn plantation, as much as 2.980 tons of concentrate will be produced, which is enough to feed 33 percent of the cattle in the farm (5.000 heads).

With the installation of a small oil extracting facility, it becomes possible to avoid long distance transportation of the grain and back transportation of the fodder, as well as the payment of taxes which is charged for the products commercialization.

Economic Evaluation

Corn crops provide to the vendor a bruit revenue of USD 83/tons before tax. Considering a yield of 1,8 tons/(ha.yr), the bruit revenue is USD 150/ha. This is an indication that the cost is below that - let us assume USD 120/ha. A simple oil extracting facility can be installed with USD 100.000, including equipments and building. Concentrate has a market price of USD 83/tons before tax. Assuming that 1 tons of grain produces 60 kg of oil and 900 kg of concentrate (and an average yield of 1,8 tons of grain/ha), the following economic analysis can be performed (Box 10).

BOX 10	
Corn oil fueled option.	
Plantation of 1.700 ha (USD/yr)	204.000
Investment on the agroindustrial	
equipments {I} (USD)	300.000
O&M of equipments (percent of I)	20
Equipments depreciation (yr)	10
Interest rate (percent yr)	15
O&M of equipments (USD/yr)	60.000
Investment return (USD/yr)	60.000

Total agroindustrial cost (USD/yr)	324.000
Installed Power (kW)	1.000
Investment on vegetal-oil motor	
and generator I (USD 300/kW)	300.000
O&M equipments costs (percent of I/yr)	20
Fuel cost (USD/m3) (see Note 1)	0
Thermal efficiency (percent)	40
Fuel high heating value (Mcal/m3)	9.160
Useful life (year)	15
Interest rate (percent / year)	15
Annual Electricity consumption	5.100
Self produced	780
acquired from CEMAT	4.320
Electricity cost [USD/MWh]	
Self produced (no fuel cost)	143
acquired	81
average	90

NOTE 1
From the above list it is possible to calculate fuel cost based on the following consideration: Cost of plantation is equivalent to the cost of concentrate acquired on the market (USD 83/tons). Thus the plantation costs off-set costs of concentrate. The agroindustrial facility has an annual operational cost of USD 324.000 to produce and process 3,060 tons of grain, yielding 183 tons of oil and 2.750 tons of concentrate. On top of the concentrate acquisition cost of USD 83/tons, transportation (distance of 400 km at USD 0,05/tons-km) and taxes (17 percent) add to a USD 34/tons which is saved with the self-production. The total saving is equivalent to USD 322.000/yr. Abating this value from the total agroindustrial facility cost (USD 324.000/yr) we arrive to a negative value, which may be attributed to vegetable oil production. This means an essentially zero fuel cost.

Option B - Vegetable Oil from Mamona

Mamona14 is a fast growing plant which can produce 1.500 kg of seed/ha from which 40 percent is oil. Under the first alternative, total electricity produced (780 MWh) will require 183 tons of vegetable oil (235 gr/kWh). Considering a production of 660 l/ha (607 kg/ha) of mamona oil, a total area of 302 ha is necessary to attend the supply of electricity.

The motivation to grow mamona is its quick response to become productive (one year) and the facility of oil extraction which requires a simple press and no other requirements like steam pre- cooking. A small oil extraction facility can be installed at low cost. For the production of 15 kg/h a press can be installed with USD 15.000 and requires 1 kW of power.

Economic Evaluation

From the above quoted figures and considering that: a) no economy of scale exist in the press equipment; b) mamona plantation cost is USD 266/ha, the following economic analysis can be performed (Box 11).

BOX 11 Mamona oil option.

Plantation of 302 ha (annual cost) 266 USD/ha =	80.300
Investment on agroindustrial equipments (I)	45.000
O&M of equipments(percent of I)	20
O&M equipments depreciation (years)	10
Interest rate (percent year)	15
O&M of equipments (USD/year)	9.000
Investment return (USD/year)	9.000
Total (annual cost)	98.300
Fuel cost (USD/m^3) see Note 1	326
Installed Power	1.000 kW
Electricity cost	
self produced	226
acquired	81
average	103

Note 1
From the above figures it is possible to calculate fuel cost simply dividing total annual cost USD 98,300 minus revenue obtained from the value of mamona residues (USD 33,200 at 131 USD/tons and 0.84 tons/ha), by the total amount of vegetable oil produced in one year (183 tons). This yields USD 355/tons (or 326/m3).

Conclusions

Option A - Vegetable Oil from Corn

We have shown that, with the investment of USD 240.000/yr on corn crop, USD 300.000 in oil extracting equipments and USD 300.000 in vegetable oil-powered diesel engines coupled with electric generators, it is possible to provide 1.000 kW of electricity to the Mogno farm. Electricity cost will average USD 90/MWh which is a little lower than a similar option using diesel oil as fuel (USD 98/MWh).

More than that the difference between both options are not properly shown by the final cost of electricity since in both cases 85 percent of the electricity will be acquired from CEMAT. This electricity has the same cost of USD 81/MWh in both options. Considering only self-produced electricity, the difference in price is much more significant USD 189/MWh and USD 143/MWh, being cheaper for vegetable oil.

Furthermore, the vegetable oil option creates new employments at the farm, can improve cattle revenue, which is not considered in our evaluation, and has environmentally benign consequences. A total of 780 MWh will be generated from renewable sources, avoiding a 710 tons of CO_2 emission per year. The difference between the average costs of electricity produced from the corn oil and diesel oil options is -8 USD/MWh; this allows us to calculate carbon abatement costs as -9 USD/tons of CO_2.

Another important aspect of the project and which deserves better discussion with the utility and DNAEE is the possibility of producing all electricity at the meat storage facility. With near zero fuel costs, the electricity would cost only USD 35/MWh (sse Table 10).

TABLE 10 - Self-generated electricity only

Investment on diesel motor and generator {I} (USD 300/kW)	300.000
O&M equipment costs (percent)	30
O&M equipment depreciation (years)	5
Interest rate (percent year)	15
O&M equipment (USD/year)	90.000
Investment return (USD/year)	89.500
Annual electricity	
self produced (MWh/year)	5.100
investment return (USD/MWh)	17
O&M costs (USD/MWh)	18
fuel cost {at 0 USD/tons} (USD/MWh)	0
Final electricity cost (USD/MWh)	35

Under this circumstance , the electricity production at the meat storage facility could be increased from 780 to 5.100 MWh/year with no further investment on these installation. More investment will be needed on crop plantation and on oil extracting equipments. Considering the potential number of cattle heads in the farm, the project is totally compatible and environmental costs for C abatement will be substantially reduced.

Social Aspects

With full power generation, this project would generate some hundreds jobs if we include the agroindustrial jobs.

CO2 Abatement Cost

Baseline GHGs emission and CO2 and N2O abatement effect

Assuming as mean GHGs emission from the Alta Floresta diesel generators 0,91 tons CO_2/MWh and 0,18 kg—N_2O/MWh (see Table 2), and an average generation during a 15-year period of 5.100 MWh/yr, then the baseline emission are 4,6 thousand tons of CO_2/yr and 0.92 tons of N_2O/yr during this period. Considering a 15-year period and an effective zero GHGs emission for the biomass cycle, then the carbon dioxide and nitrous oxide abatement effects are equal to these baseline emission.

Profitability and comparison between project alternatives

To compete with diesel-generated electricity at Alta Floresta, electricity should be produced for approximately 81 USD/MWh. As the energy cost at the consumer door for the corn oil option is only 35 USD/MWh, hence this project seems to be highly profitable. Assuming no net emission of CO_2 by the biomass cycle, the CO_2 abatement cost would be - 46 USD/MWh or - 51 USD/tons of CO_2. Considering the GHG N_2O in the analysis would reduce the effective CO_2 abatement cost by about 4 percent (see Table 2).

Option B - Vegetable Oil from Mamona
We have shown that with the investment of 45.000 in oil extracting facility and USD 300.000 in vegetable oil-powered diesel engine coupled with electricity generators, plus the annual investment of USD 84.300 in mamona crops it is possible to provide 1.000 kW of electricity to the Mogno project.

Electricity cost will average USD 103/MWh which is higher than a similar option using diesel oil as fuel (USD 98/MWh). The cost difference between both options is not properly shown by the final cost of electricity since in both cases 85 percent of the electricity will be acquired from CEMAT at a price of USD 81/MWh.

Considering only electricity produced in the farm, the price difference is more significant - USD 189/MWh and USD 226/MWh, being more expensive for vegetable oil. Furthermore the vegetable oil option creates new employment at the farm. A total of 780 MWh will be generated from renewable sources avoiding 136 tons of C emission per year. The difference between the average costs of electricity produced from mamona oil and from the diesel oil options is 5 USD/MWh; this allows us to calculate carbon abatement costs as 29 USD/tons of CO_2.

Another important aspect of the project and which deserves better discussion with the utility and DNAEE is the possibility of producing all electricity at the meat storage facility.

As already discussed, for some years most of the electricity consumed in Alta Floresta and surroundings will come from diesel based thermoelectric plant (except for a small hydro complex which will be able to deliver 9 MW to several cities including Alta Floresta by 1995). Electricity generated from fossil fuel receives a subsidy of USD 50/MWh, which if transferred to the self-producer can increase preference for full on farm generation.

If the generators installed on the facility will produce all the electricity required (5.100 MWh), the share of non-fuel costs will be significantly reduced, since no further investment on equipments will be necessary. Only the Operation and Maintenance costs (O&M) and the equipment life are different as shown on Table 11.

TABLE 11 - Only self-generated electricity

Investment on diesel motor and generator {I} (USD 300/kW)	300.000
O&M equipment costs (percent)	30
O&M equipment depreciation (years)	5
Interest rate (percent year)	15
O&M equipment (USD/year)	90.000
Investment return (USD/year)	89.500
Annual electricity	
self produced (MWh/year)	5.100
investment return (USD/MWh)	17
O&M costs (USD/MWh)	18
fuel cost {at 355 USD/tons} (USD/MWh)	83
Final electricity cost (USD/MWh)	118

Under this circumstance, electricity produced from vegetable oil will cost USD 118/MWh whih is cheaper than the one acquired from CEMAT (USD 81/MWh) if a subsidy of 50 USD will be provided to the Power Producer.

As the mamona option is much costlier than the corn oil option, we have not considered it further.

SUMMARY

Table 12 gives a short summary of alternatives. Some alternatives present a negative abatement GHGs cost and nevertheless a low likelihood of realization. This contradiction may be explained: Tailandia project was proposed by BUN to the owners of the palm oil factories; and Mogno Project needs also heavy investments on corn plantation and a refining mill which are not accounted in these preliminary estimates.

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