5

Energy Production at Jatobá

23• The Energy Forest as CO_2 Storage

Forests as CO_2 storage facilities

It is not a simple thing to account for the carbon atoms' movements around the globe.

Until recently scientists were still not able to account for 1-2 billion tons of CO_2 out of the 6-7 billions that annually are emitted to the atmosphere as consequence of human activities. They simply could not explain where the missing tons ended. Now it is generally thought that they are stored in forests and soils on the northern hemisphere. This happens because many areas have been transformed to forests since the European and Northern American forests were at a minimum 150-200 years ago. It has thus been measured that the European forests store 400 million tons of CO_2 annually – corresponding to 30 % of the European emissions.[1]

It was earlier thought that only young forests stored CO_2, based on the assumption that old forests were in balance, so that the same amount of CO_2 was emitted by decomposition of organic material (respiration) as was taken up from the atmosphere through the production of organic material in the photosynthesis.

But even the rainforests of Brazil, which have existed for thousands of years (since the last ice age), and which one would assume were in CO_2 balance, are still taking up more CO_2 than they are emitting. This is because of an ongoing production of organic material in the soil. Such a production is even more marked in the cerrado, which has a very large part of its biomass in the soil – 3 to 7 times as much as above ground.[2]

This means, as the calculations later will show, that when a cerrado area is protected against fire and other damages, organic material is stored in the trunks above ground, and especially in the root system below ground, whereby large amounts of CO_2 are stored.

In the long run it is no solution to plant forests in order to neutralize the CO_2 produced by human activity. Sooner or later there are no more unproductive areas that can be transformed to energy forests. But in the coming decades afforestation (planting forest on unforested land) is one of the ways to mitigate the CO_2 problem.

An additional problem is that when the land is cleared in preparation for the plantation, large amounts of CO_2 are released as the organic matter in the soil is decomposed. It is actually calculated that under European conditions the area will emit more CO_2 than it will store during the first ten years, and only then start to sequester (take up) CO_2 from the atmosphere.

When forest biomass is used for energy production, then it is, however, a sure winner. What happens is that a destructive energy consumption is transformed to a CO_2 neutral system. Besides the CO_2 neutral energy, these energy forests also give the possibility of increased biodiversity.

The plantations of Jatobá as a CO_2 sink

Jatobá has assisted in reducing the amount of CO_2 in the atmosphere by developing three kinds of areas:

- 28,000 ha pine plantations
- 8,000 ha eucalyptus plantations
- 10,000 ha cerrado areas that have been protected against fires

This means that nearly one quarter million tons of CO_2 are sequestered annually at Jatobá. This corresponds to environmental benefits worth $1.6 million, if the Danish rate of about $7/ton is used. During the 20 years the plantation has grown, a total of 4.8 million tons CO_2 have been taken up, corresponding to a value of over $32 million.

If one uses the price of $1.14/ton, which the World Bank paid in the Plantar project in the neighbouring state of Minas Gerais (see the chapter on CO_2 trade), then the amount of CO_2 stored in the pine plantation represents a value of $275,000 annually.

Some of the storage of CO_2 is not permanent, since it depends on the use of the biomass. If most of the pine is used for energy production, this gives a direct benefit for the environment, since a

The annual uptake of CO_2 at Jatobá as a result of the activities of the environmental factory	
Pine plantation – annual CO_2 uptake	168,000 tons CO_2/year
Humus in the pine soil – over 20 years	25,000 tons CO_2/year
Eucalyptus – 500,000 tons over 15 years	33,000 tons CO_2/year
10,000 ha cerrado reserves	18,000 tons CO_2/year
Total tons of CO_2, stored extra at Jatobá annually	244,000 tons CO_2/year

Jatobá's pine plantation as CO_2 storage

On average the pine forests of Jatobá grow with 6.5 m^3/ha/year. This corresponds to 3.25 tons, and since half of this is carbon, it means that the plantations of Jatobá, store 1.6 tons carbon/ha/year in the trunks while they grow. This corresponds to 6 tons CO_2/ha/years.

Every year 168,000 tons of CO_2 is therefore stored in Jatobá's 28,000 hectares of pine plantation.

This figure must then be compared to the amount of CO_2 that would be stored if there had been no plantation. The cerrado areas in central Brazil burn regularly and therefore do not accumulate CO_2. This means that one reasonably can assume that the pine plantations at Jatobá annually accumulate 168,000 tons CO_2 more than the area would have done if there were no plantations.

This can be converted into car driving: When a car runs 10 km/l petrol, it uses 0.234 kg CO_2/km. The 168,000 tons CO_2 correspond to the emissions from 718 million km of car driving (18,000 times around the world) or 72 million litres of petrol annually.

Storage of carbon as humus in the soil under the pine trees

The humus content in the soil increases as the pine needles decompose. This is known from all conifer plantations where there is a high amount of humus in the forest soil. These decompose very slowly, which means that carbon accumulates in the soil.

This occurs to a lesser degree in the cerrado areas, even when they are protected against fires, because there are more organisms, especially termites, that decompose the cerrado leaves and do not leave humus.

It is here calculated that a layer of 10 tons needles is formed per ha. Half of this is carbon. That is 5 tons C/ha or 18 tons CO_2/ha.

With 28,000 ha this results in 504,000 tons CO_2 being accumulated in the soil layer.

Divided on 20 years of growth this means that the atmosphere annually is spared a further 25,000 tons CO_2.

The protected cerrado as CO_2 storage

Not only the plantations store CO_2. The cerrado areas also continue their CO_2 sequestration, because they have been allowed to continue to grow unhindered.

Measurements over a number of years on cerrado close to Brasilia have shown that on average 1 ton carbon/ha/year is stored when the area is protected against fires and logging.[3]

This cannot continue indefinitely, but one can assume that it continues for at least 20 years, especially because a large part of this carbon sequestration takes place in the roots. Further proof of this can be found in the permanent measuring plots at Jatobá (described in the Funatura chapter), where the number and size of the trees have increased clearly during the last 10 years.

Since the soils of Jatobá are poorer than in the area around Brasilia, and to be on the safe side, the calculations here use an uptake half the size of Brasilia's. That is 0.5 ton C/ha/year.

Jatobá has about 10,000 ha of biological reserves (about half), which have not been affected by fires since the plantation was established. During the ten years that have passed since the new owners took over Fazenda Jatobá, a further 50,000 tons carbon have, according to this calculation, been stored in these biological reserves – or 5,000 tons C/year.

- *Annually for 1 ha: 0.5 ton carbon = 1.84 tons CO_2*
- *Annually for 10,000 ha: 5,000 t C = 18,400 t CO_2*

As a comparison one can look at what is calculated in the Danish Forestry Plan. The aim is to double the forested area in Denmark over a "forest generation" (80-100 years).[4] 450,000 ha are to be planted. These are calculated to sequester 2.6 million tons CO_2/year. This corresponds to 5.8 tons CO_2/ha/year. This is 3 times more per hectare than the 0.5 ton carbon = 1.8 tons CO_2/ha/year that the calculations above give for the accumulation on protected cerrado at Jatobá.

Jatobá's eucalyptus plantation as CO_2 storage

The 8,000 ha of eucalyptus have on the whole been felled and the major part made into charcoal. The charcoal has been used in the iron industry in Minas Gerais and has thus assisted in reducing the consumption of mineral coal – and thereby reduced the iron industry's CO_2 emissions. Jatobá has on average sold about 25 m^3 charcoal per hectare. This corresponds to 500,000 tons CO_2 that the atmosphere has been spared (because the eucalyptus trees have taken this from the atmosphere while growing, while the coal, which otherwise would have been burned, removed it 200 million years ago).

The eucalyptus plantations have for the last 15 years (they were planted 1988-89) spared the environment of 500,000 tons CO_2 – or 33,000 tons annually.

corresponding amount of fossil fuels will then be spared. If a large part is used for pressure-treated poles and timber, it means that CO_2 is removed from the atmosphere during the lifetime of the trees – 20 to 25 years. It will be stored for a further 20-25 years as poles, until they finally decompose. The result is that the atmosphere is spared this CO_2 during 40-50 years. This is a longer period than the one applying for most of the CO_2 quotas traded today.

The pine plantations on both sides of the reserve obviously accumulate much more biomass than the cerrado areas

The storage of CO_2 in the protected cerrado and in the humus layer of the forest is a permanent environmental asset, as long as devastating fires do not destroy the cerrado, and as long as the humus layer does not burn.

24• Power Production at Jatobá

The World Bank project and Jatobá

The director of Floryl, engineer Lars Jensen, tells about the perspectives for power production at Jatobá:

"When Shell wanted to sell Jatobá in 1992, there existed already long-term plans for a large scale power production. The World Bank had planned a large project and considered to place it at Jatobá. Since Shell was selling the place, it would be up to the buyers of the estate to realize or give up the project.

When I got to know about the project, I started to study biomass technology and especially gasification techniques, and in the start of 1993 I participated in a series of meetings.

We had meetings at the Shell headquarters in London with technicians from the company's department for non-fossil fuels, and with Shell's representatives on the World Bank project, where we discussed the possibilities and the probabilities of getting the biomass project realized at Jatobá.

In continuation of this, there was also a meeting at Jatobá in Brazil.

We met with a delegation from the World Bank, who carried out surveys of Jatobá and the two other possible locations in Brazil, in order to decide the location of the project.

The agenda on Jatobá was the plantation's biomass productivity, the research that had been carried out with various tree species, and a presentation of the best and most productive eucalyptus clones. The infrastructure was also discussed, including a possible connection to the electricity grid, etc.

One of the main obstacles was this connection to the grid, since it would cost about $12 million to make a connection to bring the power the long way to the towns and industries, where it could be used."

The company Floresta Jatobá (Brasil) Ltda., in cooperation with the power company of Bahia and the Ministry of Industry and Development, tried during the years 1993-94 to find partners to establish the power line. Many meetings were held, where the company attempted to find partners.

February 93: Meeting at Fazenda Jatobá with representatives from the World Bank and UNDP, Shell Brazil, the local power company, Floresta Jatobá (FJ) and LEE (L'Energie Eternelle – a French environmental organization). The agenda of the meeting was to clarify the possibilities of placing the World Bank project at Jatobá.

October 93: The World Bank Project committee holds meeting at Jatobá.
November 93: Meeting between FJ and the Minister for Planning in Bahia, to seek to promote a solution to the power connection to the location of the project at Jatobá.
August 94: Information meeting about FJ having received the approval of the government to acquire Jatobá. A formal letter where FJ offers Jatobá as site for the project.
August 94: Meeting with Mr. Waldeck Ornelas, Minister for Planning, Science and Technology in the state of Bahia.
August 94: Meeting with the director of the power company.
Finally in September 94: Answer from the chairman of the committee J.W. Beith with a rejection of Jatobá as possible site.

This meant that the World Bank project was not realized at Jatobá. This was mainly because of the problem with the expensive connection to the public grid, since the power companies at the same time were facing privatization and did not have the funds for such a development project.

Floryl constructs a biomass power plant

Since the large World Bank project did not come off, Floresta Jatobá (Brasil) Ltda. decided to establish a smaller power plant, where known, but not highly efficient, technology was used. This means that the generator is of the kind that has been used for many years, especially in the sugar industry.

The Danish foundation "Fonden til støtte for humanitære formål, til fremme af forskning og til beskyttelse af naturmiljøet" (The Foundation for Support of Humanitarian Purposes, for Promotion of Research and for the Protection of the Natural Environment), which earlier had supported the development of the environmental forest, granted financial support to the power plant through the French organization L'Energie Eternelle. The project's aim is to produce power from biomass, CO_2 neutral electrical energy.

The 1 MW power plant transforms biomass to electricity

With much ingenuity and inventiveness, it became possible to realize this project. The idea was simply to use the waste from the sawmill in the form of sawdust, chips and bark to produce steam for power production and for drying the timber.

Floresta Jatobá (Brasil) Ltda. made a contract with a turbine/boiler company about delivering and mounting a 1 MW power plant, fired with wood chips. This was in October 1994. It was a used boiler from the sugar industry in São Paulo and an Atlas vapour turbine with a generator attached.

With 1 MW of power there would be electricity for the village at Jatobá, for the administration and the sawmill, and even for some expansions.

The work started immediately. Floresta Jatobá (Brasil) Ltda. was to build the foundations for the boiler and the chimney and construct a generator house of 80 m^2.

There were deadlines in the contract for when the various parts should be finished, and there was a deadline for when the power plant should be run in and handed over.

It soon became clear that the boiler company could not meet the deadlines in the contract, and after having built 1/3 of the constructions, they simply stopped. The management of Jatobá had no expertise in construction of biomass-fuelled power plants, but decided to solve the task of finishing the construction of the power plant.

This resulted in more expenses and longer time than planned.

In connection with constructing the boiler, the project was expanded with drying kilns to dry the sawn timber.

One of the problems with the delayed boiler construction was that the production of edge-glued panels, which was planned as an additional income generation, could not start, because the wood must be kiln dried before it can be glued. Export orders on supply of panels to England had been agreed upon, and the machines for the panel production were already leased with monthly payments.

In April-May 1995 the boiler and the turbine were finally ready and could start up with manual firing, since the feeding system of wood chips was still under construction.

More problems arose when the production started. The plant was designed to burn sugarcane stems. They have a large surface and therefore dry and burn easily. When the waste comes into the fuel compartment, it dries quickly and is practically combusted when it reaches the bottom. Wet wood chips, however, act totally different, since wood has much water stored inside the cells. It was therefore not possible to make it burn rapidly. The material piled up along the walls, so that no air came to the combustion. Frequent stops were necessary to remove the unburned residues from the bottom of the boiler. It also resulted in too little oxygen, so the combustion was incomplete.

The power plant had to be rebuilt to ensure a better combustion and received additional funding from the Danish foundation through the French association L'Energie Eternelle. The capacity was increased, so that the production of the power plant could reach 1 MW.

The better combustion was obtained by preheating the air that is blown into the combustion chambers. This was done through a heat exchanger, where the hot smoke from the combustion heats up the combustion air, so that it reaches a temperature of 200° C., where it previously was only 20-25° C.

This has proved to be a very decisive transformation. The hot combustion air means that even wet sawdust can burn directly. This was not possible before, when the fresh sawdust smothered the fire in the combustion chamber.

The improvement has meant a lot for the production in the industries. Earlier the power production was totally dependent on the chipping machine. When there were repairs or stops of the chipping machine, the power production stopped, after the stock of chips was burned.

After the conversion it became possible to use the sawdust directly from the conveyor belt of the sawmill, until the chipping machine was running again.

The system has since then become still more efficient, since also the wood shavings from the pole milling machines can be sent directly into the boiler.

The boiler is now stopped once a month to clean out ashes and cinder from the combustion chamber, and maintenance of the boiler system and the turbine is carried out.

The power plant produces steam for two purposes – for production of power and for drying timber in the drying kilns. The steam is produced in the “heart” of the power plant, the boiler.

This is where the biomass is burned and the tubes, which are located inside the boiler, are heated. The water in the tubes is then turned into steam. Since steam occupies a larger volume than water, pressure is created, and it is this pressure that is used to produce electrical energy. The pressure in the boiler at Jatobá is about 15 atmospheres. It is therefore essential to have very strict safety rules on this facility. The boiler and the tubes are inspected and pressure-tested annually by the authorities.

The steam makes the turbine turn, and this turbine is then connected to the generator. The rest of the steam from the power plant is used in the drying kilns.

The whole erection of the power plant and the power production illustrate the purpose of the environmental factory – to make the commercial and environmental interests go hand in hand.

25• The Power Plant

You can see the power plant from far away. The boilers are looked after day and night, and the white smoke rises up in the air. Close by, one can clearly hear when the steam is pressed out through the tubes under great pressure to make the generator run. The power plant has a very central role in the daily life at Jatobá, and for most people at the Fazenda it has become a natural part of it all. It is here that all the electricity is produced for the industries, the offices and the residences. It is from the boiler that the heat for drying the sawn timber comes. Since the farm is not connected to the public grid, the power plant is so much more important. All the energy supply depends on the production of the power plant.

The fuel of the power plant is the waste material from the processing industries.

The sawdust from the sawmill and the waste from the milling machines at the pole production go directly into the combustion chambers. The waste timber from the sawmill must first be turned into wood chips before it can be burnt in the combustion chamber.

There are three fuel compartments, where the biomass is burned continuously by adding new material and heated air.

The heat is transferred from the fuel compartments to the boilers, where water is added continuously. This water is heated and turned into steam.

This steam is sent under high pressure through the turbine, where the energy is transformed into a rotating movement that runs the generator. This steam supply is regulated, so that the right amount comes to the turbine. This means that it produces exactly the amount of electricity the place needs.

The power plant runs 24 hours a day and is just stopped one weekend in every four, to clean the combustion chambers and to do the maintenance work that cannot be done whilst the power plant is operating.

The power plant is constantly supervised by one of the four operators, of whom one is the main operator. Pressurized steam plants must be treated according to very specific rules to prevent posing any risk. The law therefore requires very strict safety rules – including that the operators have diplomas for this specific work.

The operator regularly controls the temperatures and rotations at the critical locations. At the same time the job requires a constant vigilance towards operational irregularities, as well as a very high standard of maintenance, so that unexpected stops can be prevented.

Steam under high pressure passes through the turbine, which again is connected to the generator

Ten additional workers are attached to the power plant. They work in shifts and carry out the needed manual functions throughout the 24 hours. That is feeding the wood chip machine and doing the necessary cleaning and maintenance in and around the power plant. The power plant's staff also includes three electricians, but they work mainly in shifts with maintenance and expansion of the processing sectors.

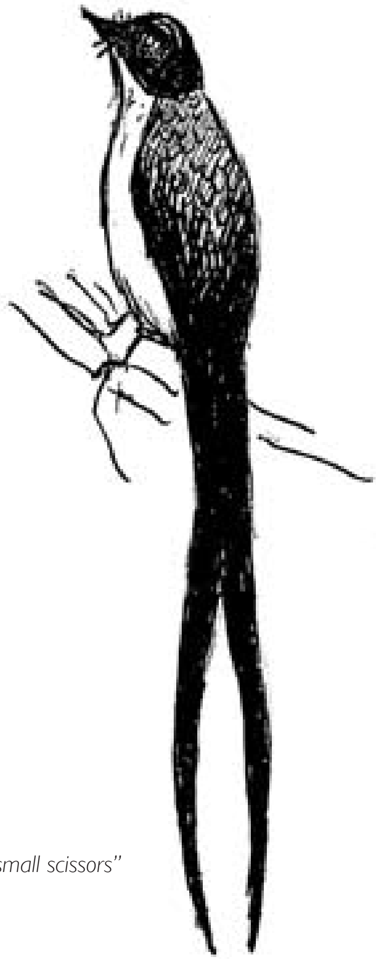
During the hours of production in the industries – that is from 07:00 morning to 03:00 night – there is a nearly constant consumption of 600-800 kW. This is within the 1000 kW capacity of the power plant. During the monthly weekend-long maintenance stop one of the emergency generators is used. At unplanned production stops or during the annual weeklong inspection stop, both diesel generators are used to keep all the productions running.

The processing sections are charged an amount that covers the operation and the maintenance of the power plant. The economy of the power plant therefore ends in zero. In return, the power plant is not charged for payment for the consumed wood waste.

The annual expenses of the power plant are about $125,000.

With a production of 3,750,000 kWh in 2002, this gives a production price of about 0.033$/kWh. This corresponds to the production price at the Danish power plants – that is the expense without calculating the costs of the power grid, CO_2 taxes and fees, profit, etc., which means that the Danish consumers pay over $0.17/kWh.

At the present, the power plant consumes 17,000 m^3 of wood – or 8,500 tons of wood –annually. This constitutes about 40% of the total waste from the processing. The power production is CO_2 neutral, because it spares the atmosphere from the greenhouse gases, which would have been emitted if the power had come from a diesel generator.



tesourinha – "the small scissors"

26• A Future Large-Scale Energy Production at Jatobá

The main idea of the environmental factory at Jatobá has since the start been to establish systems where both commercial and environmental interests are taken into account. A system that can function as a model for how one creates a good development that is sustainable and will benefit both nature and people.

There are numerous places around the world like Jatobá that are located far from the power grid, and where a local electricity production can create development, because it results in jobs in the energy production, while the energy can be used to create new possibilities.

The development of Floryl's activities under the new owners have, as has been described, required a large effort to implement what Shell had started, but not completed. Productions have at times failed, or have proven unprofitable, but today the vision of a large and coherent environmental factory is being turned into reality.

Jatobá is today a small producer of electricity, and the power is used at the industries and accommodation of the place. But work continues to develop the farm to be an exporter of energy to the region.

Brazil mainly uses hydropower for power production. 93% of the country's electrical energy is covered this way. This has been sufficient until recently, but in 2000 people were affected by lack of electricity, when rationing and fines for overconsumption were introduced because of less rainfall than normal. This lasted half a year, until the water reservoirs again were sufficiently full.[5]

The southern and eastern part of the country – that is also the São Francisco valley where Jatobá is located – has no possibility to expand the production from the hydro power stations. The Amazonas region in the north, however, is only using 6% of its capacity.

The problem is mainly a distribution problem, since it is expensive to bring the power to the areas where it is needed. Southern Brazil has under normal circumstances a surplus of energy, but there is no grid to bring it to the central parts of the country. And even though there is much capacity in the Amazonas, it is not profitable to build large power plants, since there is not sufficient demand locally, and it becomes too expensive to transport the power over large distances.

The energy crisis in 2000 started a new way of thinking. The government has for example decided that 10% of the power production must come from renewable sources apart from hydropower, before 2020. There is also a wish to reach the 25 million Brazilians who do not have access to a stable power supply. The arid Northeastern Brazil wants to develop power production from biomass.

The sugar industry has already started. They have traditionally produced their own power from the cane residues, but until now it has not been profitable to produce the power in more efficient ways and to sell it to the grid. This is changing now, and several new projects have started – among those the first project in the world that is recognized under the Clean Development Mechanism (CDM) of the Kyoto Protocol.

Brazil is in the process of privatizing the power production. This will probably lead to higher prices, which again is an advantage for alternative production methods.

The government has introduced a subsidy system, so that it pays to produce electricity instead of using diesel in remote areas. Instead of giving a subsidy to ensure cheap diesel in these areas, the funds can now be used to produce cleaner power.

The power company, Eletrobrás, has transformed a vessel into a factory that transforms plant oil to bio diesel. It sails on the large rivers of the Amazon region and uses oil from the "dênde" palm and other oil palms to produce a fuel that can be used in the generators of these isolated towns. The plan is to gradually substitute diesel as an energy source in 91 local communities.[6]

The future energy production at Jatobá

Production of energy from biomass can in the future be carried out in new ways. The following are some of the possibilities for obtaining energy at Jatobá.

- The biomass can be burned directly, and the energy is used for power production in a traditional turbine or in a Stirling engine. The power is sold through the grid.
- The biomass can be transformed by gasification in a pyrolysis plant into a gas that can be used locally for power production and into a liquid "bio-oil", that can be sold and used as fuel oil.
- The biomass can be used to produce an alcohol – ethanol or methanol. This can then be sold and used as a petrol substitute.
- The biomass can be used to produce hydrogen that can be sold and used in fuel cells.
- The biomass can be processed into briquettes or charcoal that can be sold for power and heat production.

Det er altså ikke på længere sigt givet, at al biomasse fra Jatobá skal komme fra fyrretræer, selv om denne i dag er den langt overvejende energikilde.

Eucalyptus

Eucalyptus is, as mentioned earlier, used a great deal in the charcoal production of the Brazilian iron industry. The productivity of these trees has more than doubled over the last 40 years. A productivity of 90 m^3/ha/year has been reached under optimal conditions with the best clones close to the coast. This development continues. A research project has just started between the largest forest industries and 8 universities in Brazil to develop genetically modified eucalyptus clones that produce even more and are resistant to the most common diseases.

Alcohol

At the start of the Floryl project, experiments were made with cultivation of sugarcane at Jatobá. This was because alcohol had become common as fuel for cars after the oil crisis in 1973. It is still used on a large scale in the country. It accounts for 20% of Brazil's transport energy or 30% of the energy used for cars. It is both used mixed with petrol in conventional engines, and in its pure form in engines that have been transformed.

12 different kinds of sugar cane varieties were tested at Jatobá, and experts from outside were contracted to carry out the research. The results were not good, since sugarcane requires good soil and much water. Even though it rains much during the rainy season, there are often periods of 10-14 days without rain. The plants cannot survive this.

But alcohol can also be made directly from the cellulose of the trees. The most efficient systems use enzymes for this process. The cellulose is split up to units of glucose, and yeast cells then transform these to alcohol.

The Danish Risø National Laboratory has come far with developing this process, and estimates that in a few years it will be profitable to produce alcohol (bio ethanol) for fuel from straw, garden waste and recycled paper.[7]

Another method is to use microorganisms to carry out the process. Probably such organisms have been selected and genetically modified within a few years.

The process will become more profitable if economical uses of the lignin are found. The lignin (wood consists mainly of cellulose and lignin) is even harder to decompose than cellulose.

Other energy crops

Many different energy crops are grown in Europe. Willow trees are cultivated in Northern Europe, but since they are not adapted to periods without water, they are no solution for Jatobá. Elephant grass is cultivated on the Danish island Samsø, and it is one of the productive grass species that can be grown on the soils of Jatobá.[8] They normally require quite a lot of water during the growth season, but that is no problem if they can survive the short periods of drought. They can then be harvested at the end of the dry season, when the straw contains very little water.

Elephant grass is perennial (grows several years), which means that one does not need to replant, once it is established. Planting takes place by using pieces of the roots.

Another highly productive grass is durra. It is more tolerant to drought than elephant grass. Another advantage is that is has a high sugar content that can be used for sugar or alcohol production.

The best solution is probably to choose crops that can be used for other purposes besides energy. Hemp is such a possibility. Under European conditions it produces 3-4 times as much cellulose as forests, and since the fibres are very long, it is in high demand in the paper industry. There is furthermore a big market for fibres for renewable material, for example in the car industry. Many car companies have decided to replace fibreglass and similar synthetic materials with products that can be recycled. Hemp's long fibres are particularly well suited for this. France has started a hemp production on a larger scale, where the fibres for example are used in the building industry. It is a hemp variety with less than 0.3% cannabinol, a substance the plant otherwise is known for. This is the limit set for legal cultivation of hemp plants.[9] Australia is in the process of selecting and developing varieties that can be grown under tropical conditions.

At Jatobá these energy crops should probably be grown together with soybeans – for example in systematically placed strips, such as in the GAIA project where soy and eucalyptus are grown together. An advantage is that these energy crops only become 3-4 m high, and therefore do not overshadow the soy. Another advantage is to use them in a rotation system with soybeans, as the deeper roots of the energy crops will pull up new nutrients to the surface.

Methanol

Methanol is also known as wood alcohol. It is formed through gasification of biomass and a subsequent chemical transformation of the hydrogen and carbon monoxide to methanol.

Methanol can be used as fuel in converted motors. A research project of $1.5 million has just started in Denmark to develop good and efficient systems, so that the engines can use this wood alcohol. The project is part of fulfilling the EU goal that 20% of the transport energy should come from bio-fuels by 2020.[10]

Pyrolysis

Pyrolysis is a process where biomass, in the form of powder, is heated under high temperature without access of oxygen. The 2 mm large particles are transformed to a gas like the one just mentioned under methanol production. Some charcoal is also formed. Most of the biomass, up to 75%, is transformed to a liquid, bio-oil. This is black oil, corresponding to fuel oil, with about half of its calorific value. This oil can be stored in tanks and transported to the large soy processing factories in the region.

A good eucalyptus plantation, such as this 8-year old one, produces 30-40 m^3/ha/year

A power plant has been started in the UK that uses pyrolysis oil as fuel for the 2.5 MW gas turbine generators.[11] A disadvantage of the bio-oil is that it decomposes over time, so it cannot be stored for long periods. The bio-oil is still more expensive per energy unit than mineral fuel oil.

Another possibility is to use this bio-oil for further refining. It does not yet pay to do so because of the cheap oil prices (and the extensive subsidies for this industry). But eventually, as it gets more expensive to extract the mineral oil, and the subsidies to non-renewable energy sources cease, it will be profitable to produce many chemical products from bio-oil. It will then be possible to make a combination, where the most valuable products are extracted, while the rest is used for energy. The valuable substances are for example levoglucosan and furfural, which are used to bind casting sand together.

Cellulignin and furfural

A different utilisation of biomass has been developed in Brazil. The biomass is treated with a strong acid under vacuum in a closed system. The wood biomass is suddenly transformed, so that the cell contents and certain parts of the cell wall are separated explosively from the cellulose and the lignin.

The result is a solid product in the form of a powder – cellulignin. This has a high calorific value and can be used as a "gas" in generators or boilers. It can also be used in the iron industry instead of charcoal.[12]

The liquid part can be used in the chemical industry. It contains furfural, which at the present is imported to Brazil and costs $1,500/kg.

A power plant that uses municipal waste as fuel has been started in the state of São Paulo. It is still a new technology and therefore quite expensive. A 25 MW plant is on the drawing board in Rio de Janeiro, where it will consume 300 tons of city waste daily. It will cost over $20 million.

Gasification

Shell was, as mentioned earlier, part of a large World Bank project with the aim of developing a more efficient transformation of biomass to electricity. This project has been postponed to 2005, but the development of the gasification technology has come a long way since the early 90's. This has partly been done by some of the large companies that were part of the project – General Electric and the Swedish Sydkraft. A commercial efficiency of over 30 % is now possible, and by using special systems where the gas is pressurized, more than 40 % of the biomass energy is transformed into electricity. If the wood gas is used in fuel cells instead, one can achieve more than 50 % efficiency.

A power plant in the US, which produces electricity through gasification of wood chips

It is not a simple thing to get large gasification plants to function, and some of the plants are not working. A paper factory in Pöls, Austria, established a 35 MW plant where it would use the dried and pulverized bark residues from the trees. It was not possible to solve the problem with waste substances in the gas, and the plant is at the present only used for research.[13]

It has, however, become common in Europe with biomass-fired power plants. About 25 % of the biomass energy is transformed into electricity, and a further 60 % of it is transformed into heat.

Since the power plants in the cold climates can sell this heat most of the year, there is not a great interest to develop techniques for a more efficient transformation of biomass into electricity.

Various systems for using the wood gas are in use around the world.

The simplest system is to utilize the gas in a conventional combustion engine, where it is mixed with diesel for use in diesel generators. 80 % of the fuel can here be gasification gas. Or it can be used in pure form in gas engines. Such systems are commercially available in India, for example by the company Ankur, and are used increasingly.

A gasification system has operated in the Danish town Harboøre since 1993. The plant is a 4 MW heating station for 600 households, and it uses wood chips as fuel. It has since been extended with 1.5 MW gas generators for power production.[14]

These systems have in common that the gas must be cleaned of the tar that is produced when the wood is heated.

Gasification and the Stirling engine

Most of the research within utilization of biomass for power production is related to large heat and power plants, where traditional steam turbines are used. These turbines, however, are not economically feasible for plants smaller than 1 MW, and research into other technologies is needed here.

There are two technologies that are suited for decentralized energy production – gasification and Stirling engines.

Both of these are still in the development phase, but it seems that there are advantages by combining the two systems, since this results in a more efficient use of the biomass.

The Stirling engine is a heat pump, which has been known since the beginning of the 19th century, but it has never made a commercial breakthrough. It uses heat from any kind of source. Researchers in Denmark have worked with straw and wood chips, and in 2001 a mini power plant was set up in Salling in Jutland. It produces 35 kW of power and, in addition, heat. It is the world's first industrial facility, combining the Sterling technology with gasification of biomass.[14] A great advantage of the Stirling engine is that the combustion takes place outside the engine. The actual "engine" is a heat pump, which uses hot air as its energy source. This means that various gases can be used to heat up this driving gas. The gas from gasification of wood can thus be used, even though it contains tar and particle residues, which is normally one of the main problems with this technology.

Compared to direct combustion of biomass, gasification has the advantage that one gets a more homogenous fuel. One also avoids ashes in the combustion chamber, which gives fewer problems with corrosion and coatings on the heat tubes. It also makes it easier to control the temperature in the combustion chamber.

A further advantage is that it is possible to utilize wood chips that have not been dried. In the Salling plant, wood chips with 32 % humidity are used. These are quite fresh chips..

Micro turbine

Another promising technology for decentralized production of electricity is the micro turbine. Micro turbines have primarily been developed for use in vehicles. They have not broken through, but it seems that the systems are becoming efficient and profitable for local heat and power production. It is possible to obtain an efficiency of 30 %. This means 30 % of the biomass is transformed into electricity. If the heat can be utilized, it is possible to obtain an energy efficiency of 80 %.

DONG A/S (the Danish oil and gas group) has installed an 80 kW micro turbine at Lynge heat plant on Sjælland. The turbine is supplementing the heat production of the plant, and power is sold to the grid.[15]

An advantage of micro turbines is that they can use various gases as fuels – hydrogen, natural gas, biogas, gasified biomass, etc. This also means that it is possible to use mixed gases, and no expensive cleaning of the gas is necessary.

Another advantage is the low operational costs, compared to conventional gas engines for smaller plants.

They are now testing plants in China where residues from agricultural production are used as energy source for the micro turbines. Electricity and heat is produced, but the gas is also led through pipes to the houses for cooking. It is a good example of local energy production that also creates local development.[16]

The number of examples show that there are many possibilities for developing biomass energy further, and there is no doubt that much research pointing forward within biomass energy will be started during the next decade. It is therefore probable that completely new opportunities will result in even more efficient uses of the natural resources of Jatobá in the future.

Advantages of energy production from biomass

List of environmental benefits by producing energy from biomass:

- The energy crops protect and improve the soil, since these add organic material, reduce wind and soil erosion, and retain nutrients.
- Perennial energy crops have less impact than annual crops, since they stabilize the soil and the water movements.
- Energy crops reduce water pollution, since they need few or no chemicals.
- Perennial crops can reduce floods by creating a permanent plant cover and a network of roots, which promote infiltration of water.
- Perennial crops provide better living condi-

Overview of various kinds of biomass fuels – advantages, disadvantages and production prices			
Biomass	**Advantages**	**Disadvantages**	**Production price**
Eucalyptus, perennial, possible w. 2-3 times re-growth	Known technology, many experiences, also at Jatobá	Not yet solved how to obtain high production at Jatobá	$63/ton (dry) (figures from Hawaii)
Pine, perennial, must be replanted	Known technology, many experiences, also at Jatobá	Low production under Jatobá's conditions – 10 m^3/ha/year	$36-72/ton (wood chips, Denmark)
Leguminous energy trees: acacias, leucaena and local trees – many shoot again (coppice forest)	Known technology, can be grown together with soybeans without overshadowing	Not yet solved, which species can grow at Jatobá, and how they can be cultivated	$99/ton (figures from Hawaii – under irrigation)
Elephant grass, perennial	Can be grown together with soybeans without overshadowing and as part of rotation. The plants dry during the dry season, so that they are easy to use as fuel. Quite resistant towards dry periods	Few experiences under subtropical conditions	$45-90/ton
Sorghum, annual	Very drought resistant. Cheap to sow. Many experiences with subtropical cultivation. Seeds and stalks with high sugar content – for alcohol production	Not tried under Jatobás conditions	$63/ton (Spain – with irrigation)
Artichoke (cynara)	Perennial oil from seeds, drought resistant, cheap to produce	Not tried under Jatobás conditions	$32/ton
Hemp	Many uses – for building material, fibres, etc.	Few experiences with hemp under subtropical conditions, and only few varieties without THC (hallucinogenic)	$100/ton

Overview of direct jobs, created by production of 1 TW energy (1 million MW)	
Sector	**Jobs (person-year/TWh)**
Oil	260
Coal	370
Nuclear power	75
Wood biomass	733 – 1.067
Hydropower	250
Mini hydropower	120
Wind power	918 – 2.400
Solar panels	29.580 – 107,000
Alcohol from sugarcane	3.711 – 5.392

The reason for the large figure on solar panels is that they are sold in small units, typically of 100 W. Installation and maintenance of 10 million units therefore requires many people.

The figures on alcohol production are from Brazil, where much manpower is used in the sugar plantations[17]

Advantages and disadvantages of various biomass energy systems		
Energy system	**Advantage**	**Disadvantage**
Alcohol from biomass	The product can be used as fuel for vehicles Easy to transport	Still too expensive to produce from cellulose, but more efficient micro-organisms are continuously found
Methanol from biomass	Will possibly also become usable for cars The technology is known	Still not a system for methanol to be used in car engines
Pyrolysis	The bio-oil is easy to transport and has many uses Charcoal and products for chemical industry are also produced	Expensive establishing cost
Gasification – power production	The technology is now well developed and used 40% of the energy is transformed into electricity	Still not developed economical use of the heat besides heat power plants where the large heat amounts can be sold
Stirling engines	Can use any kind of heat source Fewer demands to a clean gas, since the combustion is external	Still few examples of viable Stirling systems
Micro turbines	Can use many kinds of gases and has few demands for gas cleaning	Still a new technology and expensive to install
Hydrogen production	Many uses – fuel cells, combustion, industrial uses	Storage systems still being developed

Annual yield of energy crops (tons of dried biomass/hectare)			
Country	**Crop**	**Present**	**Future**
UK	Willow and poplar	10-15	15-20
UK	Elephant grass	15-30	
Greece	Sorghum (durra), artichoke	22	30
Brazil	Eucalyptus	10-20	40
Australia	Eucalyptus	20-30	
USA Midwest	Willow clones	13	20
	Switch grass	13	20

Area necessary to produce 1 EJ[1)] annually				
Energy source	**Specification**	**km²/EJ**	**million km² / 420 EJ[2)]**	**% of global land area[3)]**
Solar power	15% efficient solar panels	1.900 – 3.600	0,8 – 1,5	0,6 – 1,1%
	Production of hydrogen by electrolysis of water	3,000	1,3	1,0%
Wind		17,000 – 25,000	7,1 – 10,5	5,4 – 8,0%
Biomass	Energy forest	19,000 – 48,000	8,0 – 20,1	6,1 – 15,4%
	Methanol	50,000 – 120,000	21,0 – 50,4	16,1 – 38,6%
	Ethanol from sugar cane	32,000	13,4	10,3%
	Durra (sorghum)	20,000 – 47,000	8,4 – 19,7	6,4 – 15,1%

1• E means Exa – 10^{18}

2• The global energy consumption in 2001 was 420 EJ

3• % of the global land area to cover the energy consumption of 2001

tions for wild animals and plants, since they attract a larger number of species – especially birds and smaller mammals.
- Energy crops reduce the emissions of greenhouse gases as well as sulphur and heavy metals.
- Energy crops improve bare and deforested areas.

List of societal benefits:
- Creates local development when the power plants are placed where the biomass is produced.
- Creates a large number of jobs.
- Diversifies production by introducing an additional crop.
- Reduces migration to the cities.
- Strengthens the local economy.
- Saves on foreign exchange.

List of energy related benefits:
- Diversifies the energy supply – and therefore reduces the risk of price manipulations or lack of supply of raw material.
- Less vulnerable to breakdown – such as the one in Northeastern US, August 2003.
- Increases the national security of energy supplies.

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