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INTERNATIONAL TROPICAL TIMBER ORGANIZATION

ITTO PRE-PROJECT PPD 66/02 (I)

Increasing Timber Processing Utilization Efficiency and Reducing Waste

Final Report

Prepared for ITTO

by

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ABBREVIATIONS AND ACRONYMS

a	annum, year
ANAFOR	Fund for the Assistance to Forestry Development in Cameroon
°C	degrees Celsius
C	carbon
CEMAC	Economic and Monetary Community of Central Africa
CERNA	Industrial Economic Center (Ecole des Mines de Paris)
CH_4	methane
CINU	United Nations Center for Information
CNUCED	United Nations Center for Commerce and Development
CO	carbon monoxide
CO_2	carbon dioxide
CRESA	Centre Regional d'Enseignement Specialisé en Agriculture
ERA	Environment Research Action in Cameroon
FAO	Food and Agriculture Organization of the United Nations
FMU	Forest Management Unit
FOB	Free On Board
FOC	Free Of Charge
GFBC	Groupement Filière Bois (Wood sector association)
GJ	gigajoule
H_2S	hydrogen sulfide
ha	hectare
HCl	hydrogen chloride
IBAMA	Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais Renováveis ("Brazilian Institute of the Environment and Renewable Natural Resources")
IMP	Industrial Master Plan
INEE	Instituto Nacional de Eficiência Energética ("National Institute of Efficient Energy")
INPA	Instituto Nacional de Pesquisas da Amazônia ("National Research Institute of the Amazon")
ITTO	International Tropical Timber Organization
kg	kilogram
kPa	kilopascal
kW	kilowatt
kWh	kilowatt-hour
m^3	cubic meter
m^3_n	normal cubic meter (1 m^3 at 101.325 kPa and at 20°C)
MDF	medium-density fiberboard
MED	Minimum Exploitation Diameter
mg	milligram
MINDIC	Ministry of Industrial and Commercial Development
MINEF	Ministry of the Environment and Forestry
MINEFI	Ministry of the Economy and Finance
MINMEE	Ministry of Mines, Water and Energy
MIPROMALO	Local Materials Promotion Authority
MJ	megajoule
MMG	Mba Mba Gregoire (sawmill)
MTIB	Malaysian Timber Industry Board

MW	megawatt
MWh	megawatt-hour
MYR	Malaysian ringgit
N	nitrogen
NaOH	sodium hydroxide
NO	nitrogen oxide
NO_x	nitrogen oxides
O_2	oxygen
ONADEF	National Forestry Development Authority
OTU	Operational Technical Unit
PAD	Port Autonome de Douala (Douala Autonomus Port)
SEPBC	Société d'Exploitation des Parts a Bois du Cameroun
SFID	Société Forestière et Industrielle de la Doumé (sawmill)
SFM	sustainable forest management
SGS	Société Générale de Surveillance
SIGIF	Computer System for the Management of Forest Information
SO_2	sulfur dioxide
t	tonne, 1 000 kg
TIB	Transformation Intégrée du Bois (sawmill)
UPFI	Industrial Free Trade Zone Factory
USD	United States dollar

EXECUTIVE SUMMARY

Many ITTO producer member countries are facing a multitude of challenges in the sustainable utilization of their forest resources. Only a few countries can continue to build their future strategies in forest industries on a foundation of abundant or growing resource base. On the contrary, most producer countries are facing constraints in the long-term availability of natural tropical wood. Some members are even facing acute shortages and severe sustainability crises. Making more out of less is therefore becoming a common advice for tropical countries. An important educational task is foreseen: to **shift attitudes** into a more prudent resource-consciousness, **efficient utilization** of wood into higher added value products and damming the unutilized **waste streams** away from damaging the environment into novelty product flows.

In order to capture the entity of the problem, it is necessary to acknowledge that the **forest policy frameworks** are often unintentionally encouraging wasteful utilization. This is demonstrated in the following ways:

1. Fiscal reforms practiced for **short-term increase of tax revenues**, but leading to long-term damage to sustainable forestry, are a disaster for the forest, the national forest economy and the private forest product industry.
2. If the price of a natural forest resource climbs too high in auctions, concession holders are forced to **"cream" the forest**. This means the leaving of lower-grade trees standing, or abandoning a felled tree in the forest when it shows too many defects (cracks, rotten hearts, etc.). The same goes for disproportionately high fixed surface taxes. Both lead to an unnecessary waste, which can only be reduced by an **appropriate taxation system -** a flexible one.
3. **Forest management plans** stipulate the **minimum diameter** of harvestable commercial timber species. This diameter depends on forest inventories and research results. If the minimum diameter is too high, a great part of logging potential is immediately excluded from the interest of the logger. If it is too low, the yield decreases and produces high level of waste.

Careless utilization is unnecessarily common **throughout the entire supply chain** of tropical wood products. It starts from the forest compartment level. Badly planned logging operations leave behind unacceptable amounts of waste wood, part of which could be recovered for the manufacture of small-dimension wood products, engineered wood products, reconstituted panels or energy biomass in different forms. **Reduced impact logging** has proven an important success factor for making forestry operations more sustainable. While it was first developed with the purpose of reducing damage to the residual standing trees and the forest ecosystem, it has later on proved to be an economically rewarding and efficient way of conducting logging operations. Improved bucking of logs deserves also a mentioning, as it predetermines much of the opportunities and potential yields for processing at the later stages of the supply chain.

A similar kind of attitude change through better planning would be very much needed in conceptualizing that wood waste from all operations should be considered **a valuable by-product**. It should be utilized to capture its full value thereby contributing to the industry's profitability and competitiveness as a whole.

In the light of the available data, it is difficult to classify the producing countries reviewed in case studies (Brazil, Malaysia and Cameroon) according to the level of development of waste utilization. In each country and region, there is a multitude of production units each having a different capacity, size, adjusted production method, waste management, etc. They are manufacturing similar products of varying recovery rates, quality and prices.

It has to be acknowledged that the data on recovery rates is many times unreliable or erratic in tropical forest industries, what hampers also making valid proposals for improvement. A more **standardized measurement criteria** of both volume and grade recoveries should be established in sawmilling, veneer and plywood production to allow benchmarking for the bettering in the future. Importantly, **standard-measure diagnostic data** of the industries would facilitate the development of technological and process improvements.

Recent **product development** and **upgrading of manufacturing techniques** have focused on more efficient and economic use of wood fiber. Most of the commercially successful product innovations since the 1980s-1990s have been geared towards compensating the decline of large-diameter logs for solid wood and plywood/veneer production. This has brought into stream **engineered wood products** such as LVL (laminated veneer lumber), gluelam beams and I-beams. Finger-jointing and edge-gluing can absorb much of the waste wood in the form of slabs, trimmings and flitch boards. In reconstituted panels, MDF and OSB are greatly contributing to the efficiency of wood fiber usage by absorbing small-diameter logs, sawmill offcuts, peeler cores and other processing waste, or even recycled pallets and wooden packaging waste as raw material. The adoption rate of the innovations leaves a lot to desire in tropical countries, what is obviously due to financial, technical, market-related and managerial problems. Tropical countries still confine too much on production of a narrow range of commodities in a **non-integrated industry structure**, which does not possess much of internal strength to reinvest and modernize itself.

The current situation is deplorable because most of the standard mass wood products are eventually turning into their maturity and decline unless their service life, applicability or environmental appeal is improved through R&D, processing technology upgrading and intense promotion. Faltering demand may be postponed with substitution by low-cost plantation wood for natural (tropical) wood. This strategy is actually in use by countries like Chile and Brazil. These countries seldom introduce any fresh product innovations, but rather push "old" producers off-the hill on demand curve with lower-cost, but quality-mark products.

Instead of just fighting over the last stands in the globalization-driven commodity wood product markets, efficient waste utilization can support tropical producers in embarking on entirely new products. Various product segments, based on small-dimension items were identified including, e.g., garden and decking applications, children's furniture and toys, dowels, mouldings and similarly produced items like parquet panels, furniture components and picture frames. These can absorb processing waste or smaller-dimension wood, and often conceal small quality handicaps. As the dimensions are usually small, this application provides opportunities for efficient use of **offcuts and processing waste**. Painted and primed products are potential outlets for lesser-used species and plantation woods, which could replace higher-value species.

The move on more efficient waste utilization on solid wood products brings in the need for improvements in wood drying, jointing and edge-gluing technologies, as well as in wood preservation and finishing of products. When considering the suitability of solid timber waste for wood products, it is necessary to take into account the following performance criteria:

- grade quality
- engineering properties (density, strength, stiffness, hardness, creep)
- stability
- drying quality (moisture content and drying degrade)
- machining characteristics (planing, drilling, turning and sanding)
- gluing quality
- over-veneering and surface finishing characteristics

A detailed knowledge of these characteristics should ideally guide the whole production process: product design, selection of appropriate materials and tools, selection of most suitable manufacturing techniques and recommendations on intended service (end-uses). A more prudent national standardization, and building codes cleaned of biases against wood would be a valuable complementary tool to reduce market restrictions for introducing, e.g., engineered wood products.

Importantly, a more efficient waste utilization improves the **environmental protection** in producer countries in many ways. Most visibly, the dumping of the waste into landfills and waterways becomes discouraged. The former has positive climate-related impacts with lower emissions, the latter helps maintaining aquatic life and fish stocks. Avoidance of dumping also reduces the risks of pest attacks around mills and in the forest. By means of substituting fossil fuels with **wood-based bioenergy**, a much more important climatic gain can be realized. Replacing coal with wood is effective in CO_2 emissions reduction. In addition, some returns for investment payback may be received through carbon offset trading. Sulfur dioxide (SO_2) emissions from wood residue combustion are practically negligible in comparison with most fuels. Domestic bioenergy also contributes to balance of payments situation and energy self-sufficiency. The use of densified wood fuels like **pellets and briquettes** in district heat and electricity generation can support greater energy self-sufficiency and lower CO_2 emissions both in domestic heating and in industrial processes.

On experimental scale, fuel cells can break down organic waste like wood into nitrogen and carbon in controlled conditions. Wood has a potentially positive role in improving the composition of the digested mixed waste, but wood's role as a source of methane is nevertheless small. In composting wood chips and sawdust can be used as a bulking agent.

This report gives a broad introduction on some of the most potential **combustion technologies** for electricity and heat generation for the tropical conditions. These technologies and processes are usually branded and therefore names of the manufacturers are presented in this report. It is acknowledged that there remains a lot of work for making these technologies more widely applied in the tropics. Some cases are given to illustrate the perceived benefits and obstacles in this field.

The three case studies point out serious hindrances for progress towards a national policy to support more efficient processing and the creation of a viable bioenergy sector based on wood. Some are related to the lacking institutional support like incentive schemes, others are pointing at the persistent conditions of forestry like low prices of tropical logs and distant locations of the industries from the markets. These factors discourage any further consideration of residues. Obsolete equipment and lacking human resources to improve efficiency and develop new product flows were cited on various levels of forestry and industry. A tighter integration of the industry would offer better chances for waste utilization throughout the supply chain.

Furthermore, the case studies attempted to quantify the waste flows and resulting economic losses in the case countries. In Brazilian Amazon region logging residues amount to approximately 28 million m^3, and processing waste 21.7 million m^3 (20 million m^3 from sawmills). The non-utilization of this tropical wood waste costs the country USD 1.2 billion a year. Malaysia's unutilized reserves of wood residues were estimated at 22.8 million m^3, 70% of which was in the form of logging residues. Economic losses may amount to around USD 230 million per year. In Cameroon, at least half a million cubic meters are wasted each year, but its economic value was not reliably established due to imperfect data.

This report makes several suggestions on future actions that can assist tropical producer countries in general, on their path towards more efficient timber utilization of and reduced waste. As a starting point, conflicting forest and **taxation** policies, which unintentionally encourage wasteful utilization of tropical wood from the stem to the market, should be detected and removed. On **policy development**, more stringent SFM standards and obligations for logging operators to collect and reduce waste left in the compartments is envisaged as a starting point. Due weight should be given in industrial policies on more efficient wood fiber utilization and technology upgrading as a part of creating a more integrated forest industry cluster, where waste utilization is a synergetic achievement. Adequate training of operators to reduce waste on all levels of the wood product supply chain is recommended.

In the area of **market development**, the producer countries would benefit from identifying fresh market opportunities for wood products made of smaller pieces of wood (flooring, edge-glued panels, finger-jointed and laminated wood products, small-dimension products, etc. Whenever sufficient amount of processing waste is accumulated in a compact area, reconstituted panels or pulp industry concepts should be tested for their economic feasibility. Decentralized local energy and electricity options have already raised interest in the Amazon region, and they would deserve a closer look as a regional development catalyst. Also local and export markets for refined wood energy products such as special charcoals, briquettes, pellets could be tapped with better market information. Observed market resistance on variable-colored wooden flooring and other applications, where, e.g., sapwood cannot be used should be solved by supporting focused R&D efforts.

For the sake of **promoting investments and arranging financing**, royalty and forest fee schemes should be further developed to ensure the commercial attractiveness of residues recovery and utilization. Biomass fueled boiler and kiln technologies should be supported with lower import tariffs and taxes or accelerated depreciation schedules. "Green" financing opportunities for the bioenergy sector should be better explored under the Kyoto Protocol's flexible mechanisms.

Transfer of improved logging and primary processing, and bioenergy generation **technologies** should be encouraged, particularly where South–South technology transfer is possible. It is essential to improve the drying, planing, gluing and finger-jointing technologies to reap the full potential of processing waste and changing raw materials (without losing out on strength, finishing quality and price). Improvements in the wood staining methods are needed for overcoming the color variability problems.

Competence and consciousness need to be developed on all the levels of wood products supply chain, from practitioners and controllers of sustainable forest management, to felling and bucking operations where the value of log is determined by forest worker. Further on, training guidelines to the middle management for rationalizing factory-floor operations and introducing simple improvements for minimizing the processing waste per task/work station are much needed. Industrialists need to be convinced of the benefits from incorporating the rational concepts of by-products utilization and wood energy generation into the core business concepts.

Finally, it is necessary to effectively disseminate compelling information, real-life cases and technology supplier data to foresters and industrialists in the three tropical regions. The CD-ROM delivered Supplier Database attached to this report serves as the first action to this end.

1. INTRODUCTION

1.1 Background

ITTO has carried out a comprehensive portfolio of pre-projects and projects that are supporting the sustainable forest management, more efficient utilization and reduced impact logging goals. As it has been suggested by international experts, "*the waste of tropical timber use starts already in the forest when sustainable harvesting potentials of commercial species are improperly used. Fiscal reforms, and new taxation systems, (…) do have an important influence on the extent, increase or reduction of waste.*" (H. Stoll, personal comm.)

Also ITTO's work carried out in technology transfer and development of further processing of tropical timber is highly relevant for the overall improvement of utilization rates, unit consumption of roundwood, and for the creation of added value for a more prosperous industry.

The **most recent** ITTO pre-project study PPD 24/99 (I) on "Increasing Utilization Efficiency and the Reduction of Losses and Waste Throughout the Production Chain" made an important contribution in identifying the significance of waste generated by sawmills, veneer mills, and plywood plants in ITTO member countries. The results were based on a literature survey, mail questionnaire, and mill visits in selected countries. Information proved to be difficult to collect by these methods, and the results were fragmentary and impossible to generalize in a meaningful way.

The study was broad and it dealt with the waste utilization aspect in general terms, suggesting mostly conventional ways to use wood waste. The study is a valuable source of information but it is not easy to use by industry and other beneficiaries. It does not highlight specifically the economic benefits of waste utilization, which is necessary to induce the industry's perceptional change from burden of waste to benefits of by-products. In the forest management front, there is the necessity of changing from former simple forest exploitation methods to sustainable natural tropical forest ecosystem management. This transition phase calls for an adaptive process in mentality, techniques, laws, and fiscal reforms.

1.2 Review of ITTO's Project Portfolio

1.2.1 General

The following is a list of ITTO projects in the fields relevant for supporting the objective of reducing waste and improving its utilization rates (since 1999). In the project numbers given below, "PD" denotes project and "PPD" denotes pre-project. The suffix "F" denotes Committee on Reforestation and Forest Management, "M" the Committee on Economic Information and Market Intelligence, and "I" the Committee on Forest Industry.

The past experiences have been grouped under three sub-headings for the convenience of the reader. They also demonstrate ITTO's approach to address the issue from different directions, and the relevance of this work to support reduced waste generation.

1.2.2 Reduced Impact Logging and Sustainable Forest Management

Application of intermediate technologies for sustainable forest harvesting

Project number: PD 233/03 Rev.2 (I)
Project country: Peru
Status: Pending agreement

This project will help strengthen the forest concession process initiated by the Peruvian Government, and particularly small-scale forest enterprises that wish to participate in the process but lack the necessary infrastructure or financial resources. Through training, information dissemination and technical assistance, the project will promote the use of appropriate intermediate technologies for forest harvesting in forest concession areas under the management of small and medium-sized timber producers and native communities located in the major Amazon regions of the country (Madre de Dios, Ucayali, San Martín, Huanuco, Loreto, Selva Central and Cuzco).

Training of forest practitioners for the improvement of forest industry in Cambodia

Project number: PD 131/02 Rev.4 (I)
Project country: Cambodia
Status: Pending agreement

This project will implement a training program for logging and wood-processing practitioners with a minimal educational background. During project implementation, 72 practitioners will be trained in general aspects of forest management, harvesting techniques and wood processing in cooperation with the private sector.

Development of human resources in sustainable forest management and reduced impact logging in the Brazilian Amazon

Project number: PD 206/03 Rev.1 (F)
Project country: Brazil
Status: Operational

The lack of qualified and trained forestry practitioners is a key problem impeding the adoption of good forest management in the Amazon. This recently initiated project, which follows ITTO PROJECT PD 45/97 REV.1 (F): *On-site training of tropical foresters and forestry trainers* implemented in Belem, Brazil, will increase the adoption of forest management and reduced impact logging (FM-RIL) practices by timber producers in Amazonian production forests through practical training, and promote and disseminate good forest management practices amongst stakeholders in the Brazilian Amazon through extension work. The project comprises a three-part strategy designed to develop human resources in the forest sector of Amazon Basin countries. The first consists of 38 practical training courses targeting 410 forestry professionals at all levels and tailored to their diverse needs and interests. The second component will promote interest in FM-RIL and raise awareness about its importance and benefits among the numerous forest stakeholders; at least 400 people are expected to participate in these events. The third component of the project strategy is to continue the successful FM-RIL training program developed under the previous project.

Program to facilitate and promote adoption of reduced impact logging (RIL) in Indonesia and the Asia Pacific region

Project number: PD 110/01 Rev.4 (I)
Project country: Indonesia
Status: Operational

This project is increasing the awareness of key forestry sector stakeholders – managers of forest industry groups, officers of government forestry agencies, NGOs, media and community leaders – about the requirements and benefits of improved logging planning and implementation, strengthening the capacity of forestry institutions to promote and facilitate the implementation of reduced impact logging, and establishing a corps of forest technicians, supervisors and forest workers trained in the practical techniques of reduced impact logging.

Promotion and transfer of knowledge on sustainable forest management models to timber producers

Project number: PD 23/00 Rev.4 (F)
Project country: Peru
Status: Operational

This project is focusing on the training and education of Peruvian Amazon forest stakeholders in sustainable forest management techniques, including the ITTO criteria and indicators, to promote private investments in the forest sector and the use of appropriate technologies.

Sustainable production of national forests under a regime of forest concessions

Project number: PD 142/02 Rev.2 (F)
Project country: Brazil
Status: Pending agreement

One of the goals of the Brazilian National Forest Program is to expand the management of native forests in public areas to at least 10 million hectares through a regime of forest concessions. This project will conduct social and economic surveys, environmental studies and preliminary forest inventories in five Amazonian national forests to prepare them as future concession areas. Management plans for the sustainable production of timber from the five national forests will be developed, along with the rules and procedures to be followed by companies under the concession regime.

Training in reduced impact logging in Guyana

Project number: PD 68/01 Rev.2 (I)
Project country: Latin America
Status: Operational

This project is developing a national reduced impact logging (RIL) training program that includes demonstration models of good RIL practices, a training facility, the training of trainers and other personnel in RIL, and a long-term plan to sustain the program.

Model forest management area (MFMA) – Phase III

Project number: PD 12/99 Rev.4 (F)
Project country: Malaysia
Status: Operational

This project, which follows earlier ITTO projects conducted in the same model forest, is training forestry workers in the planning and implementation of sustainable forest management, demonstrating new methodologies and techniques, preparing comprehensive management plans, and monitoring management performance in the model area.

Training in reduced impact logging in Cambodia

Project number: PD 65/01 Rev.2 (I)
Project country: Cambodia
Status: Operational

This project is training foresters, supervisors, managers and trainers from the Department of Forestry and Wildlife and the private sector, including concessionaires, in the practice of reduced impact logging, with a view to strengthening efforts towards sustainable forest management in the country. It is also establishing a demonstration area in the Kompong Thom forest in central Cambodia.

Training of trainers in the application of ITTO and national criteria and indicators for sustainable forest management at the forest management unit level

Project number: PD 42/00 (F)
Project country: Indonesia
Status: Operational

This project developed a curriculum and training module for the education of concessionaire personnel in sustainable forest management based on the ITTO and national-level criteria and indicators. It trained 230 "trainers" within forest concession companies across five regions of Indonesia; these trainers now form the basis of a database of expertise at the national level maintained by APHI.

Sharing of information and experiences on private-sector success stories in sustainable forest management

Project number: PD 48/99 Rev.1 (M, F)
Project country: Global
Status: Operational

This project is surveying forestry companies active in the three tropical regions and preparing case studies on ten identified as excelling in sustainable tropical forest management. The results will be widely disseminated via an international conference (scheduled for April 2004) and a book.

Strengthening sustainable management of natural forests in Asia-Pacific

Project number: PPD 19/99 Rev.1 (F)
Project country: Asia-Pacific
Status: Completed

This pre-project assisted member countries of the Asia-Pacific Forestry Commission in the implementation of a regional code of practice for forest harvesting. This included raising awareness of the issues and potential for improved forest harvesting practices, developing a practical and comprehensive training strategy with appropriate training guidelines and modules, and reviewing the experiences of alternative model forest management areas.

Sustainable management of production forests at the commercial scale in the Brazilian Amazon

Project number: PD 57/99 Rev.2 (F)
Project country: Brazil
Status: Operational

The central aim of this two-phase project is to develop, test, evaluate and transfer a forest management system for use by timber enterprises working under typical production conditions found in *terra firme* forests of the Brazilian Amazon.

1.2.3 Efficiency

Training of forest practitioners for the improvement of forest industry in Cambodia

Project number: PD 131/02 Rev.4 (I)
Project country: Cambodia
Status: Pending agreement

This project will implement a training program for logging and wood-processing practitioners with a minimal educational background. During project implementation, 72 practitioners will be trained in general aspects of forest management, harvesting techniques and wood processing in cooperation with the private sector.

Promoting the utilization of rubberwood from sustainable sources in Indonesia

Project number: PPD 80/03 Rev.2 (I)
Project country: Indonesia
Status: Pending agreement

This pre-project will assess the feasibility of using rubberwood as a raw material for the wood-based industry in Indonesia and is a follow-up action to the recommendations of the ITTO Technical Mission to Indonesia in 2001. One of the issues for the present crisis in the Indonesian wood-based industry is the gap between wood supply and demand. This situation is likely to prevail in the future unless measures to secure the supply of logs from plantation timbers such as rubberwood are taken. At present, there are around 3.5 million hectares of rubber plantations in the country. However, while rubberwood furniture has contributed significantly to the economies of Malaysia, Thailand, India and China, in Indonesia the rubber-wood resource has been used mainly as a source of energy. The main pre-project activities will include field surveys of rubber plantations in selected sites and the collection of relevant information on rubberwood processing techniques and markets. In addition, two national workshops on rubberwood processing techniques and markets will be organised with the participation of all stakeholders to assist in the formulation of national policies for the efficient utilization of rubberwood and a full ITTO project proposal for the development of a sustainable rubberwood industry in Indonesia.

Improving the utilization efficiency in wood industries in the South Pacific region

Project number: PPD 58/02 Rev.2 (I)
Project country: Vanuatu and Papua New Guinea
Status: Pending agreement

This pre-project will investigate the level of appropriate technology needed to improve wood efficiencies in the Pacific, starting with Vanuatu, Papua New Guinea and Fiji, identify gaps in national policies, and provide direction and recommendations related to waste reduction and residue usage.

Improvement of processing efficiency of tropical timber from sustainable sources in Indonesia

Project number: PPD 57/02 Rev.1 (I)
Project country: Indonesia
Status: Operational

This pre-project, which follows up on the recommendations of the ITTO Technical Mission to Indonesia in 2001, is examining gaps between individual mills' processing competency and the international demand for processed wood products in terms of product diversity and quality with the aim of identifying the technical measures needed to improve the level of wood-processing efficiency in Indonesia.

Development of energy alternatives for the efficient utilization of wood-processing residue: co-generation and briquette production

Project number: PPD 53/02 Rev.1 (I)
Project country: Ghana
Status: Operational

This pre-project is conducting co-generation studies at three sawmills and creating awareness among stakeholders about the economic and financial benefits of co-generation.

Processing and utilization of logging residues through collaboration with local communities and forest industries

Project number: PPD 39/02 Rev.2 (I)
Project country: Ghana
Status: Operational

This pre-project is investigating ways to increase the benefits accruing to local communities from forest operations through the collection and processing of logging residues. It is also formulating a project proposal to promote collaboration between forest industries and local communities in the collection and processing of logging residues.

Strategies for the development of sustainable wood-based industries in Indonesia

Project number: PD 85/01 Rev.2 (I)
Project country: Indonesia
Status: Operational

This project is assisting the Government of Indonesia to ensure the sustainability of its wood-based industries through downsizing and restructuring.

Increasing the efficiency in the tropical timber conversion and utilization of residues from sustainable source

Project number: PD 61/99 Rev.4 (I)
Project country: Brazil
Status: Operational

The objective of the project is to investigate whether conventional timber industries in conjunction with the power generation industry can make sustainable forest industry a viable option in two major wood industry-centered cities in the western Amazon.

Timber enhancement through mechanical processing

Project number: PPD 16/01 Rev. 1 (I)
Project country: Republic of Congo
Status: Operational

This pre-project is reviewing the factors that result in timber losses and environmental destruction during logging, and ways of improving local timber processing to achieve greater efficiency in timber use.

Pre-project for the Ecuadorian tropical timber industry environmental management

Project number: PPD 15/99 Rev.2 (I)
Project country: Ecuador
Status: Completed

This pre-project designed and produced a project proposal, in coordination with the principal stakeholders (forest industries, NGOs, government and municipalities), related to the application of an environmental management system (EMS). The EMS addresses timber processing industrial issues such as water consumption, energy conservation, greenhouse gas emissions, and solid and liquid wastes. The ultimate aim is to increase the international trade of Ecuadorian timber on the basis of ISO 14000 certification and to assist the forest industry to comply with environmental regulation.

Formulation of a project proposal to support the sustainable development of small forest industries

Project number: PPD 6/00 Rev.1 (I)
Project country: Peru
Status: Operational

This pre-project is compiling supplementary information regarding portable sawmills. This includes information on the institutional planning of forest areas allocated as long-term concessions and for small-scale timber extraction, associated land tenure issues for both categories of areas, experiences gained through the operation of portable sawmills, and the technical characteristics of portable sawmills and timber resources.

Development and extension of preservation technology of tropical plantation timber

Project number: PD 52/99 Rev.2 (I)
Project country: China
Status: Completed

This project studied and disseminated timber-processing and utilization technologies for plantation timber to improve the efficiency of the wood-processing industry. Research work focused on the development of appropriate preservation standards and drying procedures for plantation timber such as *Eucalyptus urophylla* and *Acacia mangium*.

Introduction of a village industry in the community around an industrial forest plantation in Indonesia

Project number: PD 58/99 Rev.1 (I)
Project country: Indonesia
Status: Operational

This project is investigating the processing and utilization of the bark of *Acacia mangium*, *Eucalyptus spp* and *Paraserianthes falcatria* from industrial forest plantation areas in East Kalimantan to produce tannin, adhesive material, pelleted animal feed and fertilizer, which will in turn contribute to the development of local communities through the establishment of a village industry.

1.2.4 Industrial Processing and Marketing

Demonstration of rubberwood processing technology and promotion of sustainable development in China and other Asian countries

Project number: PD 103/01 Rev.4 (I)
Project country: China
Status: Pending agreement

This project will support the development of the rubberwood industry in China and increase its contribution to the national economy through the more efficient utilization of existing rubberwood raw materials. It will also introduce technical guidelines for rubberwood sawing, the use of environmentally acceptable chemical treatments, and efficient drying techniques.

Systematization and modeling of economic and technical information to train professionals related to the production, processing and marketing of timber products

Project number: PD 203/03 Rev.3 (M)
Project country: Colombia
Status: Pending agreement

This project will help raise capacity in Colombia's timber sector by developing dynamic simulation models and implementing a system containing economic and technical information on the timber process production chain for 15 potential timber species. The system and models will be applied and used in the training of personnel of institutions involved in the various stages of the timber production chain in two of the country's major forest regions.

Strengthening the capacity to promote efficient wood-processing technologies in Indonesia

Project number: PD 286/04 Rev.1 (I)
Project country: Indonesia

It is estimated that the total installed production capacity of the Indonesian wood-processing industry was around 30 million m^3 in 2000, comprising 19 million m^3 in sawmill and 11 million m^3 in plywood industries. However, wood-processing efficiency levels are low compared to neighbouring countries. This 36-month project will increase the contribution of the wood-processing sector to the national economy through the application of appropriate processing technologies, based on the findings and recommendations derived from an ITTO pre-project (PPD 57/02 Rev.1 (I)) and an ITTO technical mission in 2001.

Specifically, the project will improve national skills and capabilities in processing technologies and in product quality management and identify product standards, quality/grading requirements and technical regulations for sawnwood products in international markets. Twelve training courses in sawing and other basic wood-processing techniques, product quality management, and industrial management will be organised for practitioners, managers and supervisors of woodworking factories. The project will also facilitate the establishment of small-scale training and testing facilities in existing wood-processing factories in Java, Sumatra, Kalimantan and eastern provinces.

Promoting the utilization of rubberwood from sustainable sources in Indonesia

Project number: PPD 80/03 Rev.2 (I)
Project country: Indonesia
Status: Pending agreement

This pre-project will assess the feasibility of using rubberwood as a raw material for the wood-based industry in Indonesia and is a follow-up action to the recommendations of the ITTO Technical Mission to Indonesia in 2001. One of the issues for the present crisis in the Indonesian wood-based industry is the gap between wood supply and demand. This situation is likely to prevail in the future unless measures to secure the supply of logs from plantation timbers such as rubberwood are taken. At present, there are around 3.5 million hectares of rubber plantations in the country. However, while rubberwood furniture has contributed significantly to the economies of Malaysia, Thailand, India and China, in Indonesia the rubberwood resource has been used mainly as a source of energy. The main pre-project activities will include field surveys of rubber plantations in selected sites and the collection of relevant information on rubberwood processing techniques and markets. In addition, two national workshops on rubberwood processing techniques and markets will be organised with the participation of all stakeholders to assist in the formulation of national policies for the efficient utilization of rubberwood and a full ITTO project proposal for the development of a sustainable rubberwood industry in Indonesia.

Investment promotion and enterprise development of the timber industry in Ghana

Project number: PPD 63/02 (I)
Project country: Ghana
Status: Operational

This pre-project is critically evaluating investments in the timber industry with a view to helping managers, decision-makers and policymakers formulate appropriate strategies to ensure the sustainable development of wood-based enterprises.

Application of an experimental model for the economic appraisal of the utilization and management of Colombian flora case study: *Meliaceae* and *Anacardiaceae*

Project number: PD 132/02 Rev.1 (M)
Project country: Colombia
Status: Operational

This project is applying an experimental model with a series of biological and socio-economic variables to give an economic value to Meliaceae and Anacardiaceae species.

Assessment of the multiple benefits of downstream processing of tropical timber in producer countries

Project number: PPD 35/01 (I)
Project country: Global
Status: Operational

This pre-project is quantifying the contribution that wood-processing industries makes to national economic growth.

Feasibility study for the production of sawnwood from tropical forests using appropriate technologies

Project number: PPD 7/00 (I,F)
Project country: Ecuador
Status: Operational

This pre-project is examining the feasibility of producing high-quality sawnwood using appropriate technologies for the harvesting of timber from sustainably managed sources by groups of farmers in tropical moist forests.

Pre-feasibility study for the industrial utilization of rubberwood (Hevea brasiliensis) including the formulation of a pilot case study for implementation in a specific area of Colombia

Project number: PD 46/99 Rev.3 (I)
Project country: Colombia
Status: Operational

This project is assessing the feasibility of a rubberwood processing industry in Colombia and formulating and establishing a pilot study for the production of guidelines to assist investors and communities in developing such an industry.

Review of international wooden furniture markets

Project number: PPD 25/01 (I,M)
Project country: Global
Status: Operational

This pre-project is assessing the outlook for wooden furniture, including bamboo and rattan, into the 21st century with the aim of providing a view of those products and markets where tropical timber producers are likely to be competitive.

Pre-project for the Ecuadorian tropical timber industry environmental management

Project number: PPD 15/99 Rev.2 (I)
Project country: Ecuador
Status: Completed

This pre-project designed and produced a project proposal, in coordination with the principal stakeholders (forest industries, NGOs, government and municipalities), related to the application of an environmental management system (EMS). The EMS addresses timber processing industrial issues such as water consumption, energy conservation, greenhouse gas emissions, and solid and liquid wastes. The ultimate aim is to increase the international trade of Ecuadorian timber on the basis of ISO 14000 certification and to assist the forest industry to comply with environmental regulation.

Improved and diversified use of tropical plantation timbers in China to supplement diminishing supplies from natural forests

Project number: PD 69/01 Rev. 2 (I)
Project country: China
Status: Operational

This project is developing processing techniques for solid wood products such as joinery, furniture and building products from existing eucalypt and acacia plantations in southern China. It is also evaluating the suitability of newly planted eucalypt and acacia plantations for further processing and assisting in the transfer of technologies and the dissemination of the scientific knowledge obtained in the project to the relevant public.

Improvement of rubberwood utilization and marketing in Thailand

Project number: PD 51/00 Rev. 2 (I,M)
Project country: Thailand
Status: Operational

This project aims to help the Thai furniture industry regain its competitive edge in world markets. Specifically, through a series of appropriate training seminars and the provision of suitable methodologies it is upgrading national skills and capabilities in rubberwood resource assessment, industrial management, processing technologies and the export marketing of furniture.

Capacity building in training in planning and management of forest industries in ITTO producer member countries

Project number: PD 13/95 Rev.3 (I) Phase II
Project country: Global
Status: Operational

This project builds on an earlier project and an earlier phase of the current project. Its objectives are to: develop the curricula of selected training institutes for ongoing training activities; improve the capacity of resources persons in ITTO producer member countries in the planning and management of appropriate forest industries and in the planning and management of training courses on the same subject; and produce material necessary for self-studying and training courses.

Training workshop on further processing of tropical timber in the Asia-Pacific region

Project number: PD 20/00 Rev.1 (I)
Project country: Asia-Pacific
Status: Completed

This project organized a regional training workshop on further processing of tropical timber in the Asia-Pacific region in Seoul, Korea, with a view to promoting value-added manufacturing opportunities for tropical timber.

Development and extension of preservation technology of tropical plantation timber

Project number: PD 52/99 Rev.2 (I)
Project country: China
Status: Completed

This project studied and disseminated timber-processing and utilization technologies for plantation timber to improve the efficiency of the wood-processing industry. Research work focused on the development of appropriate preservation standards and drying procedures for plantation timber such as *Eucalyptus urophylla* and *Acacia mangium*.

Utilization of tropical plantation timber in the southern part of China

Project number: PPD 18/99 Rev.2 (I)
Project country: China
Status: Completed

This pre-project assessed the existing problems associated with the utilization of plantation-grown tropical timber in the southern part of China and developed strategies for value-adding.

Introduction of a village industry in the community around an industrial forest plantation in Indonesia

Project number: PD 58/99 Rev.1 (I)
Project country: Indonesia
Status: Operational

This project is investigating the processing and utilization of the bark of *Acacia mangium*, *Eucalyptus spp* and *Paraserianthes falcatria* from industrial forest plantation areas in East Kalimantan to produce tannin, adhesive material, pelleted animal feed and fertilizer, which will in turn contribute to the development of local communities through the establishment of a village industry.

1.3 Justification for New Project

In many ITTO member countries, industrial logging and wood processing result in a substantial amount of timber residues and wood waste. Project PD 74/90 (F, I)[(1)] concluded that the amount of residues during timber harvesting ranges from 23% to 63% of the stem volume and from 36% to 53% of the whole above-ground volume of the tree. During sawmilling operations, the amount of solid wood residues and sawdust ranged from 30% to 64% in the studied sawmills. Such an excessive waste level represents a serious impediment to progressing toward sustainable forest management and an enormous loss of opportunities for the timber companies, local communities and the governments in terms of income, employment opportunities and revenues.

Although ITTO has actively promoted efficient utilization of timber resources throughout the production chain through policy formulation[(2)] and assistance to member countries, progress in this field is slow due to many reasons, including:

(a) the relative **low price of timber** in certain areas and thereby weak incentives to make an efficient use of raw material
(b) the **lack of investment potential** as markets do not readily exist for all grades produced which end up as waste, or waste-based products which often require substantial investment (e.g., wood pulp, particleboard, MDF, and other reconstituted panels)
(c) the **lack of skills** and expertise to introduce improved processing methods and waste utilization lines

(1) "Better Utilization of Tropical Timber Resources in order to Improve Sustainability and Reduce Negative Ecological Impact".
(2) Cf. PPD 11/92 (I); and PPD 24/99 (I): "Increasing Utilization Efficiency and the Reduction of Losses and Waste Throughout the Production Chain".

(d) the **lack of knowledge** of available technologies
(e) **fragmentation** of the industry
(f) **lack of** vertical and horizontal **integration** in business strategies

In order to make full use of the timber industry in contributing to the achievement of sustainable forest management and creating value to the forest resources, efficient utilization of available raw material is necessary. This implies an integrated approach, compounding efficient harvesting operations, efficient processing operations and efficient utilization of any forest residue and wood waste, and when appropriate, recycling.

1.4 Objectives

The objective of the new study was to compile information on:

(i) the utilization of logging residues and wood waste
(ii) types of products logging residues and wood waste can be used for
(iii) available technologies for the utilization of logging residues and wood waste
(iv) current and potential markets for logging residues and wood waste
(v) sources of information regarding the end products, technologies, expertise and equipment manufacturers (Excel-format database on CD-ROM)

The study also includes a discussion on economic and environmental aspects of the utilization of logging residues and wood waste as well as on the sustainability of various options.

It is envisaged that the results of the study will be effectively disseminated by ITTO to potential beneficiaries through appropriate means. These beneficiaries include:

- sawmills
- veneer mills and plywood plants
- forest management units
- timber traders and importers
- technology and service providers to the tropical timber industry
- governments promoting full valuation of their forest resources
- other stakeholders

The study is consistent with the ITTO Yokohama Action Plan, Section 3.3, Goal 2, Action 1 and 4.

1.5 Activities

According to the terms of reference, the study did:

A. Review ITTO work in the field of utilization of wood waste and residues

B. Undertake a literature review in the field of wood waste and residues

C. Through sampling of forest and mill operations in the three ITTO producing regions, document residues and waste in the forest and at mill sites, for the latter priority being given to sawmills, in view of potential end products

D. Discuss the quantity of waste generated in the context of a sustainable supply of the production chain

E. Discuss the economics related to waste/residue generation, collection and processing, as well as environmental aspects with an emphasis on potential impacts of waste/residue utilization on natural forests

F. Compile information on products manufactured or produced from the processing or utilization of wood waste and residue

G. Describe the available technologies, provide sources of information on equipment suppliers/manufacturers and expertise and discuss product development and production costs

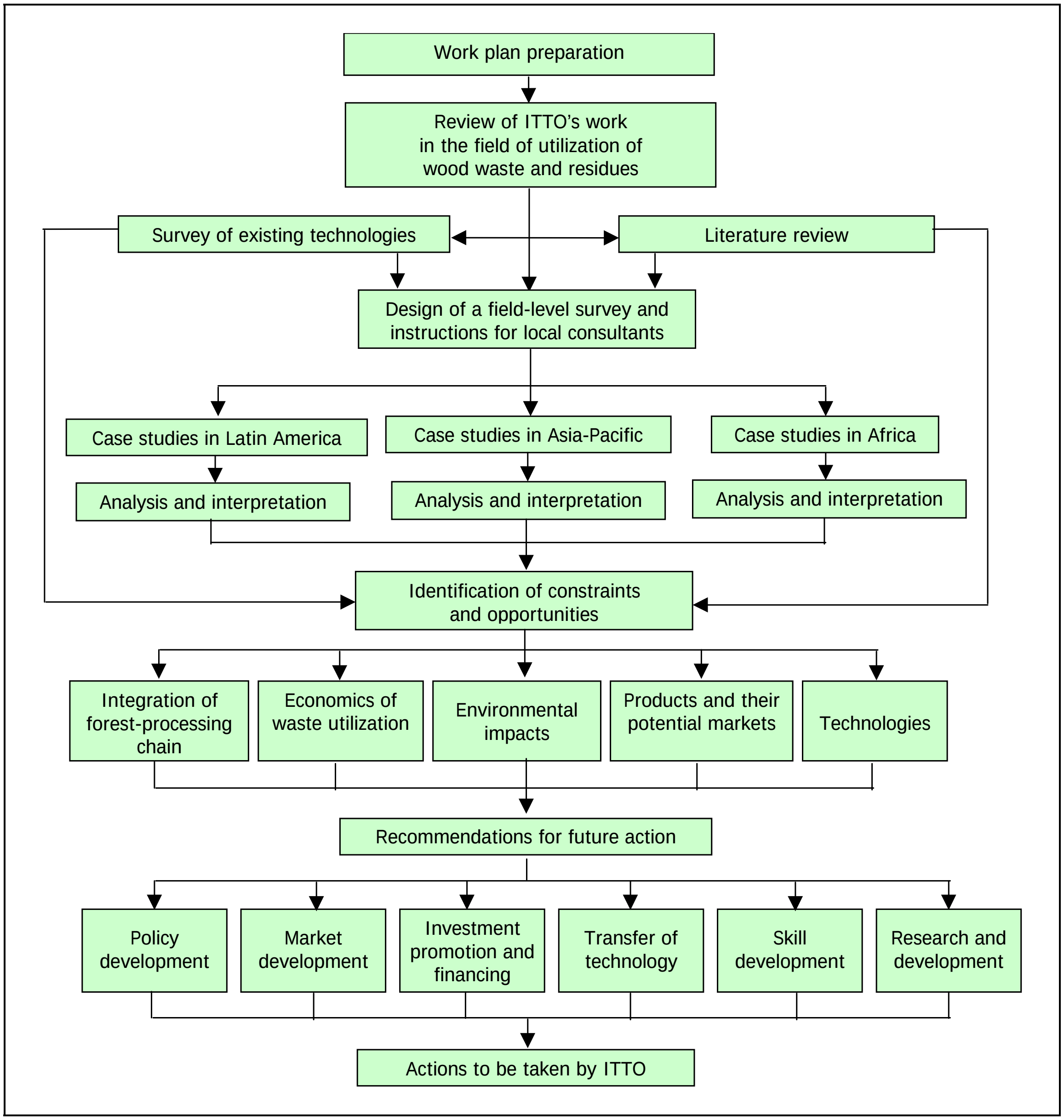
H. Prepare a preliminary report of the study, submit it to ITTO on or before September 25, 2003, and present it to the Committee on Forest Industry at its Thirty-third Session. The report should include specific ideas to further the ITTO's work in this field

I. Prepare the draft final report of the study, including an executive summary, submit it to ITTO on extended schedule by May 20, 2004, and present the study results to the Committee on Forest Industry at its Thirty-fourth Session

J. Prepare the final report of the study and submit it to ITTO (ready for printing) on or before September 1, 2004

The sequence of these activities and their elements is given in Figure 1.1.

Figure 1.1 Flowchart of Project Activities



2. BOUNDARIES OF ASSESSMENT: TYPES OF WASTE GENERATION

Different types of wood waste and residues are generated throughout the tropical timber production chain. In most cases, wood residues cannot be avoided because they are part of the processing phases and the real problem is waste. In any case, to reduce residues and waste production is always desirable.

Figure 2.1 presents a schematic flow, which shows the different types of waste generated at each stage of the tropical timber production chain. As it can be seen, there are basically two types of waste:

- **Forest or logging residues** are the result of logging and harvesting operations. The different stages of these operations basically involve:
  - road construction
  - felling of trees
  - skidding
  - crosscutting of logs
  - transportation (to mill site)

  The main amount of forest residues is generated from felled trees, as for instance, stumps, buttress logs, stem offcuts, branches, etc. It is important to mention that a considerable part of the forest residues are also originated from trees overthrown, broken or damaged by felling and skidding operations.

- **Industrial wood waste** is generated since log transportation and yard operations, passing throughout primary and further processing, up to warehousing. The main types of industrial wood waste are:
  - <u>Log transportation</u>: wood waste can be generated during log transportation (from forest to mill site). Logs rejected or left at loading station, as well as missing logs during the water way transportation are typical examples. Also, waste may be verified in terms of quality loss during loading and unloading operations.
  - <u>Log yard operations</u>: wood waste generated during log yard operations are usually associated to long storage time, which significantly contributes in damaging logs (fungi, insects, checks, etc.). Crosscutting operations also contributes to wood waste generation.
  - <u>Primary processing operations</u>: typical examples of wood waste generated during primary processing operations (sawing, peeling, etc.) are bark, cores, slabs, sawdust, shorts, trimmings, veneer waste, selective pieces caused by inadequate processing, and others.
  - <u>Further processing operations</u>: the main wood waste generated during further processing operations are sawdust, shavings, shorts, selective pieces caused by inadequate processing, among others.
  - <u>Warehousing operations</u>: storage time and condition, as well as inadequate packaging may damage the product (decay, discoloration, etc.), lowering its commercial value and hindering its selling. Depending on the damage, the product can be reprocessed, generating additional costs.

The tropical timber industry is very conservative in its business strategies. There is a major challenge in changing the industry's perception on this issue:

> Waste should be considered a valuable by-product, which should be utilized to capture its full value thereby contributing to the industry's profitability.

Promoting waste utilization requires a holistic approach where action needs to be taken both at the level of individual plants and companies, and national and international levels.

The problem of waste utilization is analyzed within the context of a conceptual framework, which involves forest harvesting, and primary and further processing and warehousing of final products before sales and transports into markets. At each stage of the production chain (analyzed by product), the sources and characteristics of waste are identified. There are a number of key functions and aspects which are critical for waste generation, such as:

- forest resource (total volume m^3/ha, harvesting intensity m^3/ha, species composition, stand structure)
- logging system influencing the damage to the felled trees and damage to the remaining trees, determining logging waste
- crosscutting (bucking)
- skidding, loading and roadside storage influencing the quality of raw material and thereby generating waste
- mill wood yard operations which generate waste if not properly managed
- pretreatment, which can improve recovery rates and reduce processing waste
- defect sensing by scanners
- optimization of log breakdown in sawing
- saw configuration and maintenance
- sawing/peeling procedure
- inventory control of logs, semi-finished and finished products (excessively long storage periods creates quality loss)
- integration of sales planning, logging (species mix, log lengths) and processing (dimensions and lengths)
- production of non-saleable dimensions resulting in quality loss or ending up in waste due to lack of market

The above factors largely define the degree of waste generation. There may be also some underlying reasons for waste generation, such as harvesting rules, which may unduly contribute to generation of forest waste. Through various improvements in the production process, waste volumes can be minimized but there will always be some waste.

There are two main avenues for waste utilization:

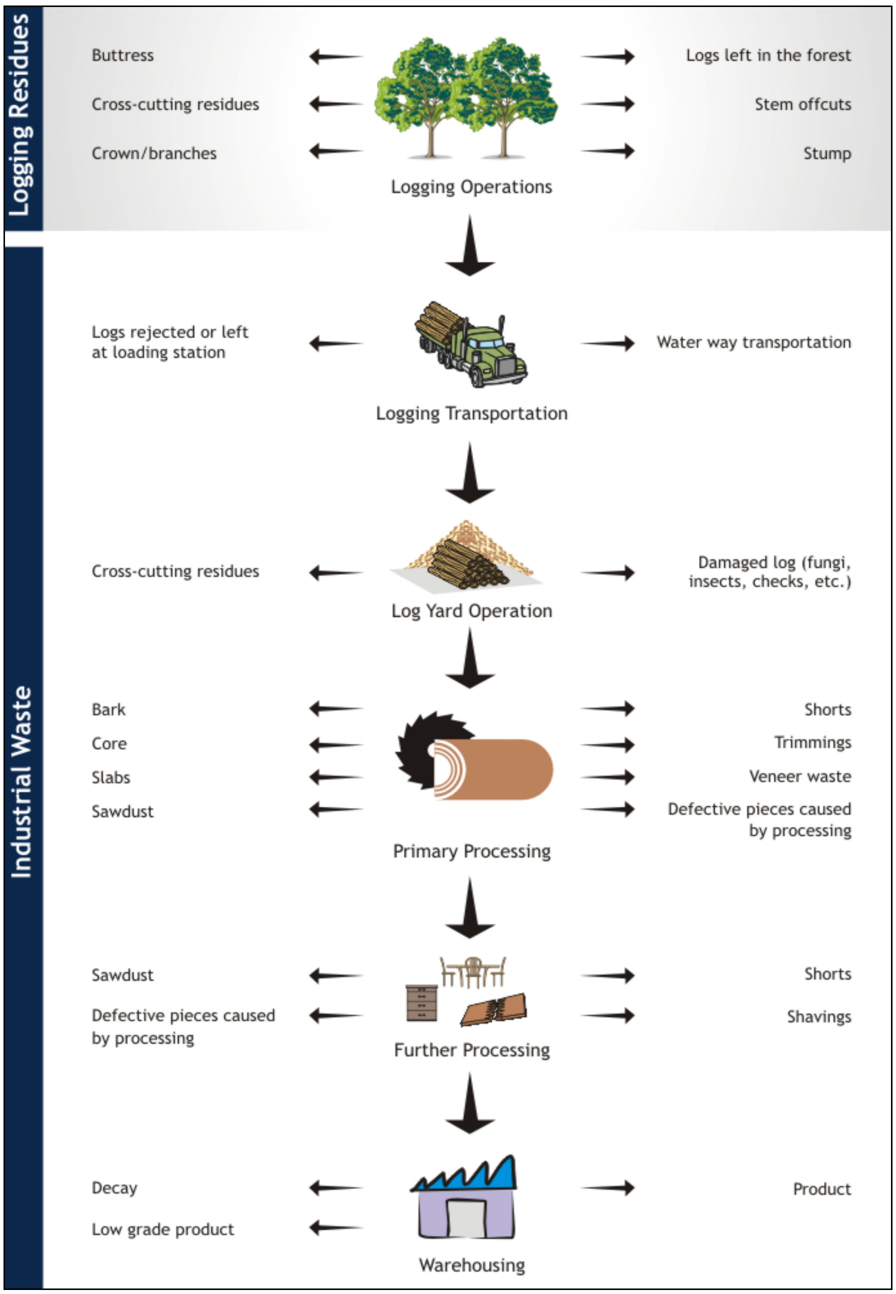
(a) **Recovery Processing Operations**, including:
- sawing of small logs or chipping them into reconstituted products
- recovery of sawmill by-products through dimensioning, finger-jointing, edge-gluing, lamination, resawing of shorts into components, etc.
- chipping for reconstituted panel products

(b) **Energy Generation**, including:

- energy generation from waste (burning techniques, combined heat and power production, etc.)
- household utilization
- other energy products (pellets, briquettes, etc.)

The study identifies and quantifies waste flows in the tropical timber industry and, for each type of waste, relevant options is identified. Their assessment is made considering volumes derived from – and needed for – industrial-scale (re)processing.

Figure 2.1 Waste Flow Generation in Tropical Timber Production Chain



3. SURVEY OF EXISTING TECHNOLOGIES

3.1 Introduction

Wood is still the primary source of energy and the cheapest fuel available in many countries. Particularly in rural areas, it sustains, cooking, processing and curing, and also cities have lively markets for fuelwood in its various forms. Wood is the mainstay for the running of local industries like brickwork, distilleries, pottery, tiles and tobacco.

Wood is used as a raw material for various artisanal and semi-industrial crafts like artifacts, tools, utensils, furniture items, etc. These may actually absorb considerable amounts of wood waste in offcuts, shavings, branches, stems, etc., thereby constituting a domestic market system for wood waste.

There are several possible options for intensifying wood residue utilization, both in grand scale and in small niche products. Some of them are not feasible for all situations or not practicable at present. Some require high investment outlays, whereas, others are relatively cheap to achieve. There are untapped potentials both in wood industry using waste wood as a raw material, and in generation of energy. Some options are in the following:

- Energy production
  - at sawmills
  - in co-generation plants
  - in converted forms (pellets and briquettes)
  - in energy cells at landfills

- Wood industry uses
  - pulp and paper
  - wood-based panels
  - engineered wood products
  - small-dimension wood products (picture frames, toys, tools, decorative items, etc.)

- Exports
  - as such (waste wood, fuelwood, chips and sawdust)
  - in converted forms (charcoal, briquettes and pellets)

- Other uses
  - composting
  - mulch
  - other

Some of the above-mentioned options may already be in use in some tropical countries. The case studies suggest that waste is intensively used in the wood-based panels industries in Brazil and Malaysia. Even in these cases, there still remains potential to increase utilization or generate better returns of low-priced residues in higher value-added by-products.

Pulp and paper and wood-based panels require large investments. The use of residues in panels and pulping are strictly process-oriented. Their technology options are limited to a few global machinery suppliers and turn-key engineering service providers. The report therefore defers assessment of these in favor of more accessible, smaller-scale processing and energy applications of waste. The prominent technology suppliers are, nevertheless, presented in the Excel-format attachment of this report (Supplier Database), which is also available in CD-ROM.

The main options for small-dimension wood products use and energy generation are discussed in the following sections.

3.2 Technological Developments in Primary Processing

3.2.1 Sawnwood

The basic production technology and core products of the sawmilling industry have remained fairly unchanged during the past decades. It is generally agreed that rough lumber has reached maturity in its product lifecycle. However, the growing demands for sustainable materials and recycling have given a new esteem to wooden products which is nevertheless still largely underutilized by the industry.

The current areas of research on the sawmilling industry include, e.g., the following:

(1) Improvement of sawing yield through:
  - using optimizers and scanners for log positioning, best opening face of log, digitalized and optical data collection, simulation programs for production of optimal recovery, dimension and grade, real time production monitoring
  - curve-sawing and thin saw kerf (for narrow dimension lumber from small logs)
  - innovations in saw doctoring (e.g., satellite/tungsten-tipped saw teeth)

(2) Design of reliable, all-automatic lumber sorting systems

(3) Faster and higher quality kiln-drying technology (airflow patterns, computer control systems, optimum temperatures, etc.)

(4) Development of cut-to-size stock production, laminated lumber, finger-jointed stock, components, etc.

(5) Improvement of surface treatment and preservation methods

(6) Expansion of sawnwood use for structural purposes (and finger-jointed stock for horizontal load-bearing structures, supported by non-destructive stress grading)

(7) Improved fire retardance of wooden structures

(8) Sawmilling properties of new species, notably the numerous tropical hardwoods (lesser-known species)

(9) Growing trend of integrating sawmilling with chips exports, panel-making or pulp industry has supported combined sawing and chipping technologies such as so called hew-saws, with controllable chip quality according to desired end-use

3.2.2 Engineered Wood Products

Engineered wood products have started to make inroads into new markets worldwide after early success in the U.S. construction market. These are composite products by nature, and they significantly reduce the volume of wood used for a given load carrying capacity, compared to traditional solid wood products. The engineered wood products that are substitutes for solid wood include:

(1) Glulam beams
(2) Laminated veneer lumber (LVL)
(3) Parallel strand lumber
(4) I-beams with oriented strand board webs
(5) Edge-glued panels (with or without finger-jointing)

Importantly, composites like LVL provide an escape route from shortages of natural, large-sized timber. In the tropical countries where timber from fast-growing plantations will increasingly replace native species, this is an important opportunity to stay in the business. The utilization of these species for structural purposes is limited by their technical characteristics, but through further processing such shortcomings can be removed. Superior strengths can be achieved of smaller-diameter and lower-quality logs.

In Europe, **weather-resistant LVL** has been developed. This product can be made stronger than solid timber and glulam, and is extensively used for joists, beams, purlins and truss frame construction. Up to 20-30 meter spans are achieved with lower volume of timber than through conventional application. LVL is formed by bonding 3 mm spruce or pine laminates into beams with WBP-type exterior gluing. The product is being manufactured also in the United States and it offers good growth prospects worldwide.

OSL (oriented strand lumber) originally utilized aspen logs which are flaked into strands, screened and oriented lengthwise into a thick mat. The mat is treated with polyurethane binder and compressed to 1-5-inch thickness with a steam injection press. OSL is either produced for industrial joinery blanks or high-strength structural beams and headers.

A more recent North American innovation combines elements of LVL and OSB technology to **laminated strand lumber** (LSL). Small-dimension aspen logs are mainly utilized in this application.

Japanese researchers have introduced a new method of producing extremely strong, square balks from softwood logs. Debarked, round logs are heated to 100ºC with microwaves and then pressed to square form. After drying the balk keeps its form and provides hardened, compact structural material. Glued lumber components, often veneered around, are common structural components in Japanese housing industry.

Finger-jointing and laminating has turned into a high-volume industry in Asia, thanks to rubberwood industry. Special lines to finger-joint and then laminate the strips into defect-free solid wood panels have become popular in furniture plants seeking an immaculate appearance to their wood surfaces. A wide range of different equipment is in use, which is at various levels of sophistication and capacities.

The majority of production takes place either in Europe or in the Taiwan Province of China. Factories exist that exclusively produce these types of panels either for export exactly as they are, or with solid wood moulded frames which might serve as table-tops. This type of panel is also sold to smaller furniture plants in the local market. With the growing usage of plantation wood and smaller diameter logs, it is expected that production of this type of panel will increase in the future. The quality of panels can vary, depending on the homogeneity of the kiln-drying processes and the amount of care taken in matching the color of the strips prior to assembling the panels. Production planning and control in such plants is relatively straightforward.

The above products are just a few examples of the products and new application areas of sawnwood in nontraditional form. Some of these products are still in the initial phase of their lifecycle while the others are already enjoying high growth rates.

3.2.3 Plywood

Together with Finland and North America, Japan is currently leading the R&D activities of new and improved plywood products. This is a result of the shortening supply of tropical logs from Southeast Asia.

Japanese R&D on plywood is focusing on the following issues:

(1) How to produce plywood with similar properties to the popular lauan plywood from lower grade (small, crooked or defective) logs of other species
(2) How to establish a fully automatic plywood manufacturing process
(3) How to produce plywood or similar products from other materials (stalks of millet, sugar cane)
(4) How to combine the use of different species in the same plywood panel

These issues are also subject to R&D efforts in other countries. Other than these, some new product innovations in the plywood industry include:

(1) Laminated veneer board (LVB)
(2) Long stick board (LSB)
(3) Plywood-like millet stalks board
(4) Bamboo plywood and similar products

LVB is composed of small sized square veneers, which are butt jointed or short scarf jointed lengthways. Veneers are then laid parallel to each other, but end joists positioned apart. Crossband veneers are laid on the surface and back or into the core. Thus LVB is a kind of patched plywood, which differs from LVL due to its thinner and wider dimensions.

LSB is still in the stage of testing, but commercial interest also exists in Japan. It is composed of long sticks, which are made with guillotine from rough rotary-cut 2.7 mm veneers. The sticks are 3-10 mm wide and 900-1 200 mm in length. They are arranged into three layers crossing each other at a 90º angle and glued in hot press.

Millet stalks board is manufactured by crushing cut-to-length stalks with rollers and dipping them in liquid phenolic resin. Stalks are then arranged in three layers at 90º angles and pressed. The production line is fully automatic. Sometimes wood veneer is overlaid on the surface. Due to this abundant resource base and comparable strength properties, millet stalks board has a significant potential as a substitute for plywood.

In Indonesia, the world’s largest exporter of plywood, secondary processing of plywood has gained more R&D efforts in the recent years. This draws on the earlier experience of the European and North American producers but is applied to local timbers. Value is added mainly through various overlays, i.e., decorative paper, polyvinylchloride, phenolic paper and melamine paper. Plywood surface can also be printed or coated with amin alkyd, polyester or polyurethane. Direct coating (without paper overlay) is used to produce “tone-color plywood”.

Moulded and curved plywood articles such as trays, bowls and plates, are also being produced for export in a significant scale.

Finland is considered the leading world exporter of technical plywood and R&D efforts have expanded the application areas of plywood into new uses in various areas of manufacturing, notably vehicle industry and ship-building (ranging from leisure boats to LPG-tanker ships). This expansion has not been based solely on improving surface or strength properties of plywood but the development work where solutions to customers’ problems have been taken as the starting point of R&D efforts.

3.2.4 Reconstituted Panels

Reconstituted panels have received more R&D attention than other sectors of wood industries during the last few years. Development of OSB (Oriented Strand Board) has mainly taken place in its origin North America, while MDF innovations have been concentrated to Europe. The product range of particleboard and fiberboard has also widened with the help of overlays and special glues/resins. All these panels offer new avenues for waste utilization in the tropics, but the domestic demand need to exist or it is to be created, because exports are often not a viable option as the prices are too low.

OSB remained for a long almost exclusively a North American product, as only a few mills gradually started operating in Europe. OSB is regarded as the successor to waferboard, which dominated the North American non-veneered structural panel market in the early 1980s. Now OSB has largely replaced waferboard and is available for sheathing, flooring, exterior siding and other special applications.

The quality problems related to OSB are mainly found in edge swelling. A French OSB producer has overcome this problem by using a melamine urea formaldehyde mix in liquid form. This transparent resin gives 15-20% higher density than the American powdered phenol resin.

The recent R&D efforts in OSB production include:

(1) Colored edge-coating to prevent moisture infiltration
(2) Slip resistant screening
(3) Bar coding identification
(4) Improved packaging and stenciling
(5) Quality certifications by APA, JAS, etc.

In production technology, flake quality and plant emissions are the critical challenges. OSB industry is researching after longer strands for improved strength properties. Stricter environmental laws require keener controls over volatile organic compound emissions.

Major progress has also been made in the field of **MDF**. Densities have been reduced to as low as 600 kg/m^3 by a New Zealand manufacturer. This grade weighs 20% less than standard

MDF, but fulfills other quality standards, the strength requirements in particular. The density 725 kg/m^3 was previously considered the lower limit for MDF. The new “Liteboard” has proven to be easily machined, lacquered and grain printed.

In Asia, where a large part of the world’s MDF capacity expansion is taking place, bagasse, cotton stalks and rubberwood have been introduced as new raw materials. China’s MDF capacity has been booming in recent years, and much of it is being manufactured into furniture and laminated flooring for the export markets.

Product diversification has been made at an accelerating speed. There are currently four standard grades of the base board in Europe. Thin melamine-faced MDF qualities have been introduced, and a variety of other surface treatments are commonly applied. A short-cycled laminating technology has been widely adopted. Primed, veneered and foil-wrapped mouldings are increasingly produced of MDF.

HPL or high-pressure laminate with a surface of transparent overlay paper (or resistant lacquer) and unprinted or printed decor paper is used mostly for kitchen furniture, especially for table tops. CPL or continuous-press laminate is also used for kitchen furniture but mainly for flooring laminates. LPL or low-press-laminate is the by far dominating process for laminates onto surfaces of wood-based panels.

Among the latest novelties is a press-formed door, which is manufactured from a single piece of MDF. The face of the board is routed to a specific design and then hermetically wrapped with PVC-foil. Window frames are expected to be the next target area for MDF.

Bending and moulding of MDF now appears to have been satisfactorily solved by research. In previous efforts, bending and moulding have been done by making several cuts across the underside of the curve. The UK-based invention uses chemical impregnation system to soften the MDF fibers structure. After a predetermined period of treatment, the component can be formed into the desired shape. As the chemicals evaporate, firm bonding again takes place between the fibers.

Other major innovations include, e.g., exterior grade MDF with a 10-year guarantee. The product has been recently introduced in Europe, although it was first launched in 1983 in the U.S. market. Another novelty, formaldehyde-free MDF, has proven successful in market nichés where hygienic requirements are strict such as museums, hospitals, laboratories and schools.

The range of **particleboards** and **hardboards** has been widening as new melamine, paper and foil finished boards in various textures, colors and patterns have been designed. A clear distinction still prevails between merchant grades and value-added furniture and flooring grades. A fully water-resistant particleboard for timber-frame construction is still in the early stages of development. Fairly little diversification is foreseen in fiberboards on top of bitumen hardboard/softboard and some printed and wood-grained hardboards.

3.2.5 Composite Boards

Wood composite boards refer to structural boards made of both wood and other materials. Mixing wood fibers with, e.g., flax, cotton, straw, paper, plastics and various minerals are being examined worldwide. The underlying reasons for applying alternative material mixes are:

(1) Efficient use of wood resources, including wood waste recovery
(2) Optimization of physical properties of the materials
(3) Special properties (e.g., fire, fungi and moisture resistance)
(4) Cost reduction
(5) Recovery of process wastes and reuse of products which need to be disposed after their useful service lives

Mineral-bonded wood and fiber composite boards provide an excellent opportunity to address the growing trend towards affordable, fire resistant building materials. In addition, industrial and constructional waste can be recycled into mineral-bonded boards. For example, mixed paper waste, often difficult to recycle on its own, can be bonded with cement or gypsum.

Among composite boards, gypsum fiberboard and gypsum-bonded particleboard have achieved greatest commercial importance. Mostly German technology is applied for these two products.

In **gypsum fiberboard**, gypsum is the basic constituent, being either mined or recovered as a by-product from power plants (FGD gypsum). Cellulose is usually derived from recycled waste paper. Cellulose is distributed to the gypsum base to give the board its strength characteristics. The mix is passed through a mat former, water-sprayed and pressed in a continuous process. Various surface treatments can be applied as well.

Gypsum-bonded particleboard absorbs almost any kind of chipped wood waste. The wood furnish provides the hydration water necessary to set the gypsum plaster. This reduces the drying time and costs. On the other hand, longer pressing times and higher pressing loads are needed to prevent spring-back forces.

Scandinavian R&D efforts have introduced **gypsum flakeboard** and **cement flakeboard**. The former is seen as an alternative for gypsum fiberboard, while the latter serves for heavy-duty constructional purposes.

The Finnish gypsum flakeboard technology uses wet wood flakes, gypsum and chemicals. The constituents are mixed in a high-speed blender and moved to the form bin. Mats are formed on caul plates and are cut, weighed and stacked prior to pressing.

Cement flakeboard production does not differ significantly from the manufacture of cement-bonded particleboard. Mixing is applied instead of gluing, and cold pressing during eight hours is generally needed. The recent process developments have reduced pressing time to four minutes, which means that a single-opening press can be used. Cement flakeboard has aroused a great interest as a substitute for asbestos-based panels, which are prohibited for health reasons.

A joint British-South-African venture has designed a process where sawdust, straw and waste vegetable matters are bonded with polymer additives to form a versatile, **recyclable panel**.

Different feedstocks and chemical additives give variable properties such as high impact resistance, water resistance, fire retardancy or high malleability. The board demonstrates a better compression strength than timber, and its nail-holding ability is ten times that of particleboard. It is well suited for, e.g., pallet manufacturing and moulded furniture components.

These composite panels are interesting opportunities developed through technical research but in many cases market development has proved to be the bottleneck of production growth as it has not been duly considered in planning stages. Brazil should study the experiences of the other countries when adapting these products to local conditions.

3.3 Small-dimension Wood Products

3.3.1 Justification

The raw material qualities are changing fast in some parts of the tropics, and usually the trend is towards smaller-sized logs. This is caused either by move away from prime logging areas to secondary (logger over) sites, or it may result from an increasing use of lesser-known species and plantation woods. As a conclusion, future growth in the tropical forest industry cannot only come from increased logging, but will be derived from adding value to the gradually reducing harvesting volumes from natural forests, which will have to be obtained through legal sustainable forest management. Further processed products that are not locked onto just a few traditional species, will offer new applications for the lesser-used species and plantation woods, as well as waste flows.

In primary products like plywood or blockboard, combined species are already frequently used, and this trend will become a necessity even more in the future. Inner core veneers can consume various species, and even softwood cores are in use inside tropical plywoods. In solid wood, finger-jointing and edge-gluing are complementary methods for improving material efficiency and can joint small pieces of wood into wider dimensions for joinery and furniture stock.

The raw material shifts do not happen without a friction at the factory floor. Unless the primary processing technologies in sawing and peeling of logs are modified to turn out a better yield from smaller logs, the waste levels may increase substantially. This is particularly a problem for plywood industries in Indonesia, which are persistently running down their old machinery, ill-suited for smaller-sized logs coming in due to the raw materials scarcity. Worsening yields and mounting waste flows are reported from sawmills, too.

The situation leads easily into a rising supply of waste that has no economic use. Some fractions may find its way to local small processors, but a common solution is to burn or dump much of the waste as it is. This has high environmental burden, usually on waterways but also on atmosphere by means of CO_2 release. Unless the processing industry itself starts utilizing the waste streams more efficiently, there can hardly be any lasting solution to the problem.

3.3.2 Technology Needs for Utilizing Small-dimension Wood in Competition with Solid Wood

In general, the secondary tropical and plantation wood comes in smaller dimensions, of mediocre (or unconventional) qualities compared with traditional timbers, and sometimes with lower natural durability. These "handicaps" call for immediate improvements in wood drying, jointing and edge-gluing technologies, as well as in wood preservation and finishing of products. But like the example of rubberwood has shown, many of the obstacles can be overcome with sufficient research and development devoted to them in the early phases of development.

When considering the suitability of solid timber waste for wood products, it is necessary to take into account the following **performance criteria**:

- grade quality
- engineering properties (density, strength, stiffness, hardness, creep)
- stability
- drying quality (moisture content and drying degrade)
- machining characteristics (planing, drilling, turning and sanding)
- gluing quality
- over-veneering and surface finishing characteristics

A detailed knowledge of these characteristics is essential in the whole production process: product design, selection of appropriate materials and tools, selection of most suitable manufacturing techniques and methods and recommendations on intended service (end-uses) and environmental conditions.

The **technical information** on those timbers, which have been traditionally used for the production of high value wood products is generally well documented. However, changing timber resources has stimulated the industry in a number of countries to search for an alternative supply of species suitable for appearance products. Traditional techniques and methods used in the manufacture of wood products often have to be modified for "new" timbers to accommodate their different properties and processing characteristics.

Product standardization needs to be mentioned as an indirect agent for reducing wasting of wood. If more joinery items, for example, would be subject to nation-wide dimensional standards, there would be a lot less over-dimensioned window and door frames, and less of innumerable component sizes that hinder raw material optimization, etc.

Standards play an important role in the development of any industry, and the more so if it is export oriented one. They provide the basis for telling whether products exceed certain minimum requirements. To this effect, the larger producing countries have established national standards for sawnwood, wood-based panels and furniture, (far fewer standards for joinery than for furniture), based on those of the countries they export to. However, in spite of the existence of national standards, customers often insist on the furniture they buy being produced to one of the more internationally recognized standards, such as DIN in German, BS in the United Kingdom, or JIS and JAS in Japan.

3.3.3 Product and Market Opportunities

Garden and outdoor accessories are a growing market segment to products made of smaller-dimension hardwoods. Decking boards have become hugely popular in Europe, particularly in the UK and France. It is an easy product to manufacture, compact for transports so that approximately 4,000 boards can fill up a 40-feet container. Decking can be treated or untreated depending on the natural durability and climate of end use. Value-adding opportunities can be captured by means of cut-to length stock, preassembled fittings or ready-to assemble components. The further the products are elaborated, the steeper the added value curve increases. Usually much of the added value is created by the foreign garden/decking contractors and distributors, who conceptualize, assemble and distribute the final products.

Mouldings imports from tropical countries have continued to grow, even though they strive towards higher value-added products. Many of the producer countries in Asia are important exporters. The serious exporters have established large, specialized production facilities, equipped with modern highly productive machinery, the majority of which are manufactured in Europe (mainly Germany) or the Taiwan Province of China. The quality of the products is high; standards of both production planning and quality control have to be first-class. Some mouldings can be covered with a primer, others come lacquered or with foil or even wood veneer overlay. Thus they can accommodate finger-jointed and lower-grade solid wood, as well as MDF. Sapwood is normally allowed only on the non-exposed side of moulding (unless painted), or not allowed at all for the highest quality pieces.

On large industrial scale, mouldings are typically an OEM (original equipment manufacturing) segment, where high-speed moulders and standardized profiles and designs rule the market. When the number of profiles is kept limited, the mouldings operation can be run extremely efficiently. The situation becomes much more complex if a wider range of mouldings are produced for furniture components.

Tolerances for dimensions are strict: at around 0.1 mm in final product, and profiles vary enormously from simple to sophisticated. Mouldings in general are made of 14-16% moisture contents wood, but picture frames require 8-10%. There are various end-use segments ranging from interior decoration, skirtings and joinery to furniture, as well as trimmings in boats.

Parquet flooring, either in the form of planks, strips, staves or mosaic, can become an outlet for offcuts from sawmills, but there are stricter raw material requirements in terms of uniform color, grain pattern and dimensional stability. Common problems for using offcuts are associated with their cumbersome reprocessing, drying (into 8-10% moisture content) and wood stain in certain species. These factors can lead into an abnormal reject percentage in final product. Parquet can be delivered for exports either unassembled, prefabricated with tongue and groove, or ready-made finished product. It comes therefore either untreated or lacquered, and, e.g., rubberwood parquet is sometimes stained. Parquet is manufactured in thicknesses of 4-23 mm, in widths of 5-20 cm and in a great variety of lengths. There are roughly 30-40 tropical species commonly imported to parquet floors in Europe.

The production of wooden flooring is big business in some of the more advanced producing countries and large export-oriented industries have been established to cater for overseas market demand. There is only limited local use of parquet flooring within the producing countries in the tropics, but it is commonly found in some of the Latin American countries that have temperate-zone climates as well. The following are the main types of parquet being produced today:

- Traditional strips, up to 10 cm wide, in lengths of up to 1.5 m, with or without tongue and groove (T&G) at the ends. Thickness varies from as much as 25 mm to as little as to 15 mm, probably averaging around 18mm. These are produced on traditional planer moulders.

- Traditional parquet, similar, but only up to 7 cm wide (the majority 5 cm) and up to 50 cm long, with the same thickness range as the previous type. These are produced on special planer moulders to plane and groove the long sides, taking only smaller cross-sections, and special small double-end tenoners to produce the T&G on the ends. These machines are usually linked by conveyors and the strips are fed in from hoppers.
- Mosaic parquet (small finger-sized elements, machined by special equipment and then graded and assembled manually). Quality can vary, depending mainly on the color matching of the fingers at the time of assembly.
- Laminated parquet, three (or sometimes only two) layers, with one thin (around 5 mm) layer of narrow strips of expensive hardwood face, of random lengths, glued onto an underlay of about the same thickness made of a cheaper specie and/or a lower grade sawnwood. The panels thus produced are usually around 20 cm wide and up to two meters long. This type of parquet is produced on special machines, and usually sold with a sealed surface, ready to assemble.

The markets and producers alike seem to favor laminated parquet because it is easier and less labor-intensive to install.

Decorative and domestic articles of wood represent a larger export market for developing countries than builders' joinery and carpentry. Included are frames for paintings, photographs and mirrors (overlap with mouldings), tableware and kitchenware, caskets and cases, statuettes and ornaments, etc. In this product category original designs and handwork add truly value to the wood, and small-sized articles command relatively high price/weight ratio in exports. With the exception of machine-moulded items, most products tend to be artisanally produced and collected from larger areas for collective exports.

Picture frame subsegment is interestingly using also lesser-used species. Picture frames are simply high-quality mouldings, with surface finishes corresponding to the quality of the moulding, cut at a bevel and assembled. Although some picture frames are completely assembled locally, it is more common for exports to be in the form of standard lengths of the corresponding mouldings, complete with surface finishes. The factories producing these are smaller than the moulding factories and are equipped with special machines that either wrap a foil on the moulding or surface-finish it automatically. As the dimensions are usually small, this application provides opportunities for efficient use of offcuts and processing waste. Painted frames are a potential outlet for lesser-used species or plantation woods, which could replace higher-value species. Their best value could be optimized in other applications such as furniture.

Wooden packaging products could consume large volumes for small-dimension wood such a shorts and rejects from sawmills, and trimmings from veneer and plywood mills. Small consumer packaging of food, tea and coffee and spices have offered some outlets for small box makers, as well as fruit crates for thin shavings and veneer offcuts. For bulky handling of materials, pallets offer a recyclable solution. In many tropical countries, the benefits of palletized handling have not yet been fully realized due to non-standardized material handling techniques and variable logistical systems. The few industries that resort to pallets may require different dimensions and often the lowest cost scrap wood is used.

The trade of wooden packaging from tropical countries to big import markets is not common. It is much more common that some packaging end up to various foreign markets while they are used to carry other export products like fruits. For exports of pallets, the technical and recycling rules tend to be rigid for instance in the European Union (*Europallets* are interchangeable throughout Europe). European pallet production is highly automated, but some cases pallets from, e.g., Ghana have proven cost-competitive in the European market. Availability of suitable nails and collapsible pallet collars may become an obstacle for exports. Pallets are normally subject to drop tests and nail holding measuring before being given a burnt-in seal of approval under the *Europallets* scheme.

An extreme small-dimension wood product is **dowel** for wood joints. Dowel production is done with purpose-built machinery, and high drying requirements (6%) are set for the sticks used as raw material. Breaking and splitting are common problems for tropical woods, and through species testing needs to be done prior to launching an attempt to commercialize the product. Dowels are potentially important for waste reduction also in joinery and furniture-making. If properly applied, dowel-joining technique can notably reduce the wastage of wood in mechanical joints.

Small products for children are a growing, heterogeneous product segment. Wooden toys are normally a mass production business, and it can be divided to certain key segments:

- push-pull toys (cars, trains, boats)
- staking toys (wood-turned parts)
- building and construction sets (simple geometric forms)
- educational toys (puzzles of plywood)
- riding toys (bigger items)
- children’s furniture (dimensionally reduced, similar items but simpler materials, finishes than in regular furniture)
- playground items (recently standardized in the European Union)

Asian sources, predominantly China, have a controlling share of the world’s wooden toy business. The toy manufacturing can utilize extremely well the smallest pieces of wood available, thus rendering a high raw material efficiency. Color variation is not a great problem for toys: in fact it can be a positive product attribute. Besides, many items are stained or painted anyway. Rubberwood has become one major material, even though it has raised some health concerns over the use of boron in initial anti-stain treatment. Toy making is still highly labor-intensive craft. Children’s furniture items tend to be simplistic, but their strength and other health requirements need to be fulfilled by all prospective suppliers.

Furniture and parts: furniture enterprises that produce in larger series usually manufacture according to designs supplied by their clients, be it a local enterprise, such as a hotel, a bank, an insurance company or a school, or an overseas customer. The products are designed especially for industrial (serial) production, therefore factors such as the minimization of panel wastage and the commercial availability of sawnwood cross-sections, are taken properly into account. These types of contracts are important capacity-builders for the producers, both from a technical and a managerial point of view. They allow firms to improve their capabilities in costing, production planning and quality control, while still producing shorter series for the ‘safe’ local market. In some cases a foreign client may also introduce new waste-reduction measures or policies to handle waste according to their corporate guidelines.

Composites: material science innovation with the application of new technologies – especially chemistry – to existing processes and products can provide substantial opportunities for product differentiation in the long term. In the short term, these innovations usually focus on the more efficient manufacturing of established products from traditional or recycled raw materials. Product development should take into account the optimization of properties of tropical wood and synthetic materials to come up with unique product qualities and possible material cost savings. A couple of innovations that are currently attracting more attention are:

1. Wood fiber composite: composed of wood fiber and synthetic fiber, the product is easily shaped by moulding press and could be used as doors skins.
2. Wood-plastic composites: composed by wood powder and plastic, especially waste plastic, and could be used as material for moulding products.

3.4 <u>Energy Production</u>

3.4.1 Charcoal

Charcoal industry provides employment and livelihoods for a sizeable number of rural dwellers in many ITTO countries. The process is still labor-intensive, and it involves the use of either a kiln or an earth mound to facilitate controlled chemical reduction of wood into charcoal. Charcoal industry supports a wide range of workers before and after the actual burning activity. Logging, transporting, crosscutting, splitting, stacking, sacking, wholesale and retail distribution are the activities that make the supply chain. Competence throughout the chain dictate how wasteful the entire process is. In urban consumption, charcoal usually provides the secondary energy for cooking, baking, smelting, and heating. Charcoal production can also support local industries like iron smelting, lime and cement production.

The waste reduction efforts in charcoal burning are mostly focusing on introducing improved kilns, and better packaging to reduce damage in transportation. Total shift in raw material use away from logs may be difficult to induce, as logs or large-size offcuts are normally preferred over smaller wood pieces due to better yield and uniform composition of the kiln batch. Some European-owned wood processing plants (mainly sawmills) have established charcoal activities to consume their waste for instance in West Africa.

Quite extensive barbecue charcoal trade still takes place between tropical countries and Europe, the United States and Japan as the major importers. There are also special-grade charcoals, which fetch very high prices in export markets. These are used for industrial filtering purposes and pharmaceutical processes (so-called activated, or white, charcoal). Some timber species yield otherwise preferred thermal qualities of charcoal, which are much sought for in the Japanese and Korean restaurant business.

3.4.2 Pellets and Briquettes

In only rare occasions it is possible to fully avoid the burning of some of the residues flows in the wood processing plant. Sometimes residues occur in excess, in other cases their quality and demand simply do not meet. Burning in open air should be avoided in all cases, even though it may be perfectly legal. The priority should always be in finding a technically reliable solution for recovering process energy, electricity generation and heating. Processed wood energy products are giving better energy yields than unprocessed, mixed wood waste.

Wood pellets and larger products of refined biomass fuel – briquettes are usually cylindrical, compressed wood fuel products made of by-products of mechanical wood processing industry. The raw material is mostly dry sawdust, grinding dust, and cutter shavings, but pellets and briquettes can also be compressed from fresh biomass, bark and forestry chips. In that case raw material must be milled and dried before pelletizing.

The diameter of pellets is usually 6-10 mm and length 10-30 mm. The moisture content is low, 7-12%. The ash content is also low, about 0.5%. The weight of a bulk density of pellets ranges 650-700 kg/m^3. The net calorific value of pellets ranges 4.7-5.0 kWh/kg (16.9-18 MJ/kg). Hence, the energy content of pellets is 3 000-3 300 kWh/loose m^3, which is equal to 300-330 liter of light fuel oil. One tonne of pellets takes about 1.5 m^3 of storage space and is equal to 470-500 liter of light fuel oil. When exposed to water, the wood pellets get damp, swell and disintegrate. The pellets stand poorly direct moisture. The average properties of pellets and their volume comparison are presented in Table 3.1.

Table 3.1 Most Important Characteristics of Wood Pellets

Size	Diameter 6-10 mm, length 10-30 mm
Energy content	4.7-5.0 kWh/kg, (16.9-18.0 MJ/kg), i.e., about 3 MWh/bulk m^3
Moisture content	7-12%
Ash content	About 0.5%
Raw materials	Sawdust, cutter shavings, wood grinding dust
Bulk density	650-700 kg/m^3
Space demand	About 1.5 m^3/t
Comparison to light fuel	1 000 l oil = 2.1 t pellets 1 t oil = 2.5 t pellets
Comparison to wood chips	1 bulk m^3 chips = 0.28 bulk m^3 pellets 1 bulk m^3 chips = 0.18 t pellets

The shape of wood briquettes, which are larger than wood pellets, is round and square. The side length or diameter is 50-80 mm. During compression, the moisture content of wood is less than 15%. The dry mass content of wood briquettes is on average 1 000 kg/solid m^3. Due to the larger size briquettes are not usually suitable for automatic feed in small units, and also in large units the briquettes are crushed before combustion.

There are various country-specific standards for briquettes in Europe. In the absence of standards developed in the tropical countries for tropical timbers, some average properties of European briquettes are presented here for reference only (Table 3.2). It is worth remembering that the energy intensity is dependent on net calorific value, moisture content, bulk density and particle size of the fuel (and wood species) concerned.

In terms of basic compression techniques, there are three basic ways, depending on whether the material is compacted with pressure only, or with the help of an external binder, or systems with prior biochemical degradation before compressing.

Most technologies are of European or North American origin. The major categories used in tropical countries are piston, screw, pelletizer and roll briquettor types of plants.

Table 3.2 Example of a European Pellet and Briquette Classification

Characteristics	Unit	Densified wood			Densified bark		
		Group 1 Pellets	**Group 2 Pellets**	**Group 3 Briquettes**	**Group 1 Pellets**	**Group 2 Pellets**	**Group 3 Briquettes**
Diameter	mm	4…10[1)]	10…40	40…120	4…10[1)]	10…40	40…120
Length	mm	≤ 5 x D[2)]	≤ 4 x D[2)]	≤ 400	≤ 5 x D[2)]	≤ 4 x D[2)]	≤ 400
Density	kg/dm^3	≥ 1.12[3)]	≥ 1.00	≥ 1.00	≥ 1.12[3)]	≥ 1.00	≥ 1.00
Moisture content	%	≤ 10.0	≤ 10.0	≤ 10.0	≤ 18.0	≤ 18.0	≤ 18.0
Ash content[4)]	%	≤ 0.50	≤ 0.50[5)]	≤ 0.50[5)]	≤ 6.0	≤ 6.0	≤ 6.0
Net calorific value [4)]	MJ/kg	≥ 18.0	≥ 18.0	≥ 18.0	≥ 18.0	≥ 18.0	≥ 18.0
Sulphur[4)]	%	≤ 0.04	≤ 0.04	≤ 0.04	≤ 0.08	≤ 0.08	≤ 0.08
Nirogen[4)]	%	≤ 0.30	≤ 0.30	≤ 0.30	≤ 0.60	≤ 0.60	≤ 0.60
Chlorine[4)]	%	≤ 0.02	≤ 0.02	≤ 0.02	≤ 0.04	≤ 0.04	≤ 0.04
Durability	%	≤ 2.3[6)]			≤ 2.3[6)]		
Binders	%	≤ 2.0	≤ 2.0	≤ 2.0	≤ 2.0	≤ 2.0	≤ 2.0

1) Diameter can differ from reported ±10%
2) Max. 20% of pellets or briquettes can be 7.5 × D
3) Density is measured by producers, as reported in DIN 52182
4) As received, per dry matter
5) Ash content can be 0.80%, if wood used as raw material contains high levels of ash.
6) Measured with Ligno-tester

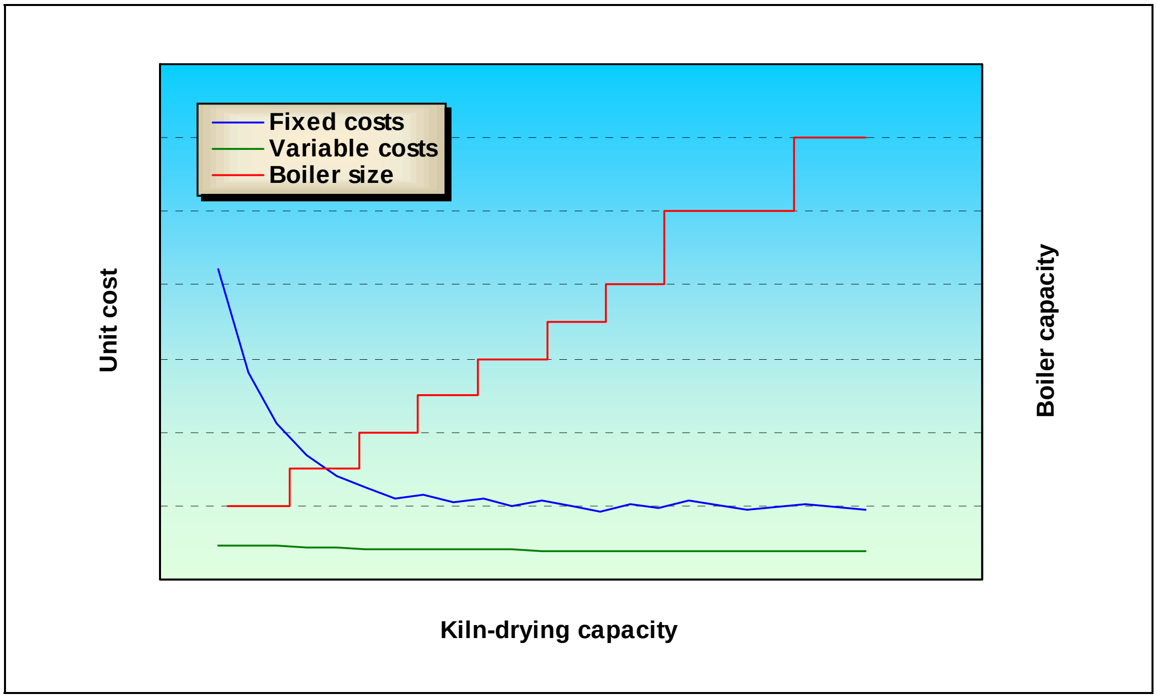
3.4.3 Energy Production at Sawmills

One of the main reasons for heat generation at a sawmill is for kiln drying sawn timber. Burning wet sawmill residues requires that boilers be designed to burn wet material. In addition, slabs, sticks and offcuts have to be crushed or chipped before using as fuel because otherwise automatic feeding in to boiler would not be possible.

The heat energy requirement in kiln drying depends on the initial and the target moisture content of timber, but usually sawmill residues contain more energy than what is needed to dry the mill's production.

The cost of heat generation with wood-fired boiler depends on the boiler capacity and average heat output. Figure 3.1 illustrates how the unit cost of heat energy decreases when drying volume increases. The heat output depends on the capacity of the boiler as well as on the fuel properties. When the boiler efficiency is high, heat energy is not wasted and the control of desired output is easier. In addition, the emissions will be lower than in an inefficient boiler plant.

Figure 3.1 Cost of Heat Generation and Boiler Size as a Function of Kiln Drying



3.4.4 Environmental Impacts of Waste Utilization

In planning and implementing investments for wood residue utilization, high priority should be given for projects where fossil fuels – especially heavy fuel oil – is replaced with wood residues. This would reduce emissions significantly.

Replacing coal with wood is effective in CO_2 emissions reduction. In addition, some returns for investment payback may be received through carbon offset trading. Sulfur dioxide (SO_2) emissions from wood residue combustion are practically negligible in comparison with most fuels. Therefore, the figures in Table 3.3 correspond to the reduction for every replaced MWh. Instead of CO_2 and SO_2 emissions, the other emissions cannot be reduced as effectively through wood residue use.

Table 3.3 CO_2 and SO_2 Emissions from Fossil Fuels

Fuel	CO_2 emissions	SO_2 emissions
	kg/MWh	
Heavy fuel oil	280	3.6-6.3
Light fuel oil	270	0.5-1.0
Coal	400-540	0.5-2.5
Natural gas	200	0
Wood	0	0

In addition to emissions reduction, replacing fossil fuels with wood residues would increase self-sufficiency in energy production increasing ability to withstand possible problems or interruptions in deliveries of imported fuels and leaving parallel resources for fuel costs.

3.4.5 Landfill Gas Production in Energy Cells

Landfill gas mainly originates from the anaerobic degradation of organic wastes. The gas composition depends mainly on waste being degraded. Usually methane (CH_4) and carbon dioxide (CO_2) make up 40-60% each. The remainder is nitrogen (N_2), oxygen (O_2) and traces of other compounds, such as hydrogen sulfide (H_2S). Landfill gas has a high heat value, typically about 20 MJ/m^3_n. Natural gas, for example, has a heat value of about 37 MJ/m^3_n.

The energy cell aims at enhancing the gas production from waste by providing more controlled decomposition conditions than a landfill. The conditions are adjusted to accelerate the anaerobic decomposition process.

Organic waste material can be broken down into nitrogen and carbon using the microbes present in the landfills. Typical nitrogen sources in a municipal landfill are, for example, food waste and green parts of garden waste. Wood waste is a carbon source. Other typical carbon sources are paper and paperboard. A suitable ratio between amounts of carbon and nitrogen (C : N ratio) is required for efficient microbial activity.

The requirements for wood waste treated in the energy cells are the following:

- wood waste impregnated with painting or chemicals is not accepted
- certain amount of inert material such as sand is acceptable in the wood waste
- wood waste should have small particle size, such as sawdust or wood chips
- the humidity of wood waste should facilitate adequate handling on site as well as proper anaerobic digestion in cell

There is not enough experience of energy cells with a high share of wood fraction. The role of wood waste as methane producer is small. However, wood waste, depending on its characteristics (particle size, humidity, and purity) can improve the structure of the digested waste.

3.5 <u>Other Uses</u>

3.5.1 Composting

Sawdust, bark and wood chips can be used as bulking agent in composting of organic municipal waste or sewage sludge from wastewater treatment plants. The need of bulking agent is about two volume units bulking agent per one unit of sludge (20%, dry substance). The need depends on the dry substance content of the sludge and the particle size of the bulking agent.

Using of sawdust and wood chips and bark as bulking agent in composting competes with other large-scale utilization methods. However, in composting the quality requirements are not as strict as in energy use and aged stores of sawdust and chips can be used. Also the bark material that has got mixed up with sand can be used in composting.

3.5.2 Mulch

Sawdust, chips, and bark can be used as mulch in gardens or vegetable/fruit cultivation. In farms, they can be used as litter in storing of manure. Mulch is used under trees, bushes or other plants in order to reduce weeds. In many countries, mulch is produced in a large scale and on commercial basis. Aged storages of sawdust and wood chips can also be used for mulch. In fact, in the plants producing mulching material wood chips are allowed to age in windrows prior to selling.

3.5.3 Other

Sawdust and wood chips can be used for recreational purposes, e.g., hiking trails and paths in parks at low costs. They are also suitable materials for use as absorbent material for accidental chemical spills. The current practice of giving away or selling solid residues to households is a practice that can be continued.

3.6 Combustion Technologies

The following pages give some examples of typical combustion equipment and boilers that are widely used in Europe for wood residue combustion. There are several manufacturers of wood-fired boilers. In most boilers, however, sawmill residues can only be used together with other higher-grade fuels because of the high moisture content. In addition, many boilers that are designed specially for the combustion of wet fuels are manufactured only in the output ranges starting from a couple of megawatts and are not relevant for small-scale use.

In the output range of 0.1-1.0 MW, there are several boilers that can use dry wood chips or pellets and briquettes. The production and distribution of processed wood residues should, however, be locally organized before that.

3.6.1 Wärtsilä Boiler Plants

Wärtsilä makes boilers for solid fuel, gas, and fuel oil combustion. For wood residue combustion, Wärtsilä has developed and patented Wärtsilä BioGrate boiler (Figure 3.2). Wet biomass fuels such as bark, sawdust, and wood chips with a moisture content of 35-65% (wet basis) can be used in this kind of boiler. Boiler versions for fuels with lower moisture content – such as sod peat, plywood and fiberboard industry by-products, or waste – are also available.

The BioGrate water and steam boilers are manufactured in two versions in the output ranges of 1-4 MW and 4-20 MW. The boiler plants are delivered in completely factory-made packages (up to 4 MW), or in combinations of prefabricated modules and on-site construction (above 4 MW). A turnkey delivery of a boiler plant includes the fuel storage, fuel conveyors, combustion equipment, boiler, flue-gas cleaning, piping, electrification, and automation, as well as the buildings for fuel storage and boiler room. The boiler plants are fully automatic and can be remote controlled.

The fuel storage is equipped with push-bar or drag-chain unloaders. Fuel is transferred with drag-chain conveyors into the fuel bin in the boiler room and then fed into the primary combustion chamber by a stoker screw through an inlet in the center of the grate. The grate is divided in sections, each of which can be programmed to rotate at a desired speed to ensure stable feeding and combustion of the fuel. The fuel feed is automatically controlled according to the outlet temperature of boiler water. The primary and secondary combustion chambers are provided with refractory linings in order to support combustion of wet fuels. The combustion air is fed in three stages. From the secondary combustion chamber flue gases flow into a fire-tube boiler, which can be assembled either vertically or horizontally. If steam is produced, the boiler can only be horizontally installed.

According to the manufacturer, the efficiency losses due to the high moisture content of bark and sawdust are minimized using an effective heat-recovery system (low flue-gas temperature) and low excess air.

Depending on local emission regulations, the boiler can be provided with different flue-gas cleaners like multicyclone, wet scrubber, or electrostatic precipitator. The flue-gas condensation unit, which is optional, increases the capacity by 10-30% depending on the fuel moisture and the return temperature of district heating water.

Manufacturer's emission guarantees for BioGrate boilers are:

- NO_x < 50-100 mg/MJ, depending on fuel nitrogen content
- CO < 120 mg/MJ
- solid particles < 50, 100 or 200 mg/MJ, depending on selected flue-gas cleaner

Measured emissions of BioGrate boilers are presented in Table 3.4.

Figure 3.2 Wärtsilä BioGrate Compact 1-4-MW Boiler Plant

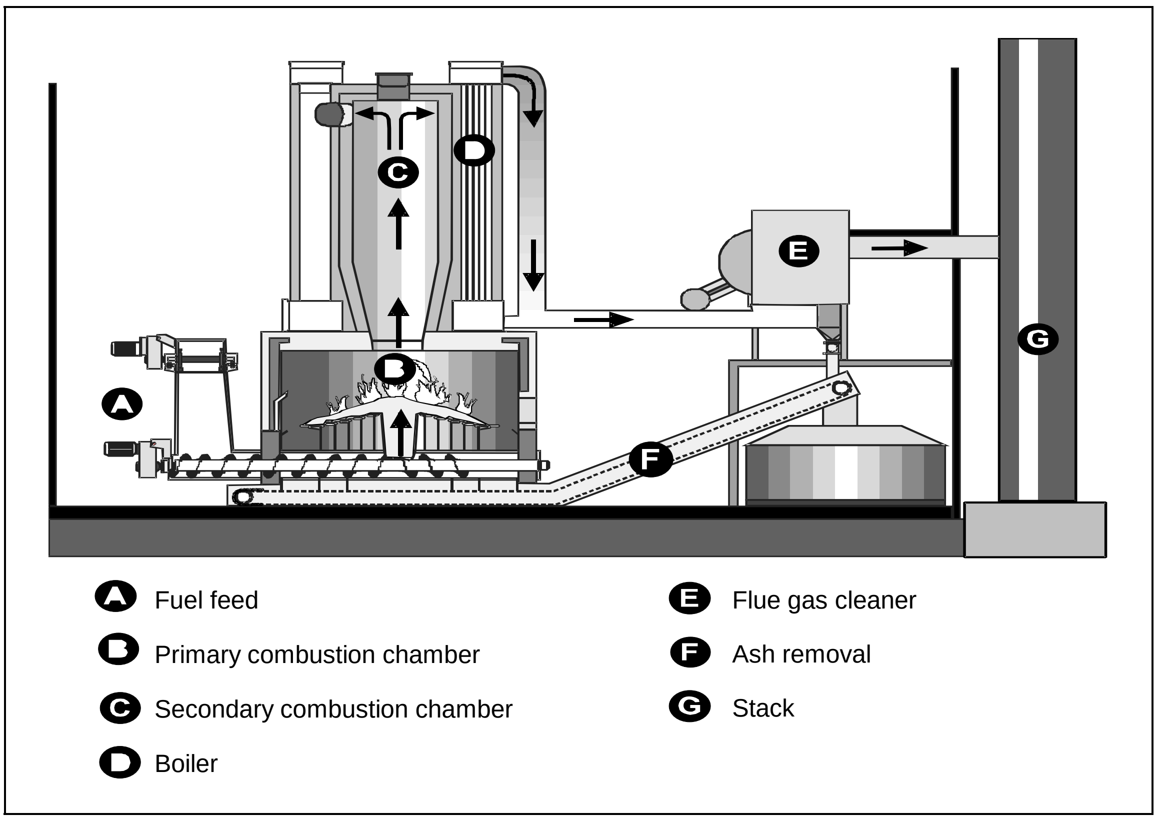


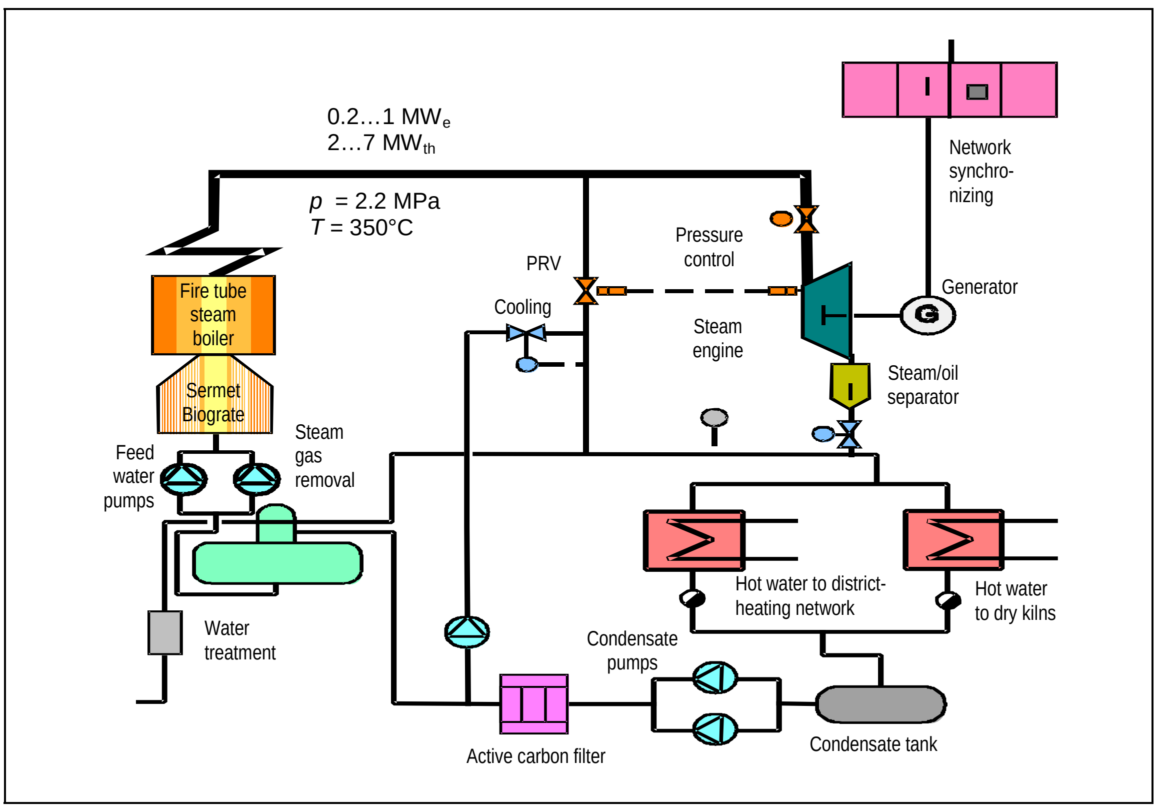
Table 3.4 Measured Emissions, BioGrate Boilers

Boiler plant	**Wärtsilä BioGrate**					
Capacity, MW	4.0	3.5	3.5	3.5	3.5	1.25
Fuel	Wood chips	Bark and sawdust (50–50)	Bark and sawdust (50–50), and sludge	Bark and sawdust (50–50), and RCG	Bark and sawdust (50–50), and PDF	Sod peat
Boiler capacity, MW	4.0	2.82	2.12	3.01	1.5	1.15
O_2, %	3.5	4.3	4.4	4.7	5.4	3.1
Combustibles in ash, %, dry basis		20	13	13.3	15	22
Fly ash, mg/$m^3{}_n$, O_2 = 6% (dry gases)	140	262	254	131	170	241
CO, mg/$m^3{}_n$	10	15	11	18-315	11	260
NO, as NO_2, mg/$m^3{}_n$	170	235	373	339	242	441
SO_2, mg/$m^3{}_n$	..	< 6	40	<7.5	<6	..
HCl, mg/$m^3{}_n$	..	< 3	< 3	< 3	< 7	..

PDF – package derived fuel.

Small-scale electricity production based on steam engine or turbine can be combined with a Wärtsilä BioGrate boiler plant. Typical capacities of small-scale plants are 0.2-1.0 MW of electricity and 2-7 MW of heat. Process scheme of a combined heat and power plant is presented in Figure 3.3.

Figure 3.3 Process Scheme of Combined Heat and Power Plant by Wärtsilä



3.6.2 Termopoint Boiler Plants

Termopoint manufactures solid fuel boiler plants in the output range of 1-10 MW (Figure 3.4). Wood residues, chips, and peat can be used as fuel.

The fuel storage is equipped with chain unloaders, and a chain conveyor moves the fuel from unloaders into the boiler funnel. Fuel feed from the funnel onto the grate of the boiler is controlled with two hydraulically operated guillotine registers. A mechanical inclined grate consists of rows of bars. Every second of the bars is hydraulically operated. The frequency of the grate motion is linked to boiler output, which increases with the frequency. Primary air is fed in three sections from underneath the grate. Air feed through every section can be regulated. In addition, secondary air through several air registers is fed above the grate in order to ensure complete combustion. Air can be preheated in case of wet fuels. Ash is collected on the ash grate after the moving grate. Ash grate opens automatically a couple of times a day, dropping ash on a wet ash conveyor that takes it to ash container. Water in the ash conveyor extinguishes ash and prevents gas leakage through the conveyor. The boiler is shown in Figure 3.5.

Figure 3.4 Termopoint Boiler Plant

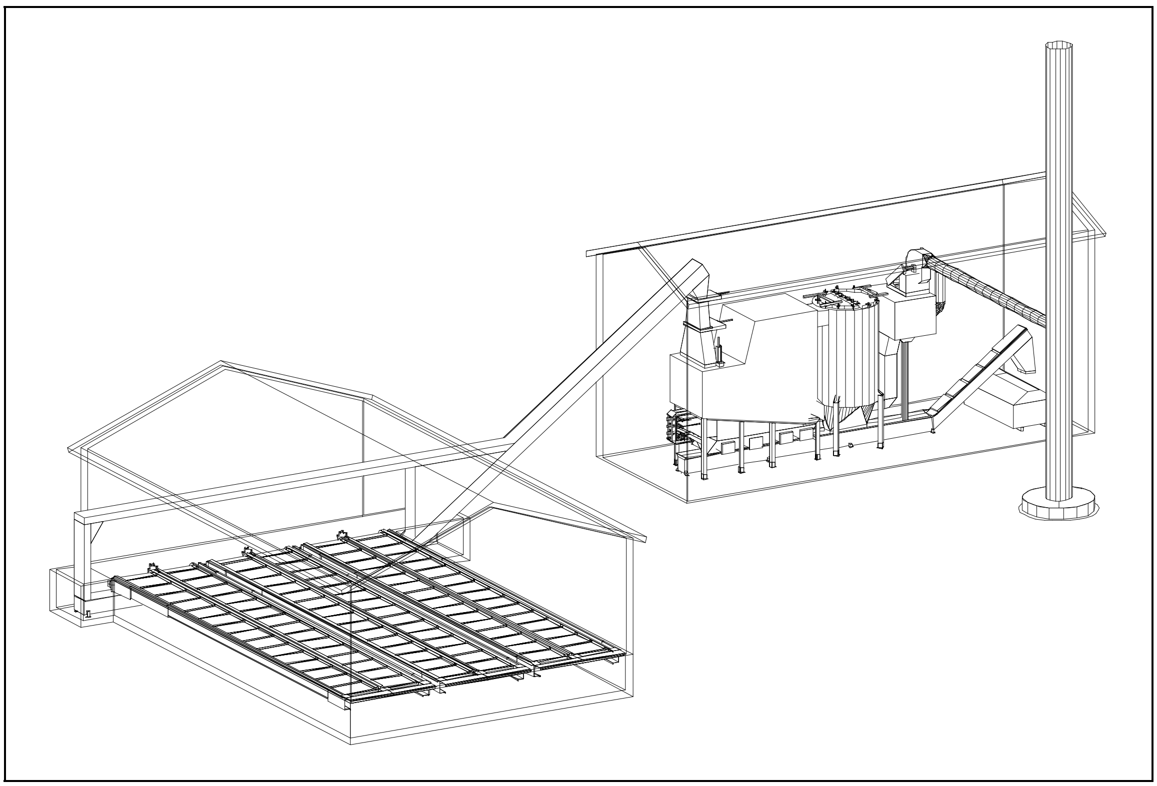
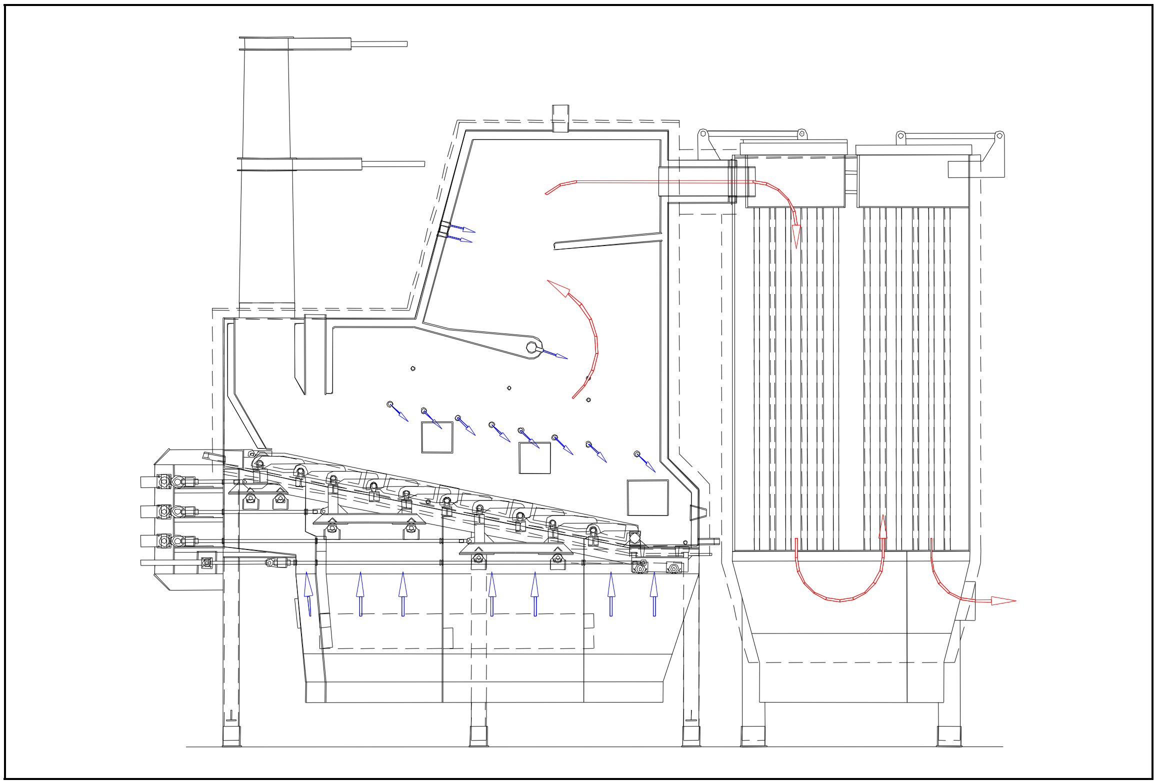


Figure 3.5 Termopoint Boiler



The combustion chamber, which has water tube walls with refractory linings, is designed to accomplish long residence time for gas in the chamber and to ensure complete combustion. The heat is partially transferred in the combustion chamber but mainly in a separate convection section that consists of fire tubes or a fire-tube boiler. After the convection section, the flue gas enters a flue-gas cleaner (e.g., multicyclone or electrostatic precipitator). The boiler plant is controlled by programmable logic and is fully automatic. The flue-gas condensation unit is available as an option.

Measured emissions of a Termopoint boiler are presented in Table 3.5.

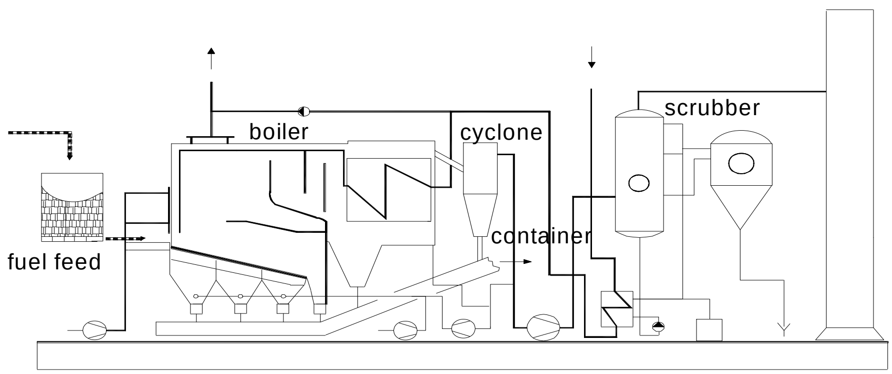
Table 3.5 Measured Emissions of Termopoint Boiler

Boiler capacity	4.0 MW
Fuel type	wood chips
Maximum fuel moisture content	42.4% (wet basis)
O_2 content	4.8%
CO emissions	0.06%
NO_x emissions	120 mg/MJ
Fly ash emissions	99 mg/m^3_n

3.6.3 Ansaldo Volund Boiler Plants

Ansaldo Volund delivers boiler plants for various fuels including wood residues (Figure 3.6). The output range of the delivered boiler plants for wood fuels is 4-43 MW for water boiler plants and 19-64 t/a for steam boiler plants.

Figure 3.6 Ansaldo Volund 4-MW District Heating Plant in Thyboron, Denmark



Main fuel: wood chips with maximum moisture content 55% (wet basis).

Fuel is carried with a bucket from the fuel storage to the hopper that is in front of the boiler. Fuel is fed onto the boiler grate with a hydraulically driven piston and is carried forward on the grate by movable fire bars. The feeding of preheated combustion air through the grate, which is divided into several air zones, can enhance the drying of the fuel.

The combustion chamber of the boiler is designed for loads less than 0.2 MW/m^3 in order to ensure as complete gas combustion as possible. Combustion air and recirculated flue gas are fed through several air nozzles in the chamber walls. Convection part of the boiler is divided in tube sections for automatic maintenance of the flue-gas temperature between 100-120°C.

The boiler is equipped with a scrubber/heat recovery system that, according to the manufacturer, provides savings of approximately 10% in fuel input. The system is of counterflow type. Condensation from the system is led into the drain. Before discharge, the condensation is cleaned in a sedimentation tank and neutralized. Control, regulation, and monitoring of the boiler plant are based on a programmable logic system.

The electric output of a biomass-fired CHP plant from Ansaldo Volund is 4.7 MW and the thermal output – including flue-gas condensation – is 13.8 MW. Fuel consists mainly of wood chips, sawdust and wood pellets. Maximum fuel moisture content is 55% (wet basis). Fuel is taken from the fuel storage with a bucket as in the previous example, but in this case it is fed first into a buffer silo. Two pneumatic throwers blow the fuel from the buffer silo into the furnace where partial drying and gasification of the fuel takes place before it drops on the grate. Combustion of the fuel takes place on a vibrating grate with three air zones. Secondary air feed and flue-gas recirculation are quite similar to the 4-MW boiler described above. Slag and ash are automatically removed and gathered in containers. An electrostatic precipitator re-moves solids of flue gas. In addition, the flue gas flows through a condenser if higher thermal output is required.

The steam pressure and temperature in turbine are almost of power plant scale (77 bar and 525°C). Steam is cooled after the turbine in district heat exchangers. The boiler plant is controlled on a programmable logic system. Local emission limits for the plant are:

- CO 270 mg/m^3_n
- NO_x 450 mg/m^3_n
- Solid particles 40 mg/m^3_n

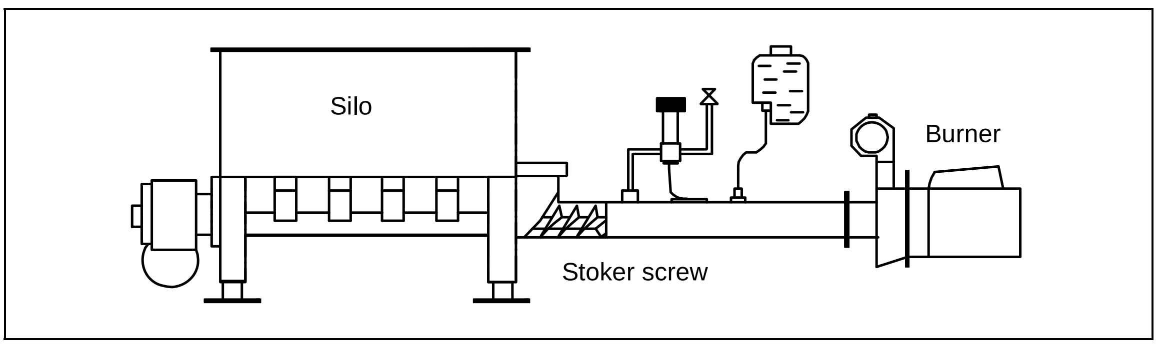
The limits are based on 10% of oxygen in dry flue gas.

3.6.4 Stoker Boilers

Pellets and briquettes are used increasingly in Europe, especially in Sweden and Denmark. They are usually made of sawdust or shavings. Processing of wood residues increases fuel price but, on the other hand, it also makes fuel easier to handle and lowers investment costs on combustion equipment. Due to the compressed form, these fuels can be economically transported for longer distances. They can be directly used in existing boilers or boilers can be easily converted for the use of these fuels. In Scandinavia, processed fuels are normally used in stoker boilers (Figure 3.7).

Stoker burners are used in output range from 10 kW up to 0.5-1.0 MW. In addition to pellets and briquettes, wood chips and sawdust mixed with other fuels can be used in stoker burners. Most stoker burners cannot use fuels with a moisture content of more than 30-40% (wet basis). Stoker burners can be installed to existing oil- or gas-fired boilers and, therefore, are very suitable for conversion. The investment on burner conversion is low but the boiler output decreases.

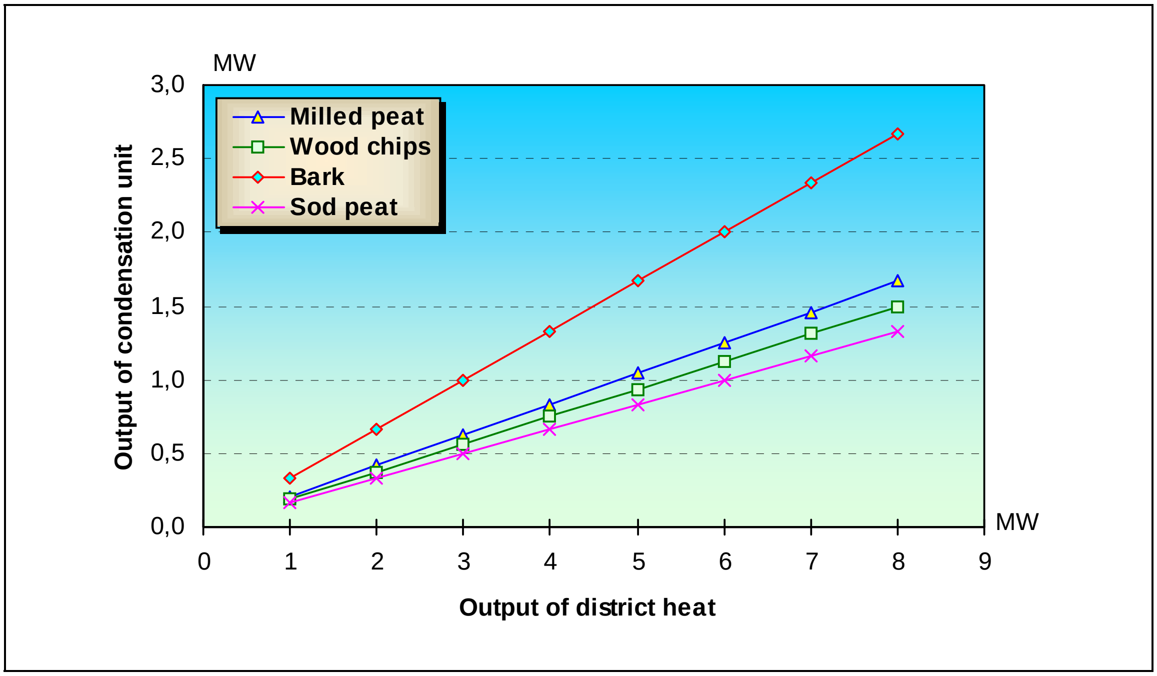
Figure 3.7 Stoker Boiler



3.6.5 Flue-gas Condensation Units

Flue-gas condensation can increase boiler output by 10-30% depending on the moisture content of fuel, the temperature of heated water, and the type of fuel used (Figure 3.8). Since the increase in output is accomplished without an increase in fuel consumption, the boiler efficiency increases in same ratio as the output. The boiler efficiency can exceed 100%, when it is calculated according to the lower heat value of the fuel.

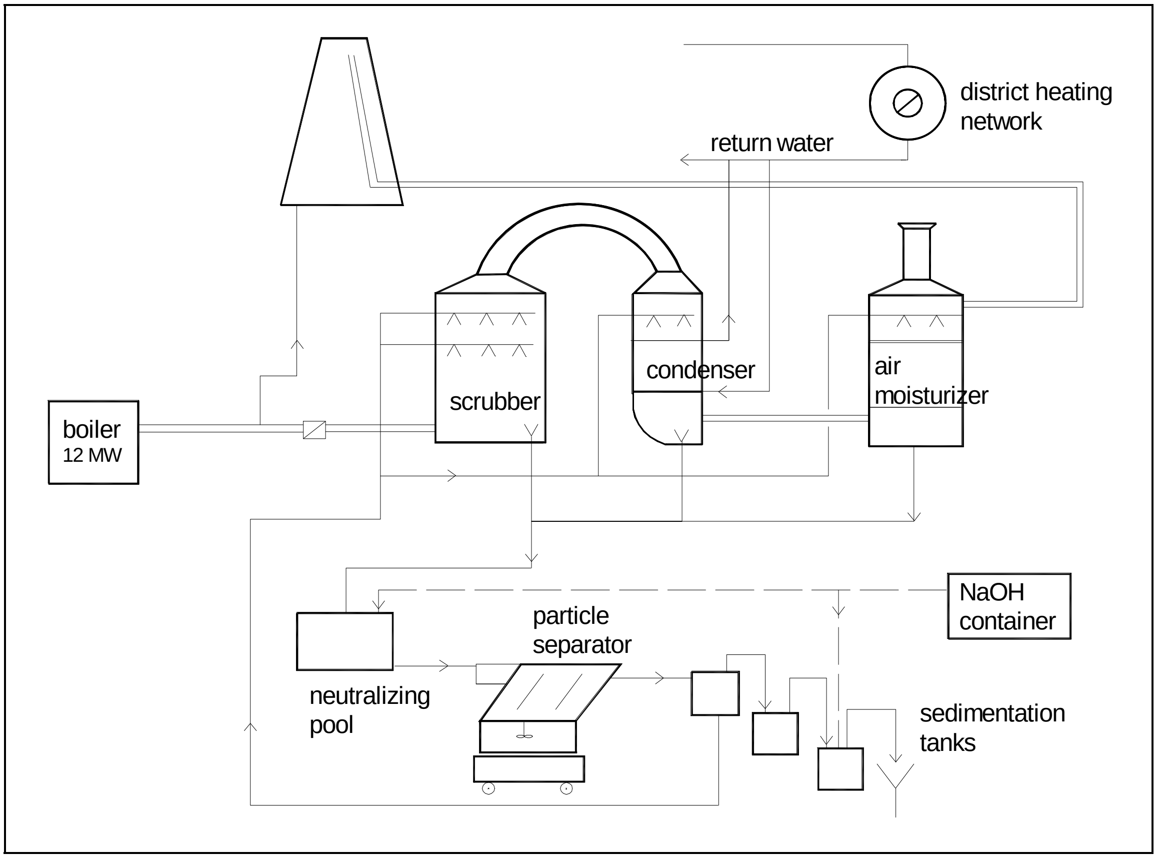
Figure 3.8 Heat Output of Condensation Unit as a Function of District Heat Output



A condensation unit usually includes a scrubber. Therefore, boiler emissions, solid-particle emissions in particular, decrease clearly. A process scheme of a condensation unit is shown in Figure 3.9. The district heating plant has a 12-MW grate boiler that is fired with bark, sawdust, wood chips, and sod peat. The flue-gas condensation unit consists of a scrubber, condenser, and air moisturizer. The flue gas from the boiler first enters the scrubber, where NaOH solution is injected against the flow from the top of the scrubber. The solution is removed from the bottom of the scrubber and neutralized before particle separation. Neutralized excess water goes to drain through discharge pools, and a part of it returns to the process.

After the scrubber, the cleaned flue gas enters the condenser, where heat recovery takes place. The condenser is a heat exchanger where district heating water goes in and water from flue gas condenses on the outer exchange surfaces. The condensation typically begins when flue-gas temperature has decreased to 60-70°C. After the condenser, flue gas enters air moisturizer, where combustion air is preheated and simultaneously moisturized with washing solution. After the moisturizer, the combustion air is saturated and the heat for saturation will be recovered again in the condenser.

Figure 3.9 Condensation Unit



The scrubber together with a multicyclone decreases particle emissions almost as well as an electrical precipitator but it reduces other emissions as well. Typical separation efficiencies are:

- particles 80-99%
- sulfur compounds 60-99%
- chlorine 80-95%
- heavy metals 60-80%

The cost of the scrubber-condensation unit increases the total costs of the boiler plant usually in proportion to the increase in output, but the investment outlay per capacity does not grow.

3.7 <u>Case: Installation of an Energy Generating Unit in a Tropical Sawmill Complex</u>

The following case describes a registered sawmilling company in a Central African, which is financially backed by a German group. It is considered one of the strongest tropical wood processors on the African continent. The person in charge of the boiler purchase is an expatriate forester.

Waste wood streams are coming from sawmills processing both white and red woods. About 80% of waste generated is in offcuts, shavings and other pieces of wood in all sizes, and 20% in sawdust. Estimated moisture content is about 60-70%. More specific data is in Table 3.6.

Table 3.6 Evaluation of Calorific Value of Waste Wood Streams Available

	Volume	**Density**	**Moisture content**	**Calorific value**	**Calorific potential**
	m^3	kg/m^3	%	MJ/kg	GJ/a
Wood waste (green) of red tropical wood	63 360	850	2	9.21	496
Wood waste (green) of white tropical wood	23 320	650	2	8.37	127
Wood waste (dried) of red tropical wood	30	650	2	15.49	0.3
Wood waste (dried) of white tropical wood	650	400	2	14.65	4

The current environmental problem results form burning the waste in open air. The smoke shrouds the village on certain wind conditions, exposing the community to a health risk. The Company has therefore decided to study the option to generate electricity for its kiln operations instead. Also the villagers themselves would be potential users of the add-on electricity.

Surveys carried out revealed that the current peak period of electricity consumption for the company were on the level of 1 100 kW, and for a short off-peak period (five hours per day) on 600 kW. The "average" requirement was established at 900 kW. Seasonal and irregular variations may result depending on the season. Requirements for the village were considerable lower at 120 kW peak between 6 and 10 p.m. and on average 100 kW. Since the company installed a second drying facility and additional planing line, their requirements raised to 1 640 kW in peak periods.

Diesel generators are used to supply the village. Villagers are currently outside the distribution system by the national electricity utility, and pay no fees. It is likely that a change into a charging electricity grid would alter the consumption habits of the inhabitants.

It has been estimated that the net capacity of the electricity generation would amount to 2.5 MW during peak periods and to 1.5 MW off-peak. No heat co-generation is deemed necessary, so the electricity generation system will have to operate on the condensation basis, connected to the river adjacent to the plant. Full energy autonomy is the Company target. Wood fuel would be used to supply 1.5 MW, while the rest would be generated with diesel to meet the peak demand.

Following from the initial assessment based on the above requirements, the Company has concluded the following parameters for the investment:

- a series of crushers would be installed (one for redwood unit, one for remanufacturing unit)
- a set of storage silos providing a three-day operating autonomy, including an extraction system
- dispensing and transfer conveyor systems
- combustion unit with ash removal, steam boiler and a super-heater
- water treatment with de-gassing system
- smoke extraction
- dust removal from smoke
- stack
- turbo-alternator or steam engine
- control cabinet for automatic operation and coupling
- personnel training

All the electricity generating units are already available in the existing plant. Remaining waste could be possibly incinerated but detailed study is needed. The boiler supplier would be sought for, and considered as an assembly contractor. Consideration will be given to an add-on slabbing unit later on. This would require the supply of steam at an average pressure of 10-15 bar, and at a rate of 10.5 GJ/h.

Special attention must be given to the production system currently under consideration, bearing in mind both the level of investment and local conditions. Certain flexibility on the types of waste is warranted to maximize biomass utilization as a whole. The level of automation is subject to operator capability assessment and other conditions at the plant. Care has to be taken on addressing the discharges and other environmental needs properly. Robustness and reliability are prioritized instead of technological finesse.

So far, the challenges in finding suppliers have been insurmountable. Country risk has been the primary obstacle in clinching a deal with any European technology supplier.

4. REGIONAL CASE STUDIES

4.1 Malaysia

4.1.1 Wood Raw Material and Wood Waste Flows

According to surveys by the Forestry Department of Peninsular Malaysia the biomass available for harvesting varies considerably. The average biomass available in the first logging operation is 76 m^3/ha, but only 45 m^3/ha is removed as sawlogs. With the damage to the residual stand, calculated to be 20 m^3/ha, the ratio of 1 to 1 in volume of logs to volume of logging residue is confirmed in Malaysia. The value of logging residues from the second logging operation is much lower than from the first logging operation due to the higher volume of non-commercial species and its smaller diameter.

On average, forest stands undergoing first logging operations will have up to 43 different species, while logged over forest stands can have up to 60 different species. In Malaysia, enrichment planting is carried out after the first logging operation in order to enhance the stocking density of the stand. The logging operation of logged-over forest is usually carried out after the stipulated time-period (usually 30 years), although in some cases this requirement is breached. Table 4.2 provides a summary of the average characteristics of the primary and logged-over forest stands in Malaysia.

Table 4.1 Yield from Tropical Forest in Malaysia

	First operation, virgin forest		Second operation, logged-over forest	
	m^3/ha	%	m^3/ha	%
Above-ground biomass	93	100	127	100
- less logging residues	28	30	67	52
- less damage to residual stand	20	22	0	52
Usable logs	45	48	60	48
- sawmill residues	14	15	30	24
Usable sawn timber	31	33	30	24

Source: Forestry Department of Peninsular Malaysia 2002

Table 4.2 Economic Characteristics of Forest Stand

Feature	Primary Forest	Logged Over Forest
No. of species	43	60
No. of commercial species	37	30
Average diameter (cm)	40-60	35-45
Yield per tree (m^3)	3.2	3.7
Average yield (m^3/ha)	65	90
Logging cost (USD/m^3)	35	30
Value of stand (USD/ha)	1 200	600

Source: Forestry Department of Peninsular Malaysia 2002

Rubberwood (*Hevea brasiliensis*) is a good example on how once perceived waste wood has found a strong niche market. Today, rubberwood is the single most important wood raw material for almost all the downstream wood industry in Malaysia. At the end of 2002, the total land area under rubber cultivation was 1.4 million ha in Malaysia. The rubber plantations are established primarily for latex production, and they must be replanted every 25 years. The annual replanting rate in Malaysia is 49 000 ha or 3.5% of the total cultivated area.

Table 4.3 provides a summary of rubberwood production from rubber plantations in the country. The wood waste generation appears to be large, but it includes materials down to 5 cm in diameter. The average sawn timber yield is 25%, which is accounted for by the extensive use of makeshift portable band sawmills. However, in more established sawmills, higher recovery rates of up to 30% have been reported.

Table 4.3 Annual Yield from Rubber Plantations in Malaysia

	Average yield	Total yield	Share
	m^3/ha	million m^3	%
Planting density	240	11.8	–
- less branches and treetops	60	3.0	–
Above ground biomass (> 5 cm diameter)	180	8.8	100
- less logging residues	140	6.8	78
Usable logs	40	2.0	22
- sawmill residues	30	1.5	17
Usable sawn timber	10	0.5	5

Source: Malaysian Rubber Board

The main reason that has hampered the recovery of waste wood from rubber plantations in Malaysia is the low price of logs (USD 20 per m^3). Furthermore, the lack of standard grading rules for sawn rubberwood also lowers the recovery, as the economic value of wood waste is subjective. Another reason for the low recovery of wood waste from rubber plantations is the fragmentation of the cultivated area, most of which are small holdings. When the plantations are owned by downstream wood processors, the recovery of wood waste is significantly high, even more than 90%. A good example is Merbok's MDF mill in the northern state of Kedah, which chips the biomass in the logging site and has reported recovery of up to 95%.

In any case, rubberwood stands out as an excellent case in which waste wood was put to good commercial use in almost all the subsectors of the wood industry. Further, the demand for rubberwood has grown rapidly over the years that its demand is high not only within the country but also within the Asian region.

Recovery rates in the **plywood industry** in Malaysia have also stagnated at about 50%, and in 2002, it was estimated that the total wood waste produced by the sector was in the range of 4.5 million m^3. Further, as peeler log diameter reduces, the recovery rate is expected to decline further. Some 14% of the residues are in the form of peeler core, while another 23% are in the form of veneer trimmings. This residue is often used to fuel the boilers to generate steam for veneer dryers. The balance of the residues is in different forms and quantities. The peeler cores from the plywood industry is often converted to pallet material, while trimmings, in some cases, are recycled as core material in plywood.

4.1.2 Mill Case Studies

Two case studies, involving two sawmills were carried out to ascertain the reality of wood waste production and utilization in Malaysia (Table 4.4).

- **Bangi Sawmill** procures most of its logs from the states of Kelantan and Terengganu on the east coast of Peninsular Malaysia. The raw material is transported almost 300 km to the sawmill. Despite the long transportation distance for logs, the sawmill that exports 100% of its sawn timber prefers to be located at its current location close to a port.

  The company's production cost of sawn timber is about USD 115 per m^3 (including direct and indirect costs of production). The average profit from the sale of sawn timber (graded) is in USD 200-300 per m^3.

The sawdust produced is incinerated at the mill site, while the offcuts are recovered into small dimension stocks to be sold to the nearby laminating plant at USD 50 per m^3. These short dimension stocks are not kiln-dried. The rest of the wood waste (including cants and bark) is used for fuel the boiler (capacity 15 t of steam/hour) that provides steam for the dry kilns.

The sawmill management indicated several problems associated with increased use of wood waste at the mill:

(1) **Limited capacity for processing wood waste** (about 500 m^3/month). There are only two laminating plants in the vicinity, although there are nearly eight sawmills.

(2) **Obsolete machinery.** Most of the bandsaws at the sawmill are more than 15 years old. For a sawmill that does not have a concession, there is little incentive to invest in modern technology. The log supply is inconsistent, as the sawmill must rely on traders. Currently, concession areas are mostly awarded to parties that are not interested in the wood-based industries.

(3) **Outdated grading rules.** Tropical sawn timber is graded based on the Malaysian Grading Rules formulated in the 1960s. They provide for a high sawing variation, which should be reevaluated if the amount of wood residues generated is to be reduced during processing.

(4) **Lack of enforcement of waste-reducing practices.** The Department of Environment and the Forest Department are relatively relaxed in their attitude toward reducing wood waste. Indiscriminate dumping of wood waste is relatively rampant in the area, which was witnessed during the site visit.

(5) **Low cost of disposal.** It costs only USD 15 for an 8-t truckload of wood waste to be disposed of. The disposal does not necessarily be on official landfills, but can also include indiscriminate dumping.

- **Lim Ah Soon Sawmill** procures rubberwood logs mostly from the states of Melaka and Johor in southern Peninsular Malaysia.

  The average production cost of sawn rubberwood is USD 75 per m^3, and the average profit of is about USD 100 per m^3. However, the biggest issue related to rubberwood sawmilling is low recovery, usually about 25-30%.

  The demand for rubberwood is high in the country, which provides an avenue to recover and use the wood waste generated. About 50% of the sawmill offcuts are re-sawn into small-dimension stocks for the production of laminated boards; the other 50% are sold to MDF manufacturers located within 100 km from the sawmill. The selling price of an 8-t truckload of offcuts is USD 100. The rest of wood waste (including cants, bark and sawdust) is used to fuel the boiler for steam generation for the dry kilns. The sawmill has a kiln-drying capacity of 100 m^3 per month. It has also invested USD 100 000 in a laminated plant, which had a payback period of one year.

  The sawmill management suggested that the potential for increased use of rubberwood waste and residues could be achieved through:

(1) **Establishment of a central collection depot.** Because most of the rubber land is in small holdings, economic harvesting and collection of wood waste is not very viable. As a result, only about 22% is removed from the forest as logs while the rest is left behind. If this waste were recovered, it could be chipped or re-sawn into small-dimension stocks. So far, this has not been very successful

(2) **Incentives for better utilization of wood waste.** They could be tax rebates or direct incentives. Waste wood recovery and use in rubberwood production is more

successful compared to wood waste of tropical forests, as the demand for rubberwood is higher in the secondary wood products industry in Malaysia.

The two sawmill cases confirm that the utilization of mill residues is not as problematic as logging residues. A primary reason is the long distance from the logging site to the mill, which is a problem faced throughout the country.

Table 4.4 Main Features of Sawmill Cases

Feature	Bangi Sawmill	Lim Ah Soon Sawmill
Established	1988	1995
Production capacity	2 000 m^3/month	1 000 m^3/month
Species	Meranti	Rubberwood
Sawn timber price (USD/m^3)	550-750	250
Log price (USD/m^3)	150-200	20
Sawn timber yield	Average of 80%	Average of 25%
Wastage	20%	75%
Types of waste	Sawdust (15%), offcuts (25%), Others including bark (60%)	Sawdust (15%), offcuts (35%), Others including bark (50%)
Recovery from waste wood	95%	95%
Kiln drying, boiler	Yes	Yes
Remanufacturing	No	Yes (laminated board)
Source of raw materials	From the east coast , 400 km away	From the south, 150 km away
Production workforce	Contract	Contract
Investment	USD 250 000	USD 150 000
Opinions of mill management on wood waste utilization	Need better regulatory measures and government incentives	Need central collection depot and government support

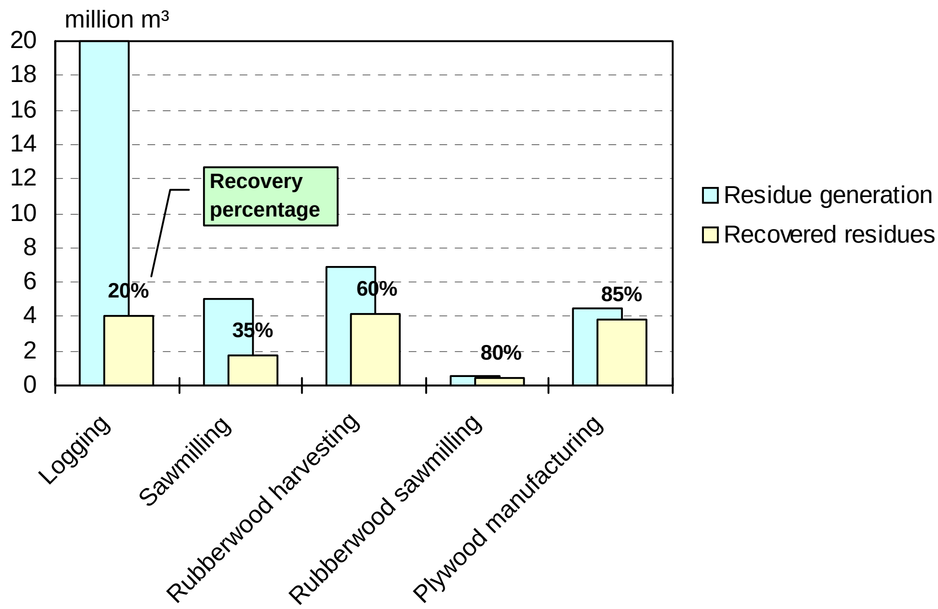
4.1.3 Volume of Waste Utilization

The recovery of wood waste and residues varies considerably between the various phases of processing. Only 20% of logging residues are recovered whereas as much as 85% of plywood making residues are recovered (Table 4.5 and Figure 4.1). The average recovery of residues in Malaysia was 38% in 2002, but it is increasing. Logging, rubberwood harvesting and plywood making all yielded about 4 million m^3 of residues meanwhile sawmilling yielded about 2.2 million m^3 that same year.

Table 4.5 Generation and Recovery of Wood Residues in Malaysia in 2002

Sector	Total residues	Recovery	Utilized residues	Share
	m^3	%	m^3	%
Logging	20 000 000	20	4 000 000	28
Sawmilling	5 000 00(	35	1 750 000	12
Rubberwood harvesting	6 860 00(	60	4 116 000	29
Rubberwood sawmilling	588 000	80	470 400	3
Plywood making	4 500 00(	85	3 825 000	27
Total	**36 948 0(**	**38**	**14 161 40(**	**100**

Figure 4.1 Generation and Recovery of Wood Residues in Malaysia in 2002



4.1.4 Economic Losses Due to Unutilization

About 23 million m^3 (62%) of wood waste and residues were left unutilized in the forest, dumped or incinerated in 2002 (Table 4.6). Most of this unutilized portion was generated in the forest. Logging residues present the largest potential by volume for increasing the utilization of residues.

Table 4.6 Generation and Recovery of Wood Residues in Malaysia in 2002

Sector	Total residues	Unutilized	Unutilized residues	Share
	m^3	%	m^3	%
Logging	20 000 (	80	16 000 (	70
Sawmilling	5 000	65	3 250	14
Rubberwood harvesting	6 860	60	2 744	12
Rubberwood sawmilling	588 (	20	117	1
Plywood making	4 500	15	675	3
Total	**36 948 (**	**62**	**22 786 (**	**100**

An average price of USD 10 per m^3, the economic value of unutilized residues is in the region of USD 230 million. It is, however, realistic to expect that all of the unutilized potential could be put to good use, so to speak. Due to logistical and other constraints, there will always remain a portion that will not be economically viable to recover. It would be easiest to increase utilization of the residues that are most readily available, i.e., sawmill residues. Table 4.7 estimates that the annual utilization of residues could be increased by 5 million m^3. At USD 10 per m^3, the corresponding increase in revenues would be in the region of USD 50 million per year in the raw material value only.

Table 4.7 Generation and Recovery of Wood Residues in Malaysia

Sector	Present utilization		Potential utilization		Change
	%	m^3/a	%	m^3/a	m^3/a
Logging	20	4 000 000	30	6 000 000	2 000 000
Sawmilling	35	1 750 000	80	4 000 000	2 250 000
Rubberwood harvesting	60	4 116 000	70	4 802 000	686 000
Rubberwood sawmilling	80	740 400	85	499 800	29 400
Plywood making	85	3 825 000	85	3 825 000	0
Total	**62**	**14 431 400**	**52**	**19 126 800**	**4 956 400**

4.1.5 Constraints in Improving Waste Utilization

It has been reported that to recover wood waste and process it into usable stock for the furniture mills will incur a cost of about USD 90 per m^3. Coupled with an inconsistent supply it clearly underlines the deterrence faced by wood waste utilization in the furniture manufacturing sector. It seems obvious that the economic losses due to the untapped wood-waste are indeed huge and must be addressed immediately to reap optimal economic returns. Based on the economic analysis above and interviews with sawmill managers during the case studies, the constraints faced in the utilization of wood waste are as listed in Box 4.1.

The successful utilization of wood waste in Malaysia appears to be dependent on the economics of the issue. As it stands currently, the prevailing incentives (if any) are not sufficient to encourage greater recovery and utilization of wood waste. However, if processing mills are convinced of the potential benefits to be derived from wood waste utilization, this scenario may soon change in the future.

Box 4.1 Main Constraints Limiting Wood Waste Utilization in Malaysia

Uncertainty of log supply. It is difficult for sawmills to commit on any long-term contracts to supply waste wood when their own log supply is insecure. Furthermore, the logistics in terms of location and collection is not in place, as the industry is highly fragmented. Transporting wood waste farther than 100 km is uneconomical. Therefore, there is a tendency to simply use the waste wood available to fuel the boiler for steam generation for the kiln drying operation, or to dispose of it indiscriminately. A collective effort on the model of the Sarawak Timber Industry Development Corporation (STIDC) appears to be worthwhile emulating in improving the reprocessing of wood waste in Peninsular Malaysia.

Reluctance toward residues of mixed species by makers of reconstituted panels. Only seven MDF and particleboard manufacturer use residues of mixed species, and hence, the demand among the reconstituted panel manufacturers is not high. In Peninsular Malaysia, where rubberwood is the predominant wood raw material, the use of mixed tropical wood waste is not necessary for most manufacturers. As the supply of rubberwood dwindles, however, most manufacturers will move toward the use of mixed tropical wood waste. Daiken Sarawak, for example, uses mixed tropical hardwood wood waste as raw material for MDF in its 100 000 m^3 plant. The company reports neither technical nor color problems. Their raw material costs about USD 40 per tonne.

Reluctance toward residues of mixed species by solid wood processors. Solid wood processors do not like to work with mixed stock wood waste, either. Variation in species, moisture contents and sizes are often cited as the main drawbacks of residue use. If mixed wood waste could be sorted out into three groups (meranti, hard species and mixed species), it could be possible to use such wood waste for the manufacture of wood products.

Reluctance to downstream investment. Vertical integration in the sawmill sector is not pursued actively, as the sawmills are reluctant to invest in downstream production due to uncertainty over the future supply of raw material. Although the government industrial policies are geared toward vertical integration and greater sectorial linkages, progress has been slow. There is no common trade organization to coordinate the activities of the various sectors of the wood industry in Malaysia suggest that each trade organization which represents a particular subsector of the wood industry has an interest in its own subsector, and in most cases, do not collaborate with each other to foster greater sectorial linkages.

Inadequate of enforcement of environmental regulations. The enforcement of environmental regulations related to wood waste disposal is not up to mark, and hence, there is much room for mismanagement. As a result, the sawmills do not feel the economic losses arising from wood waste disposal, and in most cases, the problem of wood waste dumping has no clear resolve. At this point of time, offenders are fined up to a maximum of MYR 10 000 (USD 2 600), which does not sufficiently deter further offenses. Harder punishments through a revision of the existing legislative framework is required to deter indiscriminate disposal of wood waste.

Lack of incentives for wood-waste utilization. Existing regulations pertaining to wood-waste utilization is relatively poor and, hence, there is no incentive to tap into this resource. It may be important to consider some financial incentives and tax rebates, for using wood waste in the manufacture of wood products. The model used for R&D tax deductions for enterprises can also be extended to enterprises that use wood waste as the raw material for their wood products manufacturing activities.

Box 4.1 Main Constraints Limiting Wood Waste Utilization in Malaysia, cont'd

The economic returns of wood-waste utilization do not commensurate the efforts undertaken, and inevitably, disposal/dumping or burning as fuel appear to be the best options. Logging concessions must be offered on a long-term basis, for instance, for 25 years. Under the current practice of offering small logging concessions (i.e., less than 3 000 ha), there is no incentive for the loggers to invest into machinery to extract the forest residues. It suggested that residue logging in the future would be more efficient and less damaging if carried out as an integral part of the normal logging operations. It can be carried out more effectively, with a specially trained crew, taking out residues as a special assignment, in a second operation immediately after extraction of the normal logs are completed. These crews could be equipped with lighter equipment to be more effective. Furthermore, if the residues can be tagged (marked), their removal will be legal, and thus benefits both the state government and the loggers. The demand for wood waste can be created through the concerted effort of a third party, for instance a secondary product mill operator who needs the wood waste as the raw material for the mill. Under such circumstances, the wood waste fetches a value, and its collection becomes a viable option.

Lack of know-how on residue utilization technologies. Information pertaining to the technologies available to commercially exploit the wood waste is not well disseminated, and hampers efforts to fully realize the wood waste as an opportunity. Although the need to retool the sawmilling industry is well recognized, in terms of processing smaller dimension logs and wood waste most sawmill managers are not fully informed about the options available. There is a need to show a success model to convince and attract future investments into the sector, if utilization of wood waste is to be further improved. Changing the sawmilling structure in the country, which is strictly regulated currently, is highly recommended to ensure the survival of the fittest. The sawmilling sector, which is grossly over capacity, must be subjected to market forces to ensure efficiency. Under such circumstances, sawmills will be forced to retool their sawmills through portable and smaller breakdown machines, which are capable of handling smaller dimension logs and residues. Further, sufficient industrial capacity must be created to ensure this wood waste can be used to produce by-products such as chips, molding parts, etc. This is perhaps one area where the wood-based subsidiary of the respective state governments in Malaysia could play a leading role.

Government agencies such as the Forestry Department has limited powers to implement tighter rules and regulations, as forestry comes under the jurisdiction of the respective state governments. Hence, incentives for wood waste utilization must be initiated at the state government level, rather than at the federal level. The question of readdressing the financial payouts (i.e., premium, royalty and cess) during the logging operation must be undertaken to ensure the viability of wood waste recovery. Lower premiums (currently at about USD 130 per ha/a) and higher royalty (depending on species) are certainly worth the consideration of the respective state governments. The experience of STIDC in Sarawak clearly reflects the need for initiatives at the state level, as it is more familiar to local conditions. This is particularly through because wood waste management is critical in wood-based industries, but is seldom given adequate provision in budgeting and planning. Further, as the supply of primary raw material reduces against the background of a stagnant finished goods price, there is a need to improve the recovery (both in terms of processing and wood waste), in order to remain competitive.

Lack of wood waste knowledge. Complete information on the availability of wood waste and its characteristics are not well documented, and may deter the interests of potential foreign investors. Such information is the basis on which future developments on the utilization of wood waste should be built.

Skills of logging crews. The use of contract logging crew, especially from Indonesia, may not be desirable if wood waste recovery is to be increased in the Malaysian forests. The issue of workforce must be addressed, if the desired attitudinal change is to be brought about within the sector. Forestry Training Center will have to be empowered to train logging crews and a legislation must be put in place to ensure only trained and competent crews are allowed to work as logging crews.

4.1.6 Proposed Improvements and Projects Targeted at Waste Utilization

One of the most notable success stories in the utilization of wood waste is the effort undertaken by the Sarawak Timber Industry Development Corporation. The organization has been pivotal in raising industrial capacity to use wood waste generated in the forestry and wood-based sectors in Sarawak. Table 4.8 shows the success of the scheme and it must be noted that in Sarawak, the wood industry using mill residues, especially solid residues, is already competitive.

Table 4.8 Status of Wood Waste Utilization in Sarawak

Type of product	Number of mills	Capacity
		m^3/a
MDF and fiberboard	3	240 000
Particleboard	1	80 000
Wood-cement board	2	12 000
Briquette	2	12 000
Co-generation	2	n.a.

Source: STA

Another case is the company known as Diamond Eagle Sdn. Bhd., in Sarawak. This is a chipping plant established in 1996 by Japanese investors. The plant is equipped with two Japanese secondhand disc chippers with a production capacity of 2 500 t per month each. The total investment was USD 2 million, including overhead. The company uses exclusively wood residues of all species from primary processing mills as raw material. Only one chip quality is produced. Barks are manually removed before chipping, but a 3% allowance for bark is accepted. The chipping process produces about 1.5% of fine wood dust, which cannot be exported. This wood dust is dumped at landfills. Raw material is procured from sawmills within the radius of 30 km from the mill, and it is currently experiencing raw material shortage. The raw material is purchased at a price of USD 5 per tonne (including transportation) at factory. Chartered vessels export chips, and the average FOB price is about USD 210 per bone-dry tonne. This company clearly demonstrates the economic viability of producing chips out of wood waste for the export market.

Homet Raya Sdn. Bhd. owns a co-generation plant in the Tg. Manis Timber Processing Zone, established in 1994. The plant produces steam and electricity to be used by the sister companies of Rimbunan Hijau. The plant capacity of is 1.65 MWh short of the total demand of the affiliated companies of 2.2 MWh. Diesel generators produce balance of power needed. Key data for steam production are as follows:

- Capacity 30 t/h of steam
- Pressure 2.24 kPa
- Temperature 240 °C

The co-generation plant is run on wood waste in the form of chips to ensure controlled combustion. All wood species can be used, which are chipped prior to use. Sawdust is burned in the nearby incinerator. All raw materials are supplied from the nearby sister companies. About 50 t of wood chips will last as fuel for the boiler for 8 h giving a consumption of 6.3 t/h of chips. However, the electrical grid does not cover the factory. It will be advantageous if the company could sell any surplus electricity to the State Electricity Board, but this is not possible.

The Besut Tsuda woodworking complex in Ajil, Terengganu in Peninsular Malaysia has a comprehensive plan to use almost 100 t/day of wood waste for a briquetting plant and co-generation plant (1.8 MW of electricity). With an investment of USD 2 million, the payback period is less than three years. However, with the onset of the 1997-98 economic crisis, the proposed plan did not materialize. However, the initiative shows, that an integrated woodworking complex possess the physical size to enter such a undertaking and has the managerial capacity to plan and carry through a solution to their residues and waste problems. That the financial side of the project has been hampered by the downturn is unfortunate, but nevertheless the technical and environmental side of the project stands unaffected and hopefully the completion of the co-generation and briquetting plant is soon approaching.

These examples clearly reflect the economic potential of wood waste utilization in Malaysia, and all efforts must be taken to ensure that this objective is realized in the near future.

A government initiative to establish a central wood waste collection depot is a measure worth considering. Against this background, it seem obvious that in order to improve the utilization of wood waste in Malaysia, a sufficiently large industrial capacity must be established, which will create a demand for the wood waste and residues. It has been shown previously in this report, that there are several success models that illustrate the economic viability of wood waste utilization. Furthermore, related government agencies particularly the Forestry Department of the Peninsular Malaysia and the Malaysian Timber Industry Board must be granted greater power to enforce stiffer penalties against loggers and millers who do not recover and use the wood waste and residues generated in their operations. The jurisdiction of the Ministry of Science, Technology and Environment must be expanded to sufficiently punish the whole range of offenders, who indiscriminately dump and dispose wood waste and residues, which then become an environmental issue. In the long-term, it seems apparent that the wood waste and residues generated in the forestry and wood-based industries have significant economic potential to attract recovery and use. As a leading producer and exporter of wood products in the Asian region, Malaysia must embark on a concerted scheme to achieve the aim of improving the recovery and use of the wood waste and residues for both, an economic and environmental cause.

Although Malaysia is considered an advanced country in terms of forestry and its related industry, the amount of wood waste produced annually offer a tremendous potential for exploitation. In Malaysia, logging operations contribute the largest amount of residues, which has vast potential for further processing. At this point of time, only 20% of these residues are economically utilized. On the other hand, the utilization of mill residues have had mixed success in the country. Only 35% of sawmill residues are used (20% for reprocessing into moldings and pallets, 15% usually in the form of sawdust is used to fuel the boiler). In plywood industry, a residue recovery rate of 85% have been reported as peeler core and trimmings are often used as raw materials for pallet manufacturing and plywood core material, respectively. A greater success has also been found in the MDF and particleboard plants which record a 75% recovery of the wood waste produced, which is used as raw materials for energy generation and raw materials for further processing in the manufacture of by-products.

Nevertheless, concerted effort must be taken to further exploit the vast amount of untapped wood waste produced with the forestry and wood-based sectors in the country. Wood waste should no longer be construed as an environmental problem, but rather as a potential source of biomass, which can be transformed into valuable by-products and energy source. It must be recognized that if the access to timber is not restricted, the incentive to use wood waste will not really be there. Hence, more stringent regulations and legislative measures must be put in place to enhance the recovery and use of wood waste. The nature of the logging operation must be changed to ensure that less wood waste and residues are produced, and when produced, are recovered to supply an industry, which has the means to process the wood waste. Technological adaptations must be made to the sawmills to ensure that they are capable of processing wood waste. Sufficient industrial capacities must be established to use wood waste and convert it into valuable by-products, which can improve the economic earnings of the sector. As the wood resource supply in the country tightens, the use of wood waste in the manufacture of products will gain further momentum, which will inevitably make significant contribution to the socioeconomic well-being of the country.

Frequently, it is only possible to make informed guesses on the volumes of wood waste and residues that are available in the country. No investor will come forward if a solid basis for decision-making cannot be created. Accurate information on the availability of wood waste must be made available to potential investors, as this aspect has often been cited as the stumbling block to attract interested parties. The legal framework to support the increased utilization of logging and mill residues must also be strengthened. Although the National Forestry Policy (1992) underlines efficiency in harvesting and utilization of the forest resource, it lacks concrete measures to achieve actual efficiency and sustainable forest management. Innovative royalty, cess and fee schemes must be developed to make residue recovery and utilization commercially more attractive. Severe punishments must be imposed on logging operators who produce more than the allowable amount of residues per hectare. A reevaluation of the existing industrial capacities must be done to ensure that raw material supply is sufficient without exerting unnecessary productive pressure on the resource base. This has indeed been the problem in Malaysia, as manufacturing capacities have grown too rapidly over the years, and hence, exerts pressure on the supply of raw material. Therefore, it is time that Malaysia embarks on a concerted program to improve and enhance the recovery and use of wood waste and residues, not only as a potential economic earner, but also as measure to reduce related environmental problems.

4.2 Brazil

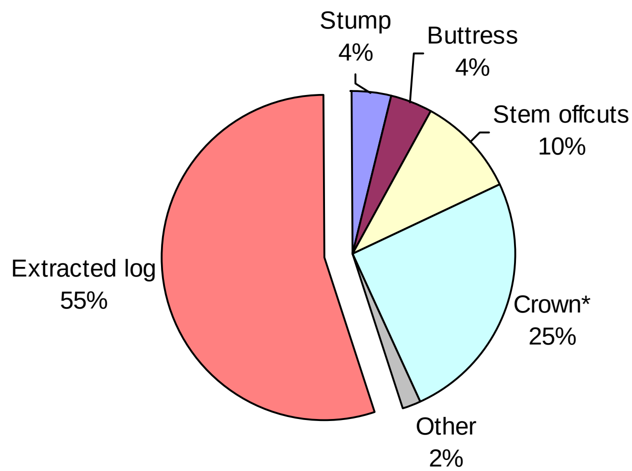
4.2.1 Wood Raw Material and Wood Waste Flows

Forest Residues

There is no available data on the volume of forest residues generated by logging and harvesting operations in the Brazilian tropical forests. Moreover, as a result of the extensive literature review, it can be stated that up to the present moment, only vague information and few studies exist covering this issue.

Based on field surveys (Annex 1), as well as on few existing literature, the consultant was capable in estimating the forest residues generated at a typical logging and harvesting operation in the Amazon region (Figure 4.2).

Figure 4.2 **Estimate on Forest Residues Generated at a Typical Logging and Harvesting Operation in the Amazon Region**



(*) Diameter > 20 cm. Source: STCP estimate based on field surveys.

As it can be observed, the estimates indicate that 1 m^3 of extracted log generates 0.82 m^3 of forest residues. The major amount of forest residues is represented by crown (56%) and stem offcuts (22%). Only a little volume of forest residues is represented by stump (9%), buttress (9%) and others (4%).

Extrapolating this data to all the Amazon region and taking into account that the Brazilian tropical industry annually processes 35 million m^3 of industrial roundwood, it is possible to predict a total generation of around 28 million m^3/a of forest residues.

It is estimated that among the total amount of logging residues in the Brazilian Amazon region, about 10 million m^3 can be considered as potential saw and veneer log, while the remaining 18 million m^3 could be utilized as raw material for reconstituted wood products, pulp and energy generation.

Besides the generated forest residues, it is important to mention the forest disturbance caused by logging and harvesting operations, which can be characterized by the direct opening of the stand on the one hand and by the damage of other trees on the other hand. Forest residues are also originated from trees overthrown, broken or damaged by felling and skidding operations. Such forest residues are of difficult quantification and very few studies have been carried out about this issue in the Amazon region.

Industrial Wood Waste

Just like forest residues, there is no information on the volume of industrial wood waste generated by the tropical timber industry in the Brazilian Amazon region. However, the existing literature is much richer. Many institutions, research centers and non-governmental organizations have carried out several studies on this topic.

Recently, studies developed by IMAZON (2000) in Paragominas region in Pará points out that wastage in the transformation of raw material by sawmills usually ranges from 50-65%, and in some cases, this rate can be even higher. Studies carried out by INPA (2000) in Amazonas show that wastage level in transforming roundwood into sawnwood (56-63%) is very much similar to those levels verified in Pará. High losses during sawmilling are the result of various reasons: wide variety of technology and machinery employed by the sawmilling industry, log quality and dimension, market outlet (local or export), etc.

Table 4.9 presents an estimate on the wastage generated by the sawmilling industry in the Amazon region. The presented value is based on field surveys carried out by the consultant, as well as the literature reviewed.

Table 4.9 Wood Waste Generation by Sawmill Industry in the Amazon Region

Activity	Range of losses (%)
Log yard operations	5-10
Sawing	40-45
Grading	2-5
Storage	3-5
Total	**50-65**

Source: IMAZON and INPA, adapted by the author based on field surveys.

Wood waste generated by sawmills industries can be classified into two groups: solid residues and particle residues (sawdust, shavings, etc.). The largest amount of wood waste generated by sawmills is represented by solid residues. According to field surveys carried out by the consultant, solid residues contribute on average with 75-85% to the generated wood waste, while the particulate residue share is lower (15-25%).

Considering the presented level of losses, it is possible to estimate that the total volume of wood waste generated by sawmilling industry in the Amazon region is around 20 million m^3/a.

In 1992-93, ITTO financed a comprehensive study on veneer and plywood manufacturing process in the Amazonian region focusing on the introduction of lesser-known species. Among other aspects, the study evaluated the yield in the manufacturing process of veneer and plywood industry, either those based on upland tree species as those based on lowland tree species.

Taking into account this study, the level of losses of veneer and plywood manufacturing process (integrated production) can vary from 51% to 55%, according to tree species used (Table 4.10).

Table 4.10 Wood Waste Generation by Veneer and Plywood Industry in the Amazon Region

Activity	Upland (terra firme) tree species	Lowland (varzea) tree species
Log yard operations	4	3
Peeling process*	30	34
Veneer preparation (drying, jointing, gluing, etc.)	7	7
Plywood manufacturing process (sanding, trimming, etc.)	8	9
Storage	2	2
Total	**51**	**55**

*) Including roundly off.

Source: ITTO (Project PD 93/90), adapted by the author

Most of the wood waste originated from veneer and plywood manufacturing processes are represented by solid residues. The main types of solid residues are roundly off residues, peeler core, clipping residues and plywood trimming residues. The share of particulate residues is much lower, basically represented by sawdust from trimming and sanding processes.

Assuming that the level of losses presented in Table 4.10 can be applied for all the Amazon region, it is possible to estimate that the total wood waste generated by the tropical plywood industry in Brazil is approximately 1.2 million m^3/a.

Volume of Residues and Wood Waste

The volume of logging residues and wood waste generated by the tropical timber industry in Brazil is very high. Table 4.11 summarizes the volume of wood waste generated at logging operations as well as during the industrial processes, with the respective percentage of contribution in the total amount.

Table 4.11 Logging Residues and Wood Waste Generation by Tropical Timber Industry in the Amazon Region

Type of residue	Volume	Share
	million m^3	%
Logging residues	28.0	57
Industrial residues		
Sawmills	20.0	40
Plywood plants	1.2	2
Other processing plants	0.5	1
	21.7	43
Total	**49.7**	**100**

The total volume of logging residues and wood waste annually generated by the tropical timber industry in the Amazon region is estimated to reach 49.7 million m^3/a. The largest amount of wood waste is generated in the forest, during logging and harvesting operations, which are responsible for 57% (28 million m^3/a) of the total volume. The remaining 43% (21.7 million

m^3/a) is related to industrial wood waste generated by sawmills, plywood plants and other processing facilities.

4.2.2 Mill Case Studies

Tramontina

Tramontina is one of Brazil's most important cutlery companies. Its main industrial facility is located in Belém, in the northern region of the country (Parà).

In this site, Tramontina has a thermoelectric power plant, with an installed capacity up to 1.5 MW, demanding a considerable volume of wood waste for running it. Raw material used is supplied by its own mill as well as by other timber industries in the region. The thermoelectric power plant is based on the co-generation concept. High-pressure steam used to produce electricity is extracted from the turbines and used for dry kilns. The electricity generated is used for running its own industry.

Recently, Tramontina established an interesting partnership with Eldorado, a timber industry located just opposite Tramontina's site (on the other side of the street). To enhance a mutual benefit, Tramontina built a sawdust transportation line linking its power plant directly to Eldorado's processing facilities. It considers a ventilation system to carry Eldorado's sawdust surplus through a 400 m long conveyor, feeding the plant with the necessary additional volume of wood waste.

With this cooperation, Tramontina is able to generate steam and electrical energy for its own operations, giving its surplus of energy (electrical and thermal) in return to Eldorado. Under this good-neighbor technology, both companies make use of the short distances between them to generate their own power, thus contributing to the environment preservation since almost no smoke or soot is produced.

Incentive to Promote Biomass as Source of Energy in the Amazon Region

Energy supply in the Amazon region represents a serious constraint for the development of local industry. This occurs due to its remote location, most of the times close to natural forests with difficult access. Power plants in such conditions are not always feasible, and many investors are reluctant to move ahead in such venture.

In order to stimulate investments in electricity generation by the private sector in remote areas, the federal government created in 1993 the Fuel Consumption Account (so-called CCC). The CCC is basically an incentive program that provides credits and other benefits to replace fossil fuel by other sources. The CCC investments in 2001 reached approximately USD 690 000.

Power plants generating electricity based on biomass fuel such as sugar cane residues, rice bark and wood waste are eligible to monthly benefits from the CCC program for a period of 8 years. According to a federal resolution of 1999, the CCC will be applied until 2013.

4.2.3 Volume of Waste Utilization

Utilization of Forest Residues in Brazil

Forest residues from tropical forests in the Amazon region are not utilized. The main reason is associated to the fact that logging residues are produced in forests far away from places of consumption. The high costs of collection and especially of transportation of the logging residues from the remote turn its utilization unfeasible. In most cases, even people living in the vicinity of forest sites do not use logging residues.

There is no data available in Brazil on the volume of logging residues from tropical forests that is utilized. In any case, some is utilized, but the percentage is very low. The utilization of logging residues is linked to:

- residues of smaller size are used as firewood for household purposes
- residues of smaller size are also used as raw material for charcoal production; many charcoal producers are concentrated near forest sites
- large branches and buttresses are processed into sawnwood by mobile sawing machines in the forest sites or into posts for farm fencing (especially the most durable tree-species)
- roundwood residues are used for construction purposes

There is no evidence that the current situation of under utilization of logging residues from tropical forests in Brazil could change, at least in the short or medium term.

Utilization of Industrial Wood Waste in Brazil

Most wood waste and residues generated by the tropical timber industry in Brazil is burnt or accumulated at mill sites, resulting in environmental damages and economic losses. In general, this occurs because wood residues have limited or no value. As mentioned earlier, tropical timber industries are usually small-sized operations, not integrated and unable to develop a consumption alternative at the site. The industry is also mostly located in regions where market for this material is nonexistent. Instead of being a source of revenue, as in the case of the temperate or boreal timber industry, wood residues become a source of costs for the tropical timber industry.

Nevertheless, along the last few years, some improvements on wood waste utilization have been identified. Traditionally, the major utilization of wood waste (solid residues) in the Amazon region is linked to charcoal production. Charcoal production facilities are integrated with sawmills and veneer mills and they are usually located at the mill site. Moreover, in rural areas, wood waste is also used for various other purposes, such as firewood (household), construction, cattle and other animal bedding, organic fertilizer, among others. In urban areas, wood waste is used as industrial fuelwood by brick plants, bakeries, restaurants, etc.

Wood waste utilization at mill for generating thermal energy is increasing. In medium and large-sized mills, which are technologically more advanced, the solid wood waste that cannot be used is generally converted into chips. Chips and other particulate residues (sawdust, shavings, etc.) are stored to be burnt in boilers. The thermal energy (steam) generated is used in the industrial process (drying, cooking, pressing, etc.). However, yet prevail those mills that do not convert wood waste into chips and burn solid residues (slabs, core, trimming, etc.) in order to generate the thermal energy. This is mostly the case of smaller mills that cannot afford equipment to produce chips. In other cases, the chipper is not the only investment. Expenditure must be done to purchase appropriate boilers to be fed with chips. This is the reason that wood waste has been gradually used as fuel for generating energy by medium and large-sized industries only.

In regions where agribusinesses are fully developed, as in Mato Grosso, market for wood chips is developing. In Mato Grosso, wood biomass is used for thermal energy generation mostly for drying soybeans, replacing fuel oil. The main driving force is the lower cost of biomass. In Mato Grosso, wood chips, sawdust, shavings and other particulate residues have been used for generating thermal energy in the cement industry.

More recently, the deregulation of the electricity sector in Brazil has allowed independent power producers to produce and sell electricity, through established utility companies or directly to consumers. The idea is to have the private sector investing in power generation, thus reducing the need of public investments. This has been considered mostly in remote areas, where large power plants would not be feasible as in many places in the Amazon region.

The integration between tropical timber industry and independent power producers has brought several advantages:

- Generation of electricity for the mill and for selling to the market. Currently, there are some places in the Amazon region where the lack of electricity has limited the development of timber industry. The independent power producers can solve this problem.
- Generation of steam, which is employed during the primary and further wood processing (drying, cooking, pressing, etc.).
- Most of the timber industries need to establish their own electricity supply, based on small diesel generators. The replacement of diesel for wood waste is a feasible option, which can provide local employment, income and improve the competitiveness of the local industry. In the last few years, the cost of electricity generation in small and medium-sized mills based on diesel in the Amazon region increased significantly. As an indication costs of electricity, generation based on diesel increased from USD 0.05 per kWh to USD 0.11 per kWh over the past 2-3 years (an increase of more than 100%). Some studies have indicated that electricity generation based on wood residues can significantly reduce costs. For a medium-sized electricity generation facility based on biomass, the cost is normally less than USD 0.04 per kWh.
- Wood residues disposed in mill sites in the Amazon region represent a problem to be solved in terms of costs and environment. Burning them for energy generation using state-of-the-art systems not only makes electricity available at lower costs but also contributes in smoke reduction, avoids rivers and soil pollution, a serious problem in tropical regions, thus improving general environmental conditions.
- Replacing diesel by wood waste is in line with the international efforts for carbon sequestration, a global concern reflected in the Climate Convention.

Another way that timber industry in the Amazon region has found to add value to by-products is by integrating their operations with further processing plants. In this case, sawmill by-products are recovered through dimensioning, finger-jointing, edge gluing, laminating, resawing of shorts into components, etc. Typical examples of recovery by-products that have been manufactured by integrated further processing plants are finger-jointed mouldings, parquet flooring and finger-jointed edge-glued panels. It is a trend observed in medium and large-sized sawmills.

Tropical wood residues generated in the Amazon region are not used as raw material for reconstituted wood panels (particleboard, MDF, etc.) production as well as for pulp production. Such fact is the result mainly of the large heterogeneity of tree species processed by the tropical timber industry coupled with long distances of transportation to the major production centers (southern region). A local mill also seems to be unfeasible as it would probably not be able to compete with the existing mills located closer to the main consuming centers.

There are no specific studies or statistical data available in terms of wood waste utilization in the Amazon region. Estimates point out that only 30-40% of wood residues generated by the tropical timber industry is used. It is important to mention that few years ago the utilization level of wood waste was much lower. A wider adoption of wood waste by the timber industry, mainly those medium and large-sized mills for energy generation purposes can be said to be the main inductor factor in improving the level of utilization. At medium and long terms, it is expected that the independent power producers will be capable of improving even more the utilization levels of wood waste. Parallel to this, the strong development of agribusiness is also expected to improve wood waste utilization as fuel for energy generation.

4.2.4 Economic Losses Due to Unutilization

As previously mentioned, in most parts of the Amazon region, there is no market for wood waste and no economic value of wood waste is a critical issue in the profitability of the tropical timber industry. It reduces the profitability of the tropical timber industry and increases environmental problems.

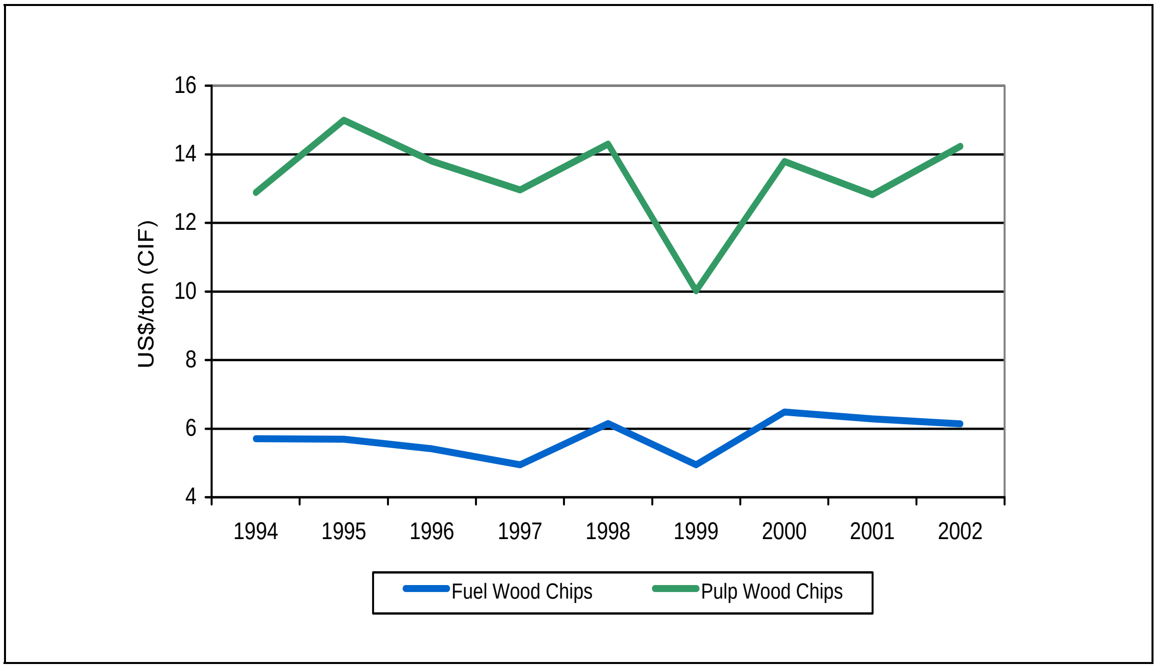
In southern Brazil, where the forest industry is much more developed, wood waste plays an important role. Wood chips market for energy generation and as raw material for the industry (reconstituted wood panels and pulp) is very well established.

Table 4.12 presents the price evolution of pine wood chips for energy generation and for pulp in southern Brazil. The price increase of pine wood chips in southern Brazil is the result of recognizing the important role of integrating operations coupled with the reduction of wood fiber availability in the region.

As previously mentioned in some places in the Amazon region, wood chips are gradually gaining importance. In Mato Grosso, the development of agribusiness created a large market of wood chips for energy generation. In such region, wood chips are burnt to generate thermal energy to dry soybeans. In fact, wood waste, which used to be a concern to local timber industry, has now become an opportunity to increase profits.

Current local price for particulate wood residues (chips, sawdust, shavings, etc.) is approximately USD 23 per tonne (delivered at the power plant). These prices are higher than those verified in the southern region. However, it is worth to mention that large distances of transportation increase the price of tropical wood chips if compared to pine wood chips. Around 60-70% of the tropical wood chip price refer to the freight. In the southern region, freight contributes only around 20% of the wood price.

Figure 4.3 Price of Pine Fuel Chips and Pulp Chips in Southern Brazil



Source: STCP

A consistent specific study on economic losses due to the non-utilization of tropical wood waste in Brazil has not been carried out. Table 4.12 presents an attempt to assess economic losses due to the non-utilization of tropical wood waste in Brazil. The underlying assumptions were:

- Out of the total volume of logging residues generated in Brazil, only 50% can be considered as potential for use. The main constraints are related to collection difficulties and transportation costs. For these residues, it was considered yield of 90% when chipping (for energy generation) and 50% when sawing or peeling (secondary processing).
- The price of USD 10 per tonne (ex factory) was considered for wood chips. In sawing/peeling processes a price of USD 150 per m^3 of end product (ex factory) was considered.
- Out of the wood waste generated in industrial processes, it was considered that 70% can be potentially used. From the potential volume, a yield of 90% was considered when chipping (for energy generation) and 60% when recovering in secondary processing.
- The price of USD 250 per m^3 of end product (ex factory) was considered for value-added products manufactured based on the mill waste.

As it can be observed from the data presented, the economic losses due to the non-utilization of tropical wood waste in Brazil are estimated to reach USD 1.2 billion per year. The total economic loss for not using logging residues is estimated in USD 456 million per year. Logging residues that could be used for chipping contributes with USD 81 million per year (18%) while logging residues for sawing or peeling participates with USD 375 million per year (82%).

In relation to wood waste generated during industrial processes, the economic loss is estimated at USD 752 million per year when not using them. The largest contribution is from those residues which could be used for further processing (value added products), estimated at USD 663 million per year (88%), while the loss estimate for not using wood waste for chipping reaches USD 89 million per year (12%).

Table 4.12 Economic Losses with Non-utilization of Tropical Wood Waste in Brazil

Wood waste utilization	Total volume generated	Potential for use	Yield	Economic losses
	1 000 m^3/a		%	USD 1 000
Logging residues				
for chipping	18 000	9 000	90	81 000
for sawing/peeling	10 000	5 000	50	375 000
	28 000	14 000	–	456 000
Industrial residues				
for chipping	14 100	9 900	90	89 000
for further processing	7 600	5 300	50	663 000
	21 700	15 200	–	752 000
Total	**49 700**	**29 190**	**–**	**1 208 000**

4.2.5 Constraints in Improving Waste Utilization

The level of wood waste utilization in the Amazon region is very low. Instead of being a source of additional revenue, wood waste became a source of costs for the tropical timber industry, besides causing several negative environmental impacts.

4.2.6 Proposed Improvements and Projects Targeted at Waste Utilization

The tropical timber industry of the Amazon region presents several opportunities to improve wood waste utilization. The success in increasing the utilization of waste depends on effective measures taken by private and public sectors.

- **Improve human resources.** Training at all levels will have a direct impact on the reduction of wood waste. It represents not only a need for dealing with newer technology, which requires more skilled operators, but also a need in to increase the product quality. Training centers supported by local industries is an interesting option. Such initiative already exists in some places (SENAI, for instance) but it needs to be strengthened. Further training in forest related activities, including silvicultural aspects, and improved felling techniques to reduce cracks, damages to surrounding trees and also to diminish wastage generated by skidder trails is important. At industry, training should cover modern techniques in terms of processing quality wood products and the importance of reducing wood waste since it negatively affects the economic returns and the environment.
- **Adopt improved technology.** Updated existing machinery and equipment is one of the most important aspects to reduce wood waste. The low level of technology currently in use in the Amazon region negatively influences the efficiency of the mills and generates large volumes of wood waste. In many cases, industry needs support to select appropriated technologies. In this aspect, technical assistance plays an important role. In general,

large mills have been investing in newer technology, but the same does not happen to the great majority of the mills that do not have sufficient capital to invest nor the necessary expertise.

Box 4.2 Main Constraints on Wood Waste Utilization in the Amazon Region

Lack of adoption of sustainable forest management practices. The concept of sustainable forest management is not clearly understood by most of the loggers. Lack of planning of logging and harvesting operations can be considered one of the main constraints to reduce the generation of forest residues since a significant part is originated from trees overthrown, broken or damaged by felling and skidding operations. Within this context, the training of chainsaw operators and skidder operators plays an important role.

Lesser-known species problem in implementing sustainable forest management plans. The basics is that tropical forest resources are not compatible with market, and thus selective logging is, in fact, the only alternative for the timber industry, as no operations could be feasible if no market is available. As a result, a considerable amount of the timber volume stays in the forest, increasing operations costs and thus reducing the competitiveness of the industry. This is particularly important in the Amazon region, where large tree species diversity is quite common.

Low price of tropical log. Brazil prohibited log exports with a double purpose of reducing deforestation rate and promoting the domestic timber industry. Despite the development of the national timber industry, logs in domestic markets fetch prices below those in the international markets. In one hand, log price is a comparable advantage to the Brazilian timber industry. On the other, it is an aspect that contributes to increase the losses levels of raw material, and consequently, the generation of large amount of wood waste.

Obsolete equipment. The Brazilian tropical timber industry is running very outdated equipment which greatly contributes to the generation of wood waste. New technologies oriented to increase wood recovery have not been incorporated by them. Only a very few medium and large-sized mills have understood the importance of up-to-date machines and equipment. However, when investments are done, most of the times they are not based on technical criteria, which leads to the adoption of inadequate technology.

Lack of qualified personnel at all levels. Lack of knowledge, skill, and training is one out of a number of constraints in improving conversion technologies in tropical timber industry in the Amazon region. As the mills are going through a modernization and expansion period, the addition of new equipment requires more skilled operators, and training becomes even more important than the utilization of simpler equipment and older processes. The lack of qualified personnel in logging and harvesting operations is also a constraint to reduce the forest residues generation.

Heterogeneity of tree species. The large heterogeneity of tree species in the Amazon region is a limiting factor in making use of wood waste in some applications. Particular residues, as wood chips, sawdust and shavings, are not used as raw material for reconstituted wood panels and pulp production. Furthermore, the long distance from mill sites in the Amazon region to pulp producing centers in the southern region of the country makes wood waste utilization unfeasible for the industries.

Production sites far from possible markets. Logging residues are usually produced in locations, which are far from the southern region, where most wood waste market is concentrated. High costs of collection and specially of transporting logging residues from remote forests to mill sites exclude an economic utilization of logging residues so far. A demand for logging residues in the forest sites themselves does not exist. Some possibilities for the utilization of forest residues are left behind.

Lack of vertical and horizontal integration in business strategies. Maybe the major constraint to reduce the wood waste generation in the Amazon region is the lack of vertical and horizontal integration. Most of the timber industry in the Amazon region is non-integrated and it occurs because the majority of the mills are small-sized.

Difficult access to new technologies. The timber industry of the Amazon region finds it very difficult to access new technologies due to some reasons like: i) low technological level presented by the national equipment suppliers; ii) high taxes on imported equipment, and iii) lack of adequate government measures and incentives in order to promote the technological update of the sector.

- **Integrate production chain.** In the Amazon region, forest activities, industrial operations, and trade are generally not integrated. Establishing an effective communication is the first measure to promote the integration of the production chain. By having a direct communication channel with the industry, sales personnel may understand clearer what the market demands are, informing production about the new tendencies. Production, in its turn, may quickly adjust its equipment and process to meet the new requirements, informing logging personnel the new wood-species demands. Once the communication is established, another possible measure to increase wood waste utilization is by integrating different production plants, e.g., flooring and mouldings, close to the primary processing mills. Freight costs would be minimized favoring the utilization of residues. It is important to mention that most of the times, the distances between mill sites of the Amazon region and the southern region, where the centers for trading wood waste are usually located, is very large, usually more than 1 000 km away. This fact hinders the development of wood waste utilization since transportation costs, in these cases, have a great impact on the final product price.

- **Develop new products.** Reprocessing shorts and solid residues into final products is an important measure to increase wood utilization. Deck tiles and parquet flooring are products that may be obtained by making use of small pieces. In flooring production, the use of staining technology to improve uniformity can be an important option in cases where sapwood and heartwood color difference restrict the end use. Value-added energy products such as briquettes and pellets are also interesting solutions to increase wood waste utilization. They are produced by compacting agro-industrial residues (rice bark, sawdust, others) under high pressures, with no additives or any other chemical elements. Briquettes and pellets are burnt in boilers, industrial ovens and fireplaces to generate thermal energy. Their advantages rely on their high density, which facilitates transportation and handling. Briquettes and pellets are usually sold in southern markets, far from the producing centers. Since they present low aggregated value, freight costs represent the most impacting component of their final price and a serious constraint in improving its utilization, most of the times making them commercially unfeasible. It is important that measures be adopted to reduce transportation costs of briquettes and pellets since they mean a rational and efficient way of recovering wood waste. Reconstituted pallets squares are another option. The product is replacing solid wood squares in the pallet industry in Europe and North America. It is basically a "particleboard block" with lower requirement in terms of surface appearance. The advantage is that it can be produced from any type of wood, including bark, and the production lines are relatively small, making it feasible in the Amazon region.

- **Develop incentives.** The government can play a vital role in the process to improve wood utilization in the Amazon region. Timber industries would certainly make more investments if they were supported by effective measures not only towards the improvement of wood utilization, but also targeting the development of the forest sector in general. Governmental incentives could target: (i) tax reductions and preferential loans for acquisition of improved equipment to increase yield; (ii) technical assistance and support to improve wood utilization and products quality; (iii) credits and other incentives for investments in wood residues utilization; and (iv) tax reduction for products obtained from wood residues. These examples of incentives would certainly benefit the great majority of the timber industries since they are small sized.

4.3 Cameroon

4.3.1 Wood Raw Material Production in Cameroon

Cameroon is well-forested with 24 million ha of forest that is about 50% of total land area. The forests are mainly closed tropical broadleaved rainforests of three predominant types: (i) lowland evergreen, (ii)lowland semi-deciduous and (iii) montane. Important commercial species include ayous (*Triplochiton scleroxylon*), sapelli (*Etandrophragma cylindricum*) and azobe (*Lophira slata*). The closed forests are concentrated in the south and along the coast. Mangroves are found in the Gulf of Guinea and acacia woodlands in the north. Cameroon has a modest area of plantation forest. About 6% of Cameroon's forests are formally protected in a network of protected areas. Significant areas of forest, including the Lac Lobeke forest, are planned to be protected as part of a transnational protected zone.

The forest contains an estimated 1.5 billion m^3 of timber (Besong, 1992). Prior to the oil boom, forestry played an insignificant role in the country's economy. With the decline of oil's role in the national economy and the need to cover the shortfall in state finances, the government has turned to forestry by increasing roundwood exports. Therefore, forest exploitation has increased, and it is estimated that about 200 000 ha of forest are lost annually. Roundwood production is estimated at 2 million m^3/a (Table 4.13), and about 1 million m^3/a is exported.

Table 4.13 Roundwood Production in Cameroon

	Production
	m^3
1999-2000	1 930 000
2000-2001	1 880 000
2001-2002	2 120 000

Source : SIGIF Tree felling volume statistics (data recorded in field book DF10)

4.3.2 Production and Trade

Cameroon is one of the world's top six exporters of tropical logs. Europe is the second largest market for Cameroonian wood products. The forest sector is heavily dominated by foreign companies. A small number of foreign companies control over 60% of all the logging and timber processing and three-quarters of all timber exports. Companies come from France (36% of the concession areas), Lebanon (10%) and Italy (9%).

Wood products industry is based on roundwood and sawnwood production, which together cover about 95% of the total forest industry production. The biggest export item is sawnwood, which accounts for 70% of total exports.

In 2002, Cameroon produced 1.27 million m^3 of industrial roundwood (Table 4.14). The roundwood exports' share of the production was about 17%. The sawnwood production was 800 000 m^3 in 2002. The export share of the production was 99%. The production of plywood and veneer was 98 000 m^3 of which about 76% was exported.

Table 4.14 Production, Imports, Exports and Apparent Consumption of Wood Products in Cameroon in 2002

Products	Production	Imports	Exports	Consumption
	m³			
Industrial roundwood	1 270 000	–	219 000	1 051 000
Sawnwood	800 000	2 000	795 000	7 000
Plywood and veneer	98 000	100 000	74 000	26 000
Fiberboard	–	–	–	–
Particleboard	48 000	1 000	47 000	2 000
Pulp, paper and paperboard (*)	–	39 000	–	39 000

(*) 1000 t. *Source: FAOSTAT*

4.3.3 Exports of Wood and Products Processed in Cameroon

With an aim of estimating the potential of waste utilization, Table 4.15 compiles exports of logs, sawnwood and other processed products. There are wide discrepancies between the numbers given by MINEF and the Customs, and Société Générale de Surveillance (SGS) and Société d'Exploitation des Parts a Bois du Cameroun (SEPBC). This is due to the fact that currently there are three control systems in use Douala port – those of the Customs, SGS and MINEF. Coordination between the systems is lacking., The control procedures should be simplified.

Table 4.15 Exports of Logs, Sawnwood and Other Forest Products

Products	Source	1997-1998	1998-1999	1999-2000	2000-2001	2001-2002	2002-2003 (*)
		m³					
Logs	MINEF	–	1 115 000	470 000	183 000	219 000	133 000
	SGS	6 186 000	1 634 000	1 015 000	412 000	287 000	178 000
	SEPBC	1 390 000	1 199 000	619 000	261 000	217 000	–
Sawnwood	MINEF	–	388 000	492 000	958 000	793 000	552 000
	Customs	407 000	476 000	987 000	657 000	641 000	560 000
	SEPBC	237 000	228 000	307 000	518 000	463 000	–
Veneer	MINEF	–	31 000	40 000	43 000	47 000	51 000
	Customs	66 000	53 000	54 000	60 000	54 000	66 000
Plywood	MINEF	–	22 000	17 000	23 000	27 000	23 000
	Customs	30 000	161 000	43 000	38 000	33 000	72 000
Particleboard	Customs	45 000	2 000	0	0	0	28 000

(*) From July to June. *Source : Fieldwork & Ngouanfo (2003)*

The export tax is applied to volume of raw logs exceeding the allowed quota and is CFA 8 800-15 000 per m³ (USD 12.60-23.60).

4.3.4 Waste Wood Flows

Types of Wood Waste Generated

The literature review and fieldwork interviews on tree-felling sites and at waste collection both in the forest and in the processing units allowed the following conclusions on the classification of waste in the situation of Cameroon:

(a) Waste resulting from the forest exploitation. Tree parts felled that remain in the site include:

- crown: upper proportion of tree, with branches and twigs, possibly including part of stem
- buttress: projecting rib at the lower end of the stem
- stump: portion of the tree remaining above and below ground after felling

(b) After handling and log loading operation in the tree-felling site, other waste can come from the following sources:

- logs abandoned on the logging area or loading area
- logs with defects and disqualified from processing
- logs not mentioned in the administration field book (DF 10)

(c) Waste resulting from the processing of logs: sawmills are the principal source due to the structure of processing industry. There occur several types of losses at the level of the sawmill, in their recovery workshops and dry kilns:

- downgrade in the log yard after conditioning measurement and classification
- slabs obtained during the primary breakdown
- other waste in the sawing process
- sawdust, which is mostly collected in an aspiration system

Theoretical Waste Volume in Cameroon

On **forestry compartment level**, waste flows were discussed with the Chief of Forest Management of the MMG company in Kribi. The losses resulting from well-managed logging activities were estimated at 13%. An independent entrepreneur reported that on average 30% of tree volume ended up in logging waste in the form of branches, twigs, rejected parts of stem, etc., and all were abandoned in the forest. Of minor importance was the 5% share of the sawdust left in forest after felling and initial sawing.

In the **wood processing industries**, the study undertaken by the ONADEF in 1989 showed that the utilization ratio of logs in the sawmills varied from 11% and 22% only. There was a wide difference between sawing for exports or for local market, whereby the higher end of recovery was recorded for export-oriented mills. These estimates are no more valid due to technological improvements and changes in regulations. For the plywood and veneer processing units, the recovery rates of the peeler logs was 23% and 22%, respectively. In 1990, there were 61 industries of primary processing with a total capacity of approximately 1 million m^3 of logs per year. On the basis of the above figures, waste from the processing industries of wood can be roughly estimated at 500 000-600 000 m^3/a.

The field visits and literature suggest that waste resulting from sawmills installed in Cameroon is 48-58%. Waste generation during 2000-2002 was estimated based on the production statistics collected at MINEF and wood products exports data collected by the customs administration of Cameroon (Table 4.16). Economic losses could not be calculated due to lack of data.

Table 4.16 Estimated Wood Waste Volumes in Cameroon

Period	**2000-2001**	**2001-2002**
	m^3	
Log production	1 880 000	2 120 000
Logs, sawnwood, plywood, veneer for exports	1 120 000	1 020 000
Domestic processing of logs	520 000	540 000
Waste	240 000	560 000
of log production	13%	26%

4.3.5 Case Studies

Case Study Mills

Two sawmills were selected for case studies. The first one was Transformation Integrée du Bois (TIB) in Mfoundi District near Yaoundé. The second one was Mbang's SFID-PFI in Kadey District in the Eastern Province.

TIB Sawmill

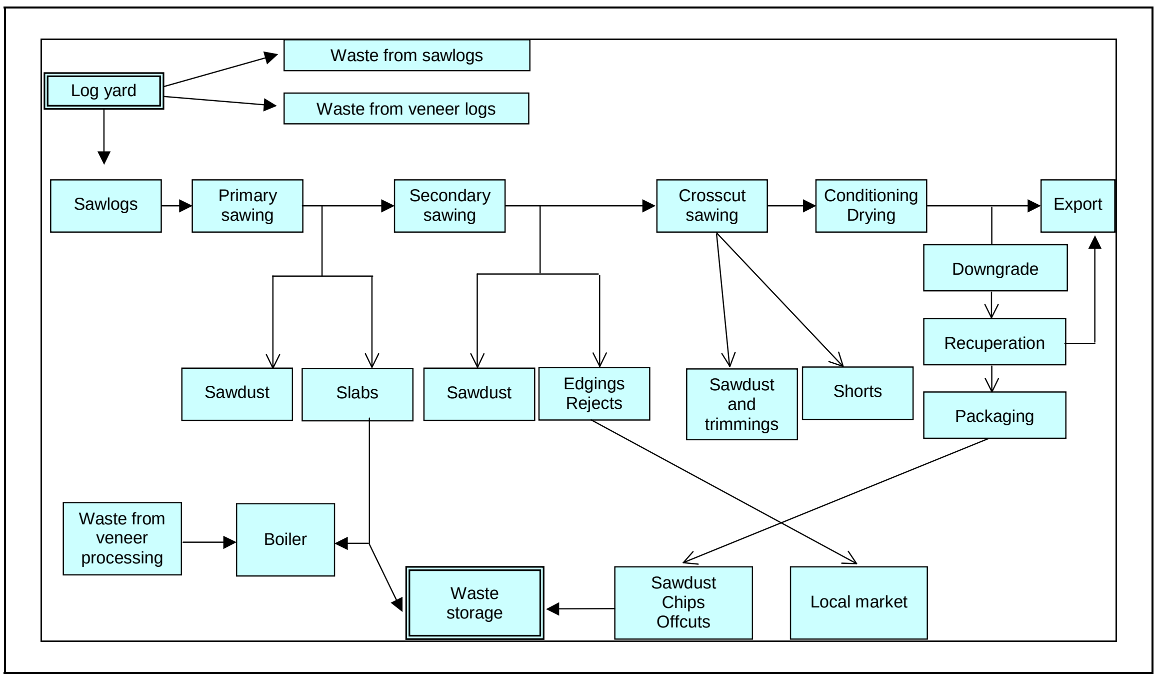
The TIB sawmill is equipped with three sawing lines (headrig 1600, 1400 and 1800) and recovery workshop divided into two sections: one for green wood and another one for dried wood. The first recovery workshop is used for trimming of green timber for the production of parquet flooring. Sawdust is collected through vacuum system.

Table 4.17 Production of Sawnwood and Recovery Products at TIB

Period	Logs	Sawnwood	Recovery products	Total recovery rate	Waste rate
	m^3	m^3	m^3	%	%
1998 (1)	13 976	6 265		44.8	55.2
1999	50 255	21 448		42.7	57.3
2000	70 591	31 487		44.6	55.4
2001	77 115	33 783		43.8	56.2
2002	78 521	28 499	3 855	41.2	58.8
2003 (2)	42 863	15 383	1 170	39.5	60.5

(1) Period: May-December ; (2) Period: January-June. *Source: Field work.*

Figure 4.4 Waste Flows at TIB Sawmill



Presentation of the Mbang's SFID-PFI Sawmill

The Forestry Company and Industry of the Doumé Industrial Free Trade Zone Factory (SFID-PFI) is a part of the Rougier Group, mainly operating in Central Africa: Gabon, Cameroon and the Congo Brazzaville. The sawmill of the Mbang's SFID-PFI is located in the Kadey District in the Eastern Province. The company specializes in sawing and drying of timbers.

The logging activities are carried out by SFID in Dimako and Cambois Company in southern Cameroon (Dja and Lobo Dstricts) in the FMUs No. 10 056, 10 054 and 10 038.

The sawmill is equipped with three production lines with three headrigs, three breakdown saws and six edgers. The production is intended exclusively for export (Table 4.18). Marketing is carried out by Rougier Group in France.

Table 4.18 Exports of Logs and Sawnwood: Sawmill SFID-PFI in Mbang

Period	Logs			Sawnwood		
	Total for Cameroon	Part of SFID-PFI	Share	Total for Cameroon	Part of SFID-PFI	Ratio
	1000 m^3	1000 m^3	%	1000 m^3	1000 m^3	%
1998-1999	1 115 114	59 436	5.3	254 485	23 279	9.1
1999-2000	469 515	42 152	9.0	492 433	33 547	6.8
2000-2001	182 759	18 401	10.1	957 884	185 232	19.4
2001-2002	219 058	5 217	2.4	793 251	47 730	6.0

Source: Customs (Autonomous Douala's port

Technology Applied

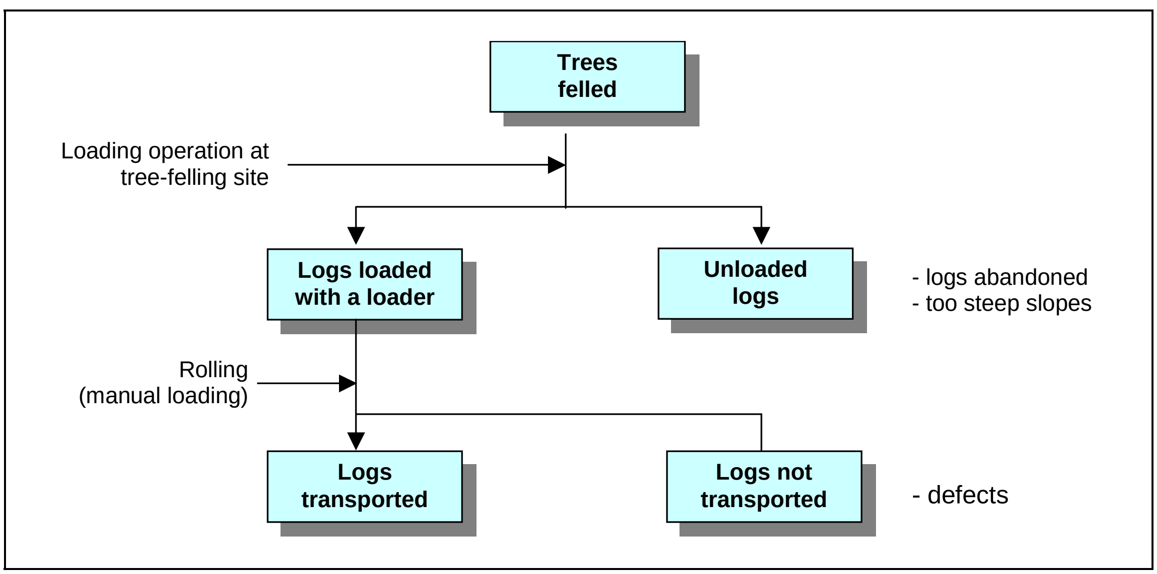
SFID-PFI recovers its sawmill's waste in two recovery workshops: one for green wood and another for dried wood. The workshop consists of band saws, edgers, planers and crosscut saws.

SFID-PFI has ten dry kilns with a total capacity of 1 660 m^3. These dryers, which are air conditioned (ACC), use the steam coming from the boiler. The boilers develop a calorific energy of 3.87 MW.

Types of Waste at SFID-PFI

The waste coming from logging activities (Figure 4.5) are regularly caused by logs abandoned in the logging site or in the log yard resulting from downgrading due to defects and other reasons. There are also waste flows at different parts of the sawmill and in the recovery workshops.

Figure 4.5 Flows of Logging at SFID-PFI in Mbang



Quantitative and Economic Assessments of Waste

To make an economic assessment on the loss due to waste in SFID-PFI sawmill, the daily production of sawnwood during fieldwork visit was recorded. The information was collected with the assistance of the responsible sawmill manager is presented in Table 4.19.

In the dry wood recovery workshop, the data was aggregated for various products recovered: these are rods of 35 mm diameter, rods of 28 mm of diameter, curl, joined.

Table 4.19 Assessment of Wood Waste at SFID-PFI's Sawmill

Products	Input volume [(1)]	Total production	Recovery rate	Waste volume
	m^3	m^3	%	m^3
Ayous sawnwood	257 308	54 709	21.3	202 599
Sapelli sawnwood	242 083	73 942	30.5	168 141
Green wood (Ayous) recovery workshop	88 239	46 239	52.4	42 000
Dry wood (Ayous) recovery workshop				19 181
Total				**431 921**

[(1)] Input volume concerns logs for sawnwood and waste to recover. *Source: Field work.*

The economic potential of the utilization of wood waste at USD 0.54 per m^3 and 312-day working year is about USD 73 000 per year.

Advantage of the Use of Waste for Energy Generation for Boilers

In the SFID-PFI, the boilers are furnished by the chips coming from the recovery workshop. The daily quantitative assessing of this waste flow gave the following values:

- Chips 3.5 m^3 per day
- Shorts 21.0 m^3 per day

Assuming that the value is USD 0.54 per m^3, the following results are achieved:

- Chips: 3.5 m^3/day × USD 0.54 per m^3 = USD 1.89 per day or USD 590 per year
- Shorts: 21.0 m^3 × USD 0.54 per m^3 = USD 11.34 per day or USD 3 540 per year

The daily consumption of boiler 3 870 kWh equals to 92 880 kWh/day (the dryers work 24 hours), and the total energy consumption is 33.8 GWh/a.

The cost of the consumption in terms of electricity is:

- 33.8 GWh/a × USD 0.11 per kWh = USD 3.72 million per year

The annual potential benefit from the use waste is then:

- USD 3.72 million – 590 – 3 540 = **USD 3.71 million per year**

According to the management of the SFID-PFI sawmill, utilization of waste wood for energy can be an important source of income for the company.

Conclusion

Recovering waste for energy has been adopted at the SFID-PFI sawmill. Although the sawmill's main activity is on exports, the utilization of waste can also generate an important source of income, improving the profitability of the company. However, the waste that is sent to pyrolysis could also be valued within the framework of the manufacture of pulp, particleboard, and other panels. It would be necessary to conduct detailed studies concerning the different technologies for waste utilization. These matters have not yet been studied at the company level.

4.3.6 Volume of Waste Utilization

The following practices of waste utilization were recorded during field visits in Cameroon:

1. **Carbonization for the production of charcoal.** This activity is being run by the local craftsmen operating charcoal kilns near the visited sawmills. Examples were TIB in Mfoundi District, MMG and WIJMA in Kribi. In Cameroon, the system of production, transportation and distribution of charcoal is still carried out by the informal sector. The knowledge of the organization of this sector and the actors who are involved is incomplete. According to Head for Wood Department in MIPROMALO, a project for the establishment of an association of charcoal kiln entrepreneurs in the Mfoundi District is under preparation. A study undertaken on the production and the consumption of wood in Yaoundé (ENSP 1994) reveals that the city consumes 2 400-3 600 t/a of charcoal. The energy balance of Cameroon in 1995 shows a significant contribution of fuelwood in the forecasts of the energy plan for Cameroon in 1995 (MINMEE).

2. **The technology of gas generation with wood or charcoal for the production of electricity.** Research has been carried out on this topic by ERA (a Cameroonian non-governmental organization) in Yaoundé.

Other possibilities and technologies associated with creation value for the wood waste concern:

3. **Manufacture of briquettes for energy from sawdust.** This type of project was observed at the time of the visit of the TIB. A recent study had been initiated in collaboration with the MINEF.

4. **Production of wood blocks.** This project was mentioned during the interview with the Profil Bois Industry. The development of wooden blocks is primarily centered on the recovery of shorts and waste from logging sites.

5. **Production of sawdust mixed concrete for the building and construction.** Research has been initiated in this field at Yaoundé University.

6. **Production of particleboard.**

4.4 Production Costs, Prices of Waste and Related Products

4.4.1 Solid Waste

Data collected from the TIB and the principal customers enabled estimation of the prices of waste by category (Table 4.21).

Table 4.21 Price of Waste with Delivery Costs Included

Category	Waste products from white species	Waste products from sawnwood yellow and red species
	USD/m^3	
Slabs	30…60	48…78
Barrière	48…60	72…144
Fausse barrière	18…30	30…60
Fuelwood type 1	3…9	9…18
Fuelwood type 2	18	27
Sawdust	11.25	
Downgraded waste	9…36	

Source: Field work.

4.4.2 Charcoal

The survey carried out with the actors of the charcoal sector revealed that the price of a bag of charcoal varies according to the location of production as follows:

	USD
• Kribi	4.50
• Edea	5.40
• Douala	5.40
• Yaoundé	7.20

4.4.3 Constraints for Waste Utilization

The most important constraints can be identified of the institutional level, i.e., regulations concerning the recovery of waste. The Forestry Administration (MINEF) has suspended since July 1999 the issuing of authorizations to salvage and evacuate timber and stopped the issuance of logging permits and personal harvesting permits. The lack of financial means by the local industrialists to install recovery units for waste utilization is a pertinent problem. Finally, the lack of know-how and expertise in wood waste utilization is a key bottleneck in Cameroon.

4.4.4 Proposed Improvements and Projects Targeted at Waste Utilization

To Forestry Authorities

(i) The MINEF should establish a legal provision aimed at introducing the specifications of the sawmills and the methods of management of wood chips.

(ii) The MINEF should take contact with various councils to reach mutual agreement on the areas allocated for collecting waste from the sawmills to make it available for the potential users.

(iii) The authorities through the MINEF should support the promoters to undertake prefeasibility studies on the available technologies of utilization.

(iv) Administrative authorities (MINEF, MINDIC, MINEFI) should set up a regulation for trade of downgraded and waste wood.

To Research and Development Institutions

(v) Researchers of such institutions as the Polytechnic Higher National School of Yaoundé (ENSP), the CRESA Forêt-Bois and those charged with the development and extension of local materials (MIPROMALO) should initiate coordinated research in partnership with the enterprises of wood sector.

(vi) A research project on “the enhanced utilization of wood waste” should be implemented. The first step would consist of making a detailed study on the waste potential available in the Cameroonian forests.

To Processing Industries

(vii) Efficient organization of waste handling, recovery and utilization based on monitoring of information on waste generation and utilization as an integral part of the core business operations.

5. RECOMMENDATIONS FOR FUTURE ACTION

5.1 <u>Policy Development</u>

- Detect and remove conflicting forest and taxation policies that unintentionally encourage wasteful utilization of tropical wood from the stem to the market.
- Help bridge gaps between national forest policies and crosscutting international policy issues such as environmental protection, sustainable natural resource management, renewable energy sources and the mitigation of climate change.
- Help impose more stringent standards and obligations for logging operators on residues left in the compartments; this could be incorporated in the concession contracts.
- Help create industrial development policies that focus on more efficient wood fiber utilization and technology upgrading.
- Emphasize the adequate training of operators to reduce waste on all levels of the wood products value chain.

- Encourage the woodworking industries to improve their self-sufficiency in energy generation.
- Support the creation of integrated wood processing industries, which would generate thermal energy for their operational needs and electricity for local communities.

5.2 Market Development

- Help identify market opportunities for wood products made of smaller pieces of wood (flooring, edge-glued panels, finger-jointed and laminated wood products).
- Help steer the processing waste into reconstituted panels or pulp and paper industry if economically feasible, or explore the energy wood chips markets.
- Study market resistance on variable-colored wooden flooring and other applications where, e.g., sapwood cannot be used.
- Explore the market opportunities of low-cost reconstituted products such as pallet blocks.
- Help identify local and export markets for refined wood energy products such as special charcoals, briquettes, pellets, etc.

5.3 Investment Promotion and Financing

- Innovative royalty and forest fee schemes should be developed to ensure the commercial attractiveness of residues recovery and utilization.
- Biomass fueled boiler and kiln technologies should be supported with, e.g., lower import tariffs and taxes.
- Ensure preferential investment conditions for small co-generation plants (heat-electricity).
- Identify “green” financing opportunities for the bioenergy sector under the Kyoto Protocol’s flexible mechanisms.

5.4 Transfer of Technology

- Help locally adapting the improved logging and primary processing technologies for higher yield and reduced waste in the forests.
- Support the co-generation technology where South–South technology transfer is possible.
- Develop the extrusion-based technologies of wood energy products.
- Improve the drying, planing, gluing and finger-jointing technologies.
- Improve the staining methods for overcoming the common color variability problems.

5.5 Skill Development

- Improve the skills of practicing sustainable forest management and reduced impact logging among the forest planners and operators.
- Introduce better logging area planning in order to reduce the rates of overthrown, broken or damaged trees during the felling and skidding operations.

- Emphasize the felling and bucking operations where the value of log is determined by forest worker.
- Develop training guidelines to the middle management for rationalizing factory-floor operations and introducing simple improvements for minimizing the processing waste per task/work station.
- Help industrialists incorporate the rational concepts of by-products utilization and wood energy generation into their business planning.

5.6 Dissemination

- Help arrange regional consultations and training on the most pertinent needs of the loggers and wood processors to reduce waste.
- Facilitate the availability of information on wood-saving technology and energy recovery from wood biomass.

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