# Issues in Developing a Central Drying Plant for Isolated Amazonian Systems: The Case of Pólo 70 in Rondolândia (MT)

***Alan Poole, INEE - March 16, 2003***

As part of the project *Generation from Sawmill Residues in the Northwest Region of Mato Grosso State* supported by the UNF/UNDP, a pilot plant for electricity generation was proposed for the cluster of sawmills known as Pólo 70, in the município of Rondolândia in Mato Grosso. This project seeks ways to exploit the energy potential of wood industry residues in ways that support sustainable forestry and contribute to the sustainable economic development of the frontier region.

The cluster in Polo 70 is relatively small. Nine sawmills currently cut 49,600 $m^3$ of logs per year. More information on the project and the choice of the site can be found in the Executive Summary of the report: *The Energy Potential of Wood Industry Residues from Wood Produced with Sustainable Forest Management Practices.* [1]

A key aspect of the proposed pilot plant is that it combines electricity generation with a centralized service for drying the planks produced by the sawmills in the cluster. The centralized provision of drying services linked to power generation is the most innovative aspect of the proposal in technical terms. To our knowledge, this approach has not been tried before anywhere in Amazônia – though its components have been tried separately.

In the pilot project as defined in the report, it is assumed in the baseline scenario that the central drying plant begins by drying ½ of the of sawn wood produced in the cluster (currently 24,800 $m^3$. This rises to 65% in the second year and 80% in the third year. The volume of wood sawn by the same mills increases to 33,480 $m^3$ in the third year, due to operational changes that the on-site drying allows. By the third year, the central drying plant would have a kiln capacity of 950 $m^3$, divided in 19 modules of 50 $m^3$ (other combinations of module size are possible). The report also presented a scenario of “accelerated drying”, where all sawn wood is dried by the third year. The financial results of the combined electricity and drying plant are significantly improved in the second scenario.

The issues involved in a central drying plant were dealt with in a summary way in the report to the UNDP cited above. Given the novelty of the business concept and the key role that the central drying plant has in the proposed pilot, it is useful at this stage to review in more detail the issues raised. These include:

1. Review of oven drying process technology
2. The impact drying capacity in Polo 70 on the dynamics of the development of this cluster of sawmills.
3. The choice between decentralized and centralized drying capacity in the cluster..
4. The choice between cogeneration and parallel generation of steam and electricity
5. The competitiveness of kiln drying in the Polo 70 cluster & impacts on transport costs
6. Possible new optimizations of the package if idea shows success

This paper reflects work done throughout the project and especially the results of a field visit to Ji-Paraná and Rondolândia made during December 3-6, 2002. The team was led by the author, Alan Poole. It included Jandir Marinelli of Benecke - a company which manufactures and installs wood drying systems - and Pericles Pinheiro of INEE. Mr. Marinelli evaluated existing and potential sites for wood-drying systems designed by his firm. Mr. Pinheiro measured electrical loads.

A second visit to the region is planned soon. This paper is part of the preparations for this mission. It raises some questions that hopefully can be addressed locally. Annex **B** summarizes issues and information needs which should be addressed in future missions to the region as the project is developed.

## Kiln drying technologies

Much of the sawn wood is dried or partially dried in sheds or the open air – as shown in the photos in Annex **A**. It is generally agreed that for the cluster to consolidate and add value on-site, it is necessary to introduce

[1] The Executive Summary of the report is available in English and Portuguese on INEE’s website: www.inee.org.br.

drying kilns. Two main kinds of technology are used for drying in kilns – one using hot air produced in furnaces; the other using steam. Examples of both kinds were visited in Ji-Paraná.

| **Sawmill** | **Total Capacity**<br>Total $m^3$ of drying volume | **Configuration**<br>Units x $m^3$ of drying volume | **Heat supply for drying** |
|---|---|---|---|
| **A** | 400 | 4 x 100 | Steam boiler |
| **B** | 120 | 4 x 30 | Hot air furnace |
| **C** | 480 | 4 x 60 (rail wagon) and 4 x 60 | Hot air furnace |
| **D** | 300 | 6 x 50 | Steam boiler |

Hot air furnace systems are cheaper to build. The simplest one, constructed with brick with an accompanying "kit' (Sawmill B) is appropriate only for certain species of wood with less demanding requirements for drying. Sawmill C, has a more sophisticated hot air kiln system, but is planning to switch to steam as part of investments on expanding drying capacity. Drying with a steam system assures better quality and uniformity of drying and is faster (the temperature inside the kiln is higher).

The steam drying systems visited have automatic control of operations and conditions in the kiln, which assists quality assurance and permits complete reports on the conditions over time of each batch (useful when providing a third party service).

In designing the project for financing it was believed by the team that the additional investment for a steam system was well justifiable. Increased service quality, reliability, transparency of reporting to the client and throughput are together a powerful set of reasons for this choice.

Photos of the different systems are shown in Annex **A**.

For fuel, the hot air furnace systems tend to use larger pieces of residues. The furnaces are manually fired as shown in the photos. Efficient boilers for steam systems prefer sawdust, shavings and finer residues. In Amazônia you find all kinds of different arrangements for boilers (often ancient), with manual feed of residues of all sizes. These precarious systems are typical of a capital starved & resource rich industry. However, some firms already use more modern steam generation technology. Such is Case D above, a firm which provides third-party wood drying services in Ji-Paraná (see photos).[2]

There are two approaches to stacking planks in the kiln. The most common is to move pallets of stacked planks with a front-loader. Some ovens use wagons on rails for loads with planks varying widely in size.

Drying is quite an energy intensive process – both in relation to the thermal energy used and the electrical load. The modern steam kiln system manufactured by Bernecke, for example, requires 350 kg steam/hour @ 8.7 atmospheres of pressure (174° C) for a module with capacity for 50 $m^3$ of stacked wood and 13,2 kW for the motors that drive the fans and pumps.

Assuming an average batch time of 10 days,[3] the energy requirement is 1,68 ton of steam and 63.5 kWh per $m^3$ of sawn wood dried. The average electricity consumption per $m^3$ of sawn wood is actually substantially higher than the electricity used to saw the wood planks - estimated to be about 40.6 kWh per $m^3$ in the Polo 70 cluster. This high electricity consumption represents a substantial barrier for installing kilns in isolated systems. Nowhere in the study area of Northwest Mato Grosso did the team find any sawmill using diesel generation. The relatively small number that have driers generate their electricity from wood residues.

[2] The experience of this firm, with which no interview was possible during the field visit, is clearly relevant to the proposed pilot project.

[3] Batch time varies with the species of the wood. Apparently the kilns can achieve somewhat shorter batch times for the longer to dry species that are common in the region. Ten days is thus probably somewhat high – conservative values were used to increase the robustness of the economic analyses and conclusions.

## Impacts of drying capacity in Polo 70 on the dynamics of development of the cluster

It was generally agreed by all sawmill owners visited that kiln drying is an essential step to add value and is crucial for the consolidation of Polo 70. Without drying it is impossible to add further value on-site to the basic sawn timber. More generally, it was repeated that there is a clear improvement in the quality of the product if the wood is kiln dried on-site.

Kiln drying is also a pre-requisite for the most profitable export markets and is increasingly required in the domestic market. There is thus a price differential between wood that is kiln dried and that which is not. As key consumers of exported products become more demanding (which they surely will), there may be more attention to whether the wood was kiln dried.

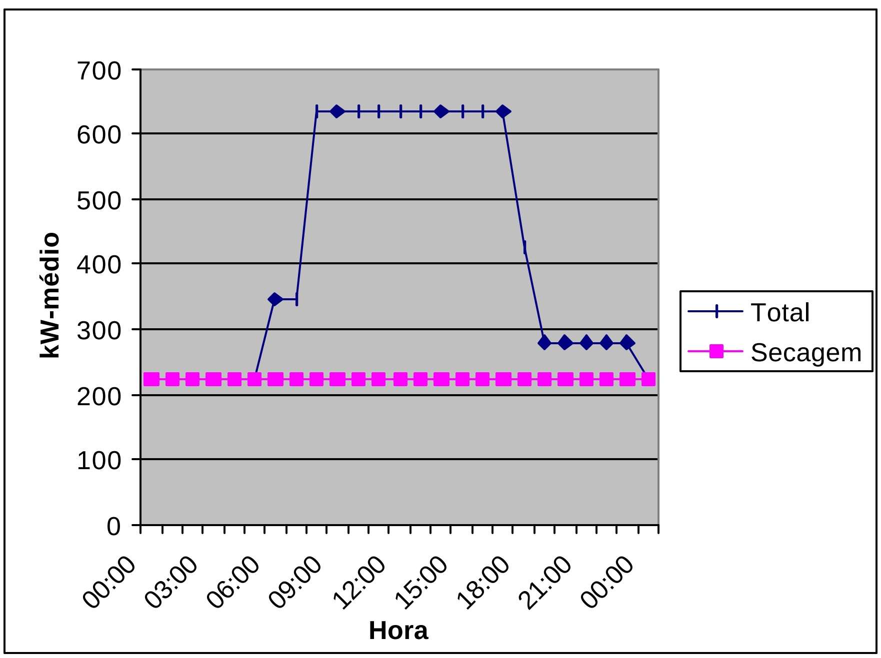
On-site kiln drying will permit (together with adequate electricty supply) the transfer of most of the next step of processing planks, especially the planing of the rough planks and some special cuts.

### *Impact on the electricity supplier*

Drying vastly improves the "load curve" of the generator compared with only supplying sawmills` electricity needs. Figure **1** illustrates the impact on average electricity demand/hour of drying all the planks produced by the sawmills in the cluster, relative to the sawmills' own demand. The load for drying is relatively continuous.

To the extent that drying capacity in the cluster leads to more wood processing on-site, the load profile should further improve. The availabliity of residues will also increase. These residues have signifcantly higher heating value since they are dry

**Figure 1 – Simplified Daily Load Curve of Polo 70 Cluster & Impact of Drying all Wood on the Electrical Load**



If the drying is done in a central plant, together with the electricity, there is an additional set of technical and economic advantages for both the electricity and drying services – as described in the next section. This synergy makes a combined plant more economically attractive than either alone as discussed in the Executive Summary of the project.

## The choice between decentralized and centralized drying capacity in the cluster

While the capability to dry wood at Polo 70 is clearly a pre-requisite for consolidating the local industry on sustainable terms, it is less obvious that centralizing the drying service in the cluster is the way to go. The usual approach is for each sawmill to install its own kiln, which is seen as a key step in the industrial process. The kilns themselves are also essentially modular, with small economies of scale above a relatively small size (perhaps 100-200 $m^3$ of capacity).

The outcome of a decentralized approach could well be a mix of hot air drying and steam drying systems, since the investment for a hot air drier is substantially less. At the same time the penetration of drying would probably be slower and more erratic, providing a less certain electricity load for the generating plant.

Assuming steam is the preferred option, there are large economies of scale in this size range (where even the central plant may be relatively small – say 15-25 tons/hour). In the case of the Polo 70 cluster, the investment for 9 small boilers would be several times higher than for one larger boiler. Then there are the operational costs and headaches for the sawmills' owners in order to run their individual systems.

The tradeoff is with the logistical changes brought by the central drying service. Soon after the planks are cut, they are stacked with interstices for the natural circulation of air. In sawmills with their own kilns the distance travelled by a front-loader would rarely be more than 200 meters. With the proposed central drying service, the sawmills would deliver planks for drying over a distance of up to 2-3 kilometers, in the case of the Polo 70 cluster.

The most efficient response would be a "just-in-time" collection system, with stacking for drying done promptly at the central plant. The pilot project already envisages a tractor-driven scheme with periodic collection of residues from each participating sawmill. A similar approach could be adopted for wood being delivered for drying. This combination should reduce the cost of both services. It will be important to have a spacious shed where each sawmill's input for the kilns is prepared. Appropriate stacking should be done rapidly after delivery.

To be able to join together in one drying batch timber from several different sawmills could be a great advantage for a central drying plant. Sawmills typically cut various species of wood. Each species has its optimum drying conditions and time. The joint drying of several mills' products in one kiln will require (a) clear demarcation of property; (b) trust and transparency of the service providor. In the pilot project, it is recommended that the sawmills buying the electricity/drying services participate as well with their own risk capital. As co-owners, transparency should be guaranteed for the vigilant.

As work has developed with this pilot project in Polo 70, it has become clearer that their equity participation in the SPC formed to generate electricity and provide drying services is essential. That share need be only ~10% of the total investment. That represents a revolution in financing their industrial expansion and is also a considerable "carrot" to require sustainable forest mangement.

The advantages of concentrating electricity generation for the Polo 70 cluster from wood residues is obviious. This adds an additional set of advantages to concentrating the cluster's steam load for drying.

First, by joining the two services in one plant there are large economies of scale for investment and management cost for: (a) the central drying plant's steam supply; (b) materials handling of the fuel residues and perhaps the wood to be dried.

Second, the joint production of steam brings technical/economic benefits for the electricity generator.

- If you have a Rankine cycle wood residue generating plant which uses all its steam to produce electricity, the ability to accompany abrupt changes in load is relatively slow. The sawmill industry is characterized by rapid and often large oscillations in load. The consequence is that the quality of the electricity supplied is degraded, with fluctuations in voltage and frequency which damage motors.

- If a Rankine cycle wood residue generating plant is linked to a plant producing steam for drying, the response time can improve dramatically, because the most limiting factor is the response time of the boiler. Steam can be quickly diverted from the drying process, while the boiler builds up steam output. Power quality is much improved

The steam required for process needs should not be small relative to that for electricity generation for this to work. The more process steam load, the better. Translated that means, the larger the share of drying that is centralized, the better.

## The choice between cogeneration and parallel generation of steam and electricity

If electricity generation and wood drying are centralized in a single plant, using steam from the same boiler, two basic technical approaches are possible.

A. Parallel generation of electricity and process steam. That means using a condensation turbine. This approach is used with some frequency in Amazônia.
B. Cogeneration of electricity and process steam for drying. That means the steam used for process has passed through the power turbine (usually). We are unaware of any example in Amazonia of this approach.

A condensation/extraction turbine for cogeneration (Option B) costs somewhat more than a simple condensation turbine (Option A). However, the extraction turbine is only about 10% of the thermalelectric plant's total cost. At the same time, the peak demand for steam in Option A would be 8.3% higher[4] and the increase in the consumption of fuel will be relatively even larger (10-15%).

It must be emphasized that the cogeneration option analyzed assumes a relatively low steam inlet pressure for the turbine (22 bar – the maximum used commercially in frontier areas) and a process steam pressure of 8.7 bar.

The trade-offs need more anlaysis. However, if you've centralized steam loads for drying (something no-one has done), I believe one would be throwing money away if you didn't use some sort of cogeneration.

It must be remembered that until now, third party financing has not generally been available to sawmill entrepreneurs investing in drying or electricity generation in the frontier areas. They improvise projects, often buying second hand equipment to minimize capital costs. A properly designed cogeneration project with new equipment has not even been an option for the great majority of individual sawmills.

## The competitiveness of kiln drying in the Polo 70 cluster & impacts on transport costs

Third party drying services exist in Ji-Paraná. They provide a useful reference for evaluating the comptetiveness and pricing of the proposed central drying plant in the Polo 70 cluster.

Until now, the great competitive advantage of drying in Ji-Paraná has been the much lower cost of electricity. The driers consume considerable electricity – and until late 2002, the models sold by one manufacturer use double the new designs. That means the weight of electricity costs has been even higher than the values used in the UNDP study.

With the earlier technology in installed plants, the reduction in electricity costs was roughly R$ 50 per $m^3$ of wood dried.[5] This was a very big advantage for locating in Ji-Paraná.

[4] At 0,176 MWh/t steam condensation plant of 1.25 MW requires 7.1 tons of steam, plus steam for process of 7.2 tons for a total of 14,3 tons of steam. The cogeneration option has a maximum demand of 13.2 tons.

[5] This is a very approximate calculation for illustrative purposes. It assumes 3 batches of wood per month with 125 kWh per $m^3$ of wood dried. The cost of electricity is assumed to be R$ 400/MWh less than in the isolated system with diesel gensets. A range of differences in cost is possible. On the Ji-Paraná side the drier may be connected at a high voltage level – A4. In this case the difference could be even greater as discussed in the text.

With the pilot plant the situation changes substantially. The difference in the cost per MWh falls from R$ 350~450 to zero, or perhaps R$ 100 if the Ji-Paraná plant is connected at A4 instead of at low tension.[6]

In terms of electricity costs per $m^3$ of dried wood, the difference falls even more dramatically (probably at least by 90%), since the new drying technology uses half the electricity of the existing systems. Indeed, compared to existing drying plants in Ji-Paraná the electricity cost per $m^3$ of dried wood could be less at the Polo 70 cluster – irrespective of the voltage of connection. This strngthens near term competitiveness of on-site drying in the cluster, though this additional technological advantage would not apply when compared to new drying plants in Ji-Paraná.

In principle, on-site drying in the Polo 70 cluster results in significant gains in transport costs, which in turn improves competitiveness. This point was frequently made in local interviews. However, it has proven difficult to make a quantitative estimate.

It was very roughly estimated to cost about R$ 20-25 to transport a ton of cargo to Ji-Paraná. There was considerable discussion of whether transport cost is set by the volume of the product or the weight. This can be influenced by the way the load is stacked – but the basic limit seems to be weight. This is different from the transport of logs to the sawmill, which is charged by volume (probably taking into account the species).

With drying there certainly is a reduction in weight per $m^3$ of wood. The degree of reduction varies with the species. For example: *Angelim pedra* falls from 1250 kg/$m^3$ as sawed to 780 when dried. Ipê, which is denser and has finer fibres, falls from 1250 kg/$m^3$ to 900.

The additional on-site beneficiation permitted by drying further reduces both the weight and the volume transported. Full processing to final products as shipped today from Ji-Paraná would imply a reduction of as much as one-half. Though processing may not go so far in the cluster – the impact on relative transport costs could clearly be significant.

A possibly important factor influencing the relative transport costs is the effect of a drying-cum-beneficiation strategy on the way loads are stacked on trucks. Tighter packing could remove volumetric constraints on the loads compared with current practice – if these constraints exist. More information is needed on this point.

In summary, while transport gains may not in the past have been sufficient to overcome the electricity cost disadvantage of on-site drying at Polo 70, they do exist. With the dramatic reduction or elimination of the electricity cost advantage of Ji-Paraná, transport gains become decisive and need to be better evaluated. We don not believe differences in other costs will be significant in the choice.

[6] The Brazilian electricity rate structure strongly favors higher voltage consumers. Consumers thus try to connect at the highest voltage possible.

## Possible new optimizations of the package if the basic idea is successful

We believe it is important to emphasize an "evolutionary" approach to this market segment which concentrates on commercializing improved steam turbine technology. R&D in this general area tends to be oriented towards "revolutionary" solutions, usually involving the development of systems based on the gasification of biomass.

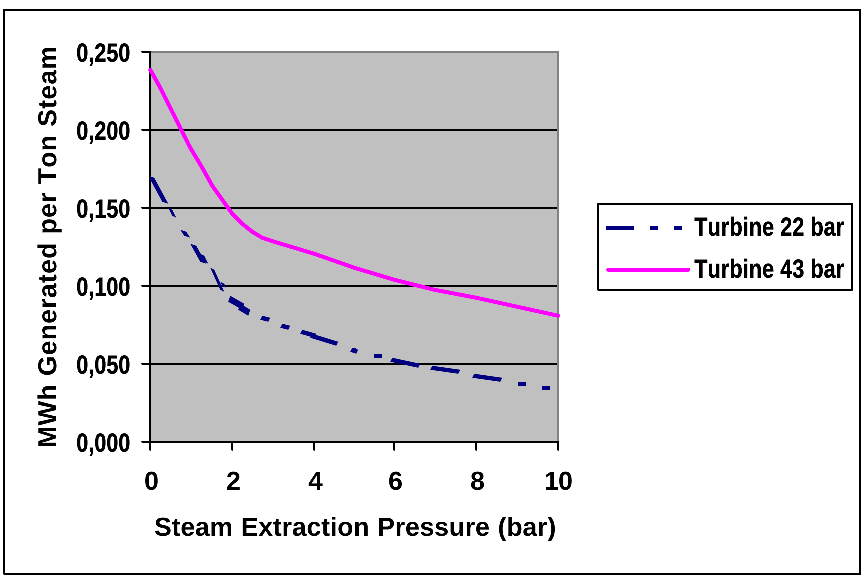
While systems of electricity generation based on gasification are interesting in Amazonia, they do not appear to be a priority for this segment. There are two broad alternative approaches using biomass gasification

- Open-cycle gas turbine systems – These generate more electricity per ton of steam, but the commercial scale tends to be too large and the technology too complex for use in most clusters.
- Internal combustion engine (usually diesel cycle) systems - These generate even more electricity per ton of steam and in principle, could be commercialized in this size-range. However, they are unable to produce process steam at the necessary temperature for the commercial drying process (~175° C). They would only be interesting if drying temperature needs were reduced to ~120° C. In any case, this technology is still very complex operationally to use in this segment.

The most interesting technology for a "revolutionary" approach could be closed-cycle gas turbines. These have a furnace which can use any fuel and a heat exchanger. The big attractions of the system are its simplicity of operation & maintenance as well as possibly faster turbine response to load changes. Unfortunately, almost nothing is known about this alternative. In the late 1980s a package system of 500 kW was commercialized by a US firm, but does not appear to be available today.

Following the evolutionary strategy, a key advance would be to use higher pressure turbines at smaller scales. For cogeneration systems the electricity generated per ton of steam doubles if the next commercial level for boilers - 43 bar - were adopted with existing drier technology (extraction @ 8-9 bar), as illustrated in Figure **2**. In this graph,

**Figure 2: Approximate Relation of Electricity Generation to Turbine Entry and Extraction Pressures**




Another approach to consider would be to reduce the temperature and steam pressure of the wood drying process – also illustrated in Figure **Y**. This would also increase the electricity generated per ton of steam. In southern Brazil, a new cogeneration plant with wood drying substituted steam drying with pressurized hot water. However, the wood species are different, so this design cannot necessarily be extrapolated.

The trade-offs regarding operating temperature level for kilns in the Amazon region deserve evaluation in detail with a manufacturer of drying systems. The value of a shorter turn-around time will be a key factor.

Until now, manufacturers of drying systems have not felt the need or challenge to optimize a system using cogenerated steam. This has not been a serious commercial option. However, they have already demonstarted creativity. In the aftermath of the electricity supply crisis, one manufacturer (Bernecke) reduced the electricity consumption of its new models of kiln driers by half.

The residues from the basic processing of logs have a relatively high moisture content. Use of kiln capacity to dry fuel would significantly increase its lower heating value, as shown in Table **M**.[7]

**Table M : Relation of Moisture Content to Heating Value**
Generic average for native species

| Moisture Content (%) | 9% | 16% | 23% | 28% | 33% | 37% | 41% |
|---|---|---|---|---|---|---|---|
| Lower Heating Value (kcal/kg | 4100 | 3750 | 3400 | 3000 | 2790 | 2600 | 2450 |

It is possible that given, the existing infrastructure for drying, the marginal cost of drying would be quite low.

7 In the UNDP report the lower heating value was assumed to be 3000 kcal/kg, which may be optimistic, especially in the rainy season.

## ANNEX A: Photos of the Drying Systems in Four Sawmills in Ji-Paraná

### Case A

**Overview of four 100 m$^3$ drying modules.  Product finishing line is in the same shed to the left**

**Product finishing line in shed with driers**

**Stacking in a 100 $m^3$ drying module**

**Residue handling and boiler**

## Case B

**Stacked wood in drier of 30 m$^3$ volume**

**Hot air drier with furnaces and control system**

**Fuel bins for furnaces**

**Residue collection – incinerator in background**

## Case C

**Loading the kiln**

**Kiln with rail wagon system for loading and stacking (under construction)**

**Manually fed furnaces for air drying system.  Fuel is dry blocks cut in semi-finishing.**

**Sawdust collection – site for future boiler**

# Case D

**General layout of six driers**

**Stacked wood in 50 $m^3$ drier**

**Boiler general view**

**Boiler feed**

## ANNEX B – Points to Consider in Next Field Visits

- Accompany temperature in Case B "kit" drying kilns.
- Improve information on drying time by species. Variation with season?
- Obtain a printout of a run with with Bernecke controls. Calibrate with our own measurements?
- Obtain more information about the third party price for drying.
    - Interview Case D about business experience
- Possible price differentials for kiln dried wood.
    - The evaluation of the increased value of oven-dried wood we heard is distinct from that given by Orlando of IPN
- Some residues may have market value with appropriate equipment. Would a plant centralizing residue collection be well-placed to make this investment and run this operation?

- Logistic issues for central drying service:
    - If planks are stacked at the sawmill with air interstices, is it feasible to transport them at low cost to the central drying plant?
    - Is it possible to conceive a "reverse just-in-time" system of sawed planks? That means: (a) the sawmill leaves the sawn wood in compact stacks which are soon delivered to the central drying plant; (b) the delivered planks are rapidly assembled in stacks with air interstices at the central drying plant for short-term storage; (c) stacks of wood are separated by species (or other drying criteria) and stored under a shed until they are introduced as distinct lots in
    - Handling of residues used for boiler fuel – how are larger pieces handled (chipped?)

- Longer distance transport issues:
    - How is wood stacked today for transport from Rondolândia to Ji-Paraná? (air interstices?)
    - Is the price of transport for stacked wood fixed by weight or by volume?
    - What is the current cost of transport to Ji-Paraná per ton or $m^3$?