WOOD WASTE UTILIZATION

IN THAILAND

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Wood Industry Development Division

Bureau of Forestry Research and Development

Royal Forest Department

Wood Waste Utilization in Thailand [1]

1. Overview of Forest Resources and Utilization

Thailand covers a land area of 51,311,502 hectares with a population of approximately 63.4 million. Forest areas accounted for about 32.7% of total land area, which are conserved for environmental balance. The total forest area was reportedly composed of tropical evergreen forest (40 %), mixed deciduous forest (34%), dry dipterocarp forest (21 %), and others (5 %), respectively. Royal Forest Department (RFD) affiliated with the government national forest policy has launched many projects such as the Reforestation Campaign in Commemoration of the Royal Golden Jubilee for the King in 1996, the private reforestation project, community forest project, and intelligent forest utilization and etc to increase forest lands targeting at 40% of the whole country area of which 25% is conservation and 15% is economic forest. Also, the Government has been encouraging the state-run Forest Industry Organization (FIO), the sole agency authorized to buy and sell confiscated teak logs, to expand commercial forest plantations in the government reforestation project due to growing domestic demand for wood. Although commercial forest plantations currently account for about 3 percent of total reforestation of 11,696 square kilometers, as the RTG forest policies emphasize conservation rather than sustainable resource management of commercial forests for two decades since the logging ban in 1989. However, forest degradation and deforestation still occur in some parts of country mainly due to poverty, low agricultural productivity and skewed land distribution by illegal occupation or encroachment activities of land for agriculture and tourism. At the moment, the authorities are vigorously surveying to preserve forest and overhaul the unproductive agricultural lands, simultaneously encouragement of tree plantation in private forested land. At the same time, the extensive plantations will take another 3-5 years, starting with fast growing trees. However, it will take several years to be able to supply commercial hardwoods. Consequently the needs to use timber, wood and forest products still remain gigantic.

Thailand's wood consumption is 0.2 cubic meters/year/person or 12.68 million cubic meters/year. After logging ban in 1989, wood consumption such as log, sawn timber, wood products, pulp and paper, which usually employed national product need to be imported over than U.S.$ 2,412 million (2007).

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Supplies of rubber wood (para wood) from rubber plantations, which are the alternative materials of timber from forest areas, remained tight. According to The Thai Agriculture Ministry's estimate, the rubber wood production potential is around 7 million cubic meters from annual mature rubber tree replacement of around 200,000 rai (roughly 32,000 hectares) out of the total planted area of 12 million rai (roughly 2 million hectares) over the past five years. However, the actual cutting rate is around 3-4 million cubic meters, far below the official estimate, due to continued surge in prices of natural rubber products to around 100 baht/kg (roughly U.S.$ 2.6/kg), compared to an average of around 60 baht/kg (roughly U.S.$ 1.5/kg) in the previous year. The record prices of natural rubber products encouraged farmers to prolong the tapping of rubber trees. As a result, wholesales prices of rubber wood at factory currently surge to around 350 baht/cubic feet (roughly U.S.$ 9/cubic feet), compared to around 240 – 250 baht/cubic feet (roughly U.S.$. 6/cubic feet) in the previous year. The prices are reportedly higher than the critical prices that will encourage some export-oriented furniture manufacturers to switch to imported hardwoods like oak and poplar.

Eucalyptus plantation, approximately 480,000 hectares are the major source for pulp and paper industries.

Teak plantation, which was promoted to planting 15 years ago to private lands, have reached an amount of 160.000 hectares and provided wood for furniture and flooring industries. The trend of using Teak from plantation is also increasing.

2. Overall of Forest Products' Trade

Ever since country's economics has been reckoned with the worldwide scene and turn in the globalize aspect, export-oriented wooden furniture and picture frames have been adapted and produced as international designs and styles, along with its steadily environmental concerns. In the meantime, sluggish growing of domestic demand of solid wood for interior decorations and renovations and commercial construction is still high potential demand. Major suppliers of hardwoods to Thailand are mainly from neighboring Asian countries like Malaysia, Burma, Cambodia, Laos, and Indonesia. Most hardwoods from Malaysia and Indonesia are used for construction purposes. Meanwhile, high-value tropical hardwoods imports like teak, rose wood, and Ma-ka (*Afzelia xylocarpa* Criab), which are used in furniture and interior design, are mainly from Burma, Laos, and Cambodia. Imports of temperate hardwood lumber, which are mainly from the U.S, are used for flooring materials, furniture, wooden frames, picture frames, and interior design materials.

In 2005, imports of U.S. hardwoods declined sharply due to strong competition from relatively cheaper Chinese and European hardwoods. However, the quality of Chinese hardwoods is reportedly low. Also, the market for wooden flooring materials was threatened by relatively cheaper laminated MDF flooring materials, particularly in middle-end housing projects (a house worth 3-8 million bath), which currently have a dominant share in the housing market. Nevertheless, import demand for U.S. hardwood remained strong in export-oriented manufacturers, particularly in picture frames and wooden furniture. U.S. hardwood is reportedly competitive in both quality and price against other temperate hardwood, due to sustainable supplies, standards, and variation of wood. It is expected that about 70 percent of imported U.S. hardwood is utilized by export-oriented manufacturers, while the balance belongs to domestic-oriented manufacturers.

U.S. Hardwood has high market opportunity in wooden furniture industries, particularly when domestic rubber wood prices are currently so high that furniture manufacturers are currently seeking new types of hardwoods. Some grades of U.S. oak and poplar are reportedly able to compete with rubber wood in term of prices. Moreover, the quality of wood itself is superior, which is suitable for Thai furniture manufacturers who are moving towards to high-end market.

High competition in overseas markets and decreased domestic supplies of traditional hardwoods has forced Thai furniture manufacturers to source imported hardwoods, rubber wood, medium density fiberboard (MDF), metal and rattan for alternative materials. Also, Thai furniture industry has diversified into export oriented manufacturing, particularly in wooden furniture, which accounts for about 70 percent of total wooden furniture production. Rubber wood furniture accounts for about 70 percent of total wooden furniture production, following by hardwood furniture (15 percent), and panel furniture (15 percent). However, wooden furniture manufacturers are currently facing difficulties in sourcing domestic rubber wood, due to the shortages as mentioned earlier in the report. Also, rubber wood prices surged to imported hardwood levels, making the products substitutable. Furniture manufacturers are reportedly seeking alternative materials.

According to forestry statistics record in 2007, the trading items of forest products rising in consumer purchasing power and continued strong demand were dividend in 2 categories as:

2.1 Major Forest Products derived wholly from wood are the largest ex-im market in total value not less than 5,500 million USD per annum as tabulated on table 1 and 3.

Table 1 Value of Thailand's Exports of Major Forest Products, 2005-2007

Unit: USD

Items	2007	2006	2005
Logs	699,545	195,100	1,558,754
Sawn timber	373,652,697	396,380,318	343,098,188
Wood Products	1,386,858,576	1,397,534,574	1,481,837,313
Paper	1,255,093,879	1,248,472,969	1,108,525,398
Pulp	176,250,424	133,265,622	107,446,892
Total	**3,192,555,121**	**3,175,848,583**	**3,042,466,454**

Source: Forestry Statistics of Thailand, 2007

Whilst above mentioned wood products comprise of plywood, veneer sheets, veneered panels, particleboards, fiberboards, parquet panels, wood in chips or particles, fuelwood, wood charcoal, wooden furniture, wooden doors, windows and their frames, other wood products. Their income were highest about 45% of total exports, meanwhile imported merely 8% of total imports. Timbers used as raw material for wood products relied greatly on imported wood from neighbor and US-EURO countries as well as on domestic rubber wood and other plantation grown wood.

Table 2 Volume of Thailand's Exports of Major Forest Products, 2005-2007

Items	Unit	2007	2006	2005
Logs	Cu.m.	5,373	2,498	7,991
Sawn timber	Cum.	1,734,571	1,313,631	1,361,935
Fuelwood	Kg.	1,008,752	200	193,980
Wood in chip or particles	Kg.	359,436,824	230,255,875	476,868,357
Wood Charcoal	Kg.	39,631,049	2,153,081	2,469,082
Veneer Sheets	Cu.m.	1,704	1,453	1,971
Particle Board	Kg.	1,110,438,071	1,095,315,444	874,709,931
Fiberboard	Kg.	678,790,945	543,469,427	458,618,675
Plywood	Cu.m.	62,703	1,510	2,052
Flooring Panels	Kg.	541,532	11,975	10,708,287
Wooden Furniture	Unit	24,738,450	25,853,995	29,994,079
Other Wood Products	Kg.	110,703,266	135,962,801	108,686,520
Paper	Ton	1,276,621	1,185,741	1,028,654
Pulp	Ton	293,278	211,537	187,488

Source: Forestry Statistics of Thailand, 2007

Table 3 Value of Thailand's Imports of Major Forest Products, 2005-2007

Unit: USD

Items	2007	2006	2005
Logs	95,966,758	127,648,026	142,350,776
Sawn timber	387,173,091	443,904,322	597,405,633
Wood Products	202,089,606	149,018,670	131,873,518
Paper	1,352,260,485	1,288,419,301	1,301,888,993
Pulp	374,499,515	327,346,483	292,683,218
Total	**2,411,989,455**	**2,336,336,802**	**2,466,202,138**

Source: Forestry Statistics of Thailand, 2007

Table 4 Volume of Thailand's Imports of Major Forest Products, 2005-2007

Items	Unit	2007	2006	2005
Logs	Cu.m.	231,052	293,236	395,578
Sawn timber	Cu.m.	1,702,234	934,050	1,939,771
Fuelwood	Kg.	721,029	942,022	62,875
Wood in chip or particles	Kg.	754,777	2,484,890	1,537,553
Wood Charcoal	Kg.	40,101,261	40,116,808	33,386,250
Veneer Sheets	Cu.m.	27,784	28,886	30,147
Particle Board	Kg.	13,761,682	9,933,461	6,045,920
Fiberboard	Kg.	26,600,851	18,504,854	16,610,148
Plywood	Cu.m.	317,322	164,031	108,496
Flooring Panels	Kg.	214,779	628,228	391,531
Wooden Furniture	Unit	2,448,677	4,079,228	937,553
Other Wood Products	Kg.	62,128,766	47,774,464	31,696,000
Paper	Ton	1,859,303	1,785,837	1,649,868
Pulp	Ton	487,838	472,682	454,324

Source: Forestry Statistics of Thailand, 2007

2.2 Minor Forest Products traditionally known as non-wood forest products including both plant and animal products. Most of them are regarded as fundamental needs for daily life 's subsistence of the rural people, such as medicinal plants, edible plants, rattan, bamboo, bee products, lac, pine resin, raw hides and skins of reptiles. Their data on the exports and imports in current 3 years are shown on table 5 and 6.

Table 5 Value of Thailand's Exports of Minor Forest Products, 2005-2007

Unit: USD

Items	2007	2006	2005
Minor Forest Products	37,875,418	43,533,693	28,093,433
Furniture of Rattan	2,752,301	1,785,694	2,397,706
Furniture of other including osier, bamboo, or similar materials	10,468,395	39,783,487	38,127,898
Total	**51,096,114**	**85,102,874**	**68,619,037**

Source: Forestry Statistics of Thailand, 2007

Table 6 Value of Thailand's Imports of Minor Forest Products, 2005-2007

Unit: USD

Items	2007	2006	2005
Minor Forest Products	57,175,570	66,314,849	54,596,317
Furniture of Rattan	619,642	335,909	223,385
Furniture of other including osier, bamboo, or similar materials	1,532,179	11,887,909	8,936,923
Total	**59,327,391**	**78,538,667**	**63,756,625**

Source: Forestry Statistics of Thailand, 2007

3. Forest Products Industry in Thailand

At present, mostly of small and large sawmills was permitted from government have been closed because of logging ban. However it is found that 384 of sawmills and 50 of sawn timber by manpower are still employing (Table 7).

Furniture factory in Thailand has 6,259 factories. The majority of products are group of sofa, table, chair, and shelf etc. Both of natural and artificial colors are produce. Most of manufacturing furniture are common produce by skilled labor more than unskilled labor.

Manufacturing of plywood was started up in 1957 (Thai Plywood Co.,Ltd., established by the Forest Industry Organization, FIO). Exported veneer was started up production in 1971 (Thai Chipboard Co.,Ltd.). Nowadays, number of

veneer and plywood factories has 14 and 21 mills, respectively. The majority of plywood factories produce veneer by themselves.

In case of laminated wood for flooring and top-table board, rubber wood and planted woods, i.e. Eucalyptus and Teak, were used as raw materials.

Manufacturing of fiberboard in Thailand has prominently two types : hardboard and medium density fiberboard (MDF). All of hardboard processing employ producing method of wet process and using Eucalyptus and wood from plantation e.g. KraTinTePa (*Acacia* sp.) and also Bagasse as raw materials. In case of MDF manufacturing, small stem and big branches of rubber wood are mainly used as raw materials.

Table 7 Sawmills and Wood Products Factories in 2007

Items	Total Mills	Classified by Region					
		Bangkok	Central	North	North-east	South	East
Sawmills	384	45	164	59	67	33	16
Sawn timber by Man-power	50	0	19	23	3	0	5
Wood Working by Machinery	6,259	1,975	2,473	623	537	296	355
Wood Working by Man-power	843	29	306	206	238	27	37
Plywood	21	6	11	0	0	4	0
Veneer	14	2	10	0	0	2	0
Fiberboard	10	1	7	0	1	1	0
Particleboard	19	0	8	0	1	7	3
Pulp and Paper Mills	4	1	3	0	0	0	0
Sawn Timber Shop	4,4472	1,113	1,581	469	749	288	272
Wood Products Shop	6,063	1,716	1,866	1,082	954	188	257

Source: Forestry Statistics of Thailand, 2007

Even though manufacturing of particleboard was started up in 1958 but it came to be popular when established another large factory in 1986. Nowadays, there are 19 particleboard factories with total capacity 1,423,900 cu.m/year. Raw materials are rubberwood, eucalyptus and bagasse.

In 1996, there are 6 pulping factories and 46 paper factories in Thailand with total capacity of short fiber 626,000 tons/year and 2,842,000 tons/year.

4. Wood Waste Situation and Outlook

4.1 What is Wood Waste ?

Waste is referred to as rubbish, trash, garbage, or junk depending upon the type of material and the regional terminology. In living organisms, waste relates to unwanted substances or toxins that are expelled from them (from Wikipedia).

Wood waste is therefore waste material consisting of wood pieces or particles. Presumably this includes all types of wood such as demolition wood waste, manufacturing wood waste, furniture, etc. and probably urban logs.

Wood waste can include sawn lumber, pruned branches, stumps, and whole trees from street and park maintenance. The primary components of urban wood waste are used lumber, shipping pallets, trees, branches, and other wood debris from construction and demolition (C&D) clearing and grubbing activities (California Integrated Waste Management Board 2001).

Hence, wood waste is a very broad category, include a large spectrum of wood products from primary and secondary processing such as bark, slabs, sawdust, chips, planer shavings, sander dust, end trims, used or scrapped pallets, and construction wood wastes. However, wood wastes also include logs, branches, and brush from urban tree removals and land clearing for construction, farming and industrial projects.

In case of urban wood waste from C&D, it is not the same as cut from fresh wood. Its recycling performance have to be take peculiar precaution involving to environmental effects, due to contaminate with wood preservatives, binders, paints, glues, plastic laminating materials or other non-wood materials. It can also mean particleboard, flake board, plywood, fiberboard and manufactured wood, which may have plastic laminates, chlorinated adhesives, or phenol and urea formaldehyde resins. Other products, which have been allowed to be burned in industrial wood burners, include pelletized wood pulp from mills, which may use chlorine bleach. Wood pallets have been discussed as biomass fuels. It is unreasonable to expect that the metals staples and nails be removed before incineration in industrial wood burners.

Painted wood may include lead or mercury (particularly in demolition debris). Mercury has been used as a fungicide in paint. Treated woods are usually coated with creosote, copper chromium arsenate, or pentachlorophenol. Pentachlorophenol is a chlorinated compound, which will form dioxins and furans when burned. Burning wood treated with copper chromium arsenate (CCA) will release arsenic and chromium. Any small bit of CCA-treated wood will greatly escalate dioxin emissions

from industrial wood burners. Some wood burners that are permitted to be taking "clean" wood wastes have been allowed to accept a certain percentage of chlorinated wastes, since wood waste suppliers are unable to completely isolate all vinyl-coated material. In construction/demolition wastes, there is likelihood of PVC (polyvinylchloride) contamination from many sources common in building materials. For example, all households' electrical wire is coated with PVC plastic. Since this wire is made of copper, it's an extremely dangerous mixture to have burned, since the copper will catalyze increased dioxin formation out of the PVC.

4.2 Source and type of Wood Wastes

The wood waste described herein is the wood harvested from the cultivated rubber tree plantation by farmers. Eucalyptus and Teak plantation are also accompanied with local source known as "The Economic Tree Plantations". Other alternative trees, for instance *Acacia mangium*, *Acacia auriculiformis*, *Azadirachta excelsa, Alstonia schlolaris*, *Anthocephalus chinensis,* and *Leucaena leucocephala* are categorized as fast growing trees and normally harvested at the age of five to ten years. Fruiting trees after harvesting consist of Mango tree, Jackfruit tree, Tamarind tree and Cashew Nut tree are also sold to process into a variety of finished and sawn timber. Senile big trees planted for shading recreation, as like *Samanea saman* or *Albizia lebbeck*, are adopted as wooden engraving handicrafts.

Logging residues also be counted as waste refer to any wood lying on the ground as a direct result of logging operations and trees severely damaged during logging operations. Approximately one-third of all logging residues originate from felled trees and the balance from residual trees destroyed or damaged during logging and extraction. The residues may range from portions of the trees including high stumps to entire trees broken during the logging process and left on the ground. They can be roughly divided into the following categories:

- High stumps (leaving usable wood in the stump)
- Stem section above the first branches (top log)
- Branches
- Off-cuts, rotten log parts
- Standing trees broken or severely damaged in the crown
- Standing trees severely damaged (butt trunk and root damage)
- Splintered trees and logs
- Logs lost and not recovered

Unfortunately, very little is known about recovery rates for plantations in Thailand. This statistics from Forest Economics Division are not yet available. It is not known how much from the wood and residues or waste left coming out of the

forests and private plantation. Such also depends on the end use, distance to markets, standards of the industry, and whether one considers final harvests or thinning operations.

Wood-processing wastes or mill wastes consist of any wood fiber not used during the conversion process at a mill i.e. sawmill, veneer mill, plywood mill, or pulp mill. It includes losses due to improper and lengthy storage. The following categories make up mill wastes:

- Discarded logs (rotten or visibly or invisibly damaged)
- Bark
- Sawdust
- Slabs, ribs
- Peeler cores
- Grading off-cuts
- Sander dust
- Shavings
- Rejects

The most attractive options for using large volumes are turning waste into charcoal briquettes, using it for co-generation, and using it as secondary raw material within the wood-based panel subsector.

Furthermore, sawmill wastes are an important raw material for the molding industries, incense stick, and in a myriad of way by the small-scale artisan sector in the rural areas. Horticultural and agricultural uses are also possible.

5.Wood Waste Processing in Thailand

All these end uses have similar processing requirements in that, the wood waste has to be separated from other wastes, cleaned by removing contaminants and fasteners, and, in some cases, processed through grinding or chipping. The final uses of the wood waste often determine show clean and consistent the feedstock must be.

Estimating the volume of mill wastes available for further processing is difficult. Production figures are often not reliable. Recovery rates vary depending on log sizes, dominant species processed, standard of processing equipment and level of horizontal and vertical integration. Hence aggregate figures should be viewed with caution. The sawn-timber is produced in sawmill located close to the production forest. During the process, between 45-50% from the log inputs are converted

into waste, i.e. log-end, bark, sawdust, wood-slab, lumber-edge, and chips, which is mostly unutilized.

Many sawmills in Thailand are set up and managed in traditional ways (i.e. they are equipped with band saws and set up to cut large-diameter logs). It is difficult to envision significant investments in this sector in the near- to medium-term future as log supplies are uncertain in many areas. However, some retooling should be considered to increase recovery rates by raising the performance and productivity of breakdown saws and resaws. Water storage of logs or sprinkler storage can also minimize waste experienced during dry periods. Even substantial investments in the sawnwood and plywood sub-sectors would likely reduce mill residues by only 5 to 10 percent. Thus, the question of how best to utilize residues remains.

Large quantities of mill residues are used as fuelwood for brick making, tobacco drying and domestic cooking in Northern part of Thailand.

In the manufacturing process of most wood processing company in Thailand which produced sawn timber, wooden furniture, parquet flooring, they produce large amounts of wood wastes (i.e. wood shavings and sawdust). Instead of being dumped or incinerated, or using conventional fuels (i.e. bunker oil, diesel, gas, etc.) the wood shavings and sawdust are transported via pneumatic collector system and used as a source of energy in the boiler supplying hot water to the kiln dryers and hot presses.

The potential utilization of wood waste from the wood processing industry in Thailand resemble other ASEAN countries can be divided into three broad categories:

1. Energy production, such as:
    - Boiler fuel for kiln-drying, wood conditioning, lacquer-curing, etc.
    - Co-generation plant fuel
    - Industrial fuelwood (e.g. for brick making, noodle production, tobacco drying, and steam generation.
2. Secondary raw materials to be used by the wood-based industries for:
    - MDF
    - Particleboard
    - Block board
    - Laminated board
    - Charcoal briquettes
    - Parquet
    - Pallet manufacturing
    - Small-scale wood products, e.g., in cottage industry

- Use in paper and pulp industry

3. Secondary raw materials to be used by industries outside the wood industry sector:
   - Fertilizer and mushroom growing
   - Livestock litter/bedding

Charcoal briquettes

Wood briquetting includes the conversion of loose wood waste into a dense, compact and consolidated unit through the application of high temperature and pressure. Both sawdust and bark are suitable for briquetting, although sawdust is the preferred raw material. Briquettes can also be carbonized to create charcoal of very high quality. Briquettes have to compete with other fuels, such as wood and agricultural residues, kerosene and diesel, which are often cheaper.

Co-generation

Co-generation is the process by which a factory uses its waste energy to produce heat or electricity. The steam produced can provide large amounts of lower-temperature energy for such applications as kiln drying. Considerable overall energy savings can be obtained, and investment in cogeneration is thus very attractive with short payback periods.

Wood chips, Particleboard and Fiberboards

Sawmill and plywood mill residues of mixed hardwood species can form an important raw material for the chip and board industries. This is particularly attractive for large-scale uses where mills have the opportunity to sell their unwanted waste in a cyclic, well-organized manner based on long-term contracts. In fact, under such conditions, wood residues are no longer viewed as a problem. Rather, they are viewed as valuable by-products that can help increase profit margins. However, the relative location of residues and markets for final products has to be analyzed carefully. Due to the downturn in many Asian economies, plywood production was most affected while particleboard and MDF producers registered slight increases. This difference can probably be explained by the very different raw material requirements. Particleboard and MDF manufacturers have a considerable comparative advantage in that they can make use of much cheaper raw material. This price divergence will probably continue, as new technologies make it increasingly possible to use mixed tropical hardwoods. In the future, the role of wood residues as raw material for the expanding particleboard and MDF sub-sectors will increase and local raw material shortages and higher prices for mill residues will likely result.

There are two common processes in making Particleboard and Fiberboards :

1. Dry Particle or Fiber Bonding - The dry and semi-dry processes consist of mixing graded material with bonding resins and forming them into the finished product, using a power press and molds. This process produces material with superior hardness and better nail and screw holding properties, desirable in boards used as timber substitutes. These are generally referred to as particleboards or chipboards.
2. Wet Process - The wet process reduces sawdust and chips to, a semi-liquid state of wood fiber. This is mixed with bonding resins and a fiber mat formed in a deckle box, similar to those used in hand papermaking. From this point on, a variety of different kinds of board can be produced, but all may be classed as fiberboards.

PARTICLEBOARDS

Panels, doors, furniture, and wallboard can be made from sawdust and woodchips, bonded with resin. The materials and processes for fabricating panels, doors and wallboard are similar. Most of them can only be operated on an industrial scale, as heavy presses are required.

Materials - The Wood Waste

Particles are produced by hammer milling planer shavings and chips, chipped or hogged veneer, or slab wood. Because of their higher moisture content, green planer shavings are damaged less by the planer and when hammer milled, break into sliver-like components. The properties of board made from them are better than those of boards made from dry shavings. Little bark is included in either fiber or particle board because (a) Dirt and grit are almost always present; (b) Pulping bark may require different conditions than wood; (c) Particle bark may be stringy or flaky. This creates problems in screening, resin distribution and mat formation; (d) Bark is dark colored and shows up in the finished boards, either as dark flecking or as a uniform dark tinge.

Equipment that will reduce whole wood to fiber and fiber bundle, suitable for insulation and hardboard such as hammer mills, chippers, grinders, defibrators, continuous steam cookers, and disc refiners can be obtained from manufacturers of wood pulping machinery.

Materials - Resins

The bond in particleboards is produced by the cured (hardened) resin. The small amount or resin required, even though only 6 to 10 percent, is by far the most expensive ingredient of particleboard. The amount depends on the size and shape

of the wood particles, so selection of an optimum particle size is economically very important. However, the quality of the resin binding agent has more influence than that of the sawdust and chips on the quality of the finished product. Conditions of use determine choice of resins. Hygroscopic resins (water absorbing) should not be used for products that will serve in damp conditions. Thus, urea-formaldehyde resins are used only for interior wallboard where moisture is no problem, because they are lower in cost than phenolic resins (phenol-formaldehyde) but cannot withstand high temperatures and moisture. Phenolic resins are most suitable for exterior use products or where water resistance or surface hardness must be increased. However, even this product is not suitable for exterior use in damp climates. Resins that dehydrate (lose water) completely are not suitable when the finished product is to be used in warm, dry climates.

Manufacturing Operations

Commercial board manufacture involves receipt of the raw wood waste. Particle or solid material passes through a hogger or hammer mill or flaker, then rejoins small size waste (chips, flakes, and sawdust) to pass through grinding mills and screens for final sizing. The milled material is conveyed, often by air blowers along ducting systems, to a cyclone separator, which removes dust, then into dryers (usually of the rotary drum type) to adjust the moisture content to 6 or 7 percent. It is then stored in bins until needed.

Dry wood material is weighed into a mixing vat and the required quantity of liquid or powder binders added. Liquid binder may be sprayed on the particles in a continuous operation or mixing may be carried out in batches, by tumbling the particles and binder in a drum or mixer. The moisture content of the particles must be controlled while the resin is being added. The mixture is measured out in measuring boxes, then conveyed to trays that are loaded into the press. Presses are continuous press, single-daylight, or multi-daylight, that is to say, many boards can be pressed in each operation. Pressing time depends on thickness, temperature, and whether or not a perform is used. For 6-mm thick board, pressure is maintained for 15 minutes; for 16-mm thick board, pressing time is expanded to 35-45 minutes. Pressures vary from about 15 kilograms per square centimeter to 30 kilograms per square centimeter, depending on the final board density required and the type of waste material used. Pressing temperatures used are 120 to 160 degrees Celsius. After pressing, the boards pass through trimming saws and go to storage awaiting dispatch.

In some particleboard plants, an extrusion press is used—a continuous operation in which the board is squeezed out between heated rollers. The particleboard

produced in this way has X-definite directional properties. It is weaker or less rigid in one direction than in the other. Cost of the equipment may be less than for hot presses.

Hardboard

To produce the most dense hardboard for interior partitioning or dense ceiling boards, the matted fibers are pressed between the platens of a hotpress. Existing plywood presses may be used to avoid a new capital investment.

After manufacture, hardboards may be either (a) dipped in moisture repellents, such as asphalt; (b) humidified (placed in racks in humid chambers); (c) oil tempered-passed through a bath of oil, then baked until the oil diffuses through the board (tempering improves both strength and water resistance); or (d) painted, scored, sanded, or embossed to improve appearance.

MDF-board

Medium density fiberboards are produced when binders are introduced into the fiber mat and the board is hot pressed to a density of 26 to 50 pounds per cubic foot (400-800 kilograms per cubic meter). After partial drying, they may be laminated with one or more plies of low-grade veneer, to produce a wood-faced panel.

Insulation Board

Insulation board is produced when such mats are dried without further hotpressing. The board is held together by the normal fiber bonding. Insulation board plants usually must be large-capacity because of the cost of continuous dryers. There may not be sufficient whole wood waste to justify the installation of conventional insulation board plants competitive with existing plants using pulpwood. Insulation boards require little or no resin, but resin and alum are added to decrease water absorption. Asphalt may be added to increase wet strength. It is reported that dried mats, unpressed, may be soaked in molten sulphur and cooled to a fiber-reinforced product, sometimes called poor man's fiberglass, with good strength and water resistance.

OTHER BUILDING MATERIALS

Wood Cement Boards

Sawdust can be used as a cheap, lightweight aggregate for building blocks. Such blocks are light and porous, hold nails and screws well, and have fair insulation properties. However, there is a disadvantage of using sawdust in masonry. It undergoes comparatively large movements with changes of moisture content that result from changes in humidity or wetting and drying. When using it with Portland

cement, it is necessary to ensure that materials in the sawdust, such as resins and acids, do not upset the hardening qualities of the cement. Adding hydrated lime to the mix, between one-sixth and one-third volumes of lime per volume of cement, will normally guard against this, but certain sawdust gives setting difficulties even with lime present. Other special treatments include immersion of the sawdust in boiling water for ten minutes, followed by washing with water, followed by further immersion in boiling water containing two percent ferric sulphate, more washing and draining. Alternatively, use of 4 or 5 percent by weight of a setting accelerator, such as calcium chloride, has been found useful. However, to avoid expensive additives, first check test whether the proposed mix hardens satisfactorily using only hydrated lime.

Use of the correct quantity of water is most important. The strongest mix will be that on which it is impossible to draw a cement "skin" to the surface during trowelling, while a smooth surface can still be produced. It should have a moist earth consistency with no appearance of free moisture. For a 1:3 mix (by volume) of cement, and sawdust, the weight of water should be from 80 to 140 percent of the weight of cement. (The variation is due to the degree of dryness of the cement). Excess water causes shrinkage during setting, deep crazing several months after laying, and lower strength as well.

The practical ratio of cement to sawdust is from 1:1 to about 1:5 by volume, ranging from heavy, strong, and dense products from the former to lighter products from the 1:5 mixes, low in strength and fire resistance and prone to increases in movement with moisture changes. Leaner mixes can be cut and nailed readily but the richer ones become difficult to nail as drying proceeds. Addition of an inert aggregate, such as sand or granite chips, reduces shrinkage but also reduces insulation properties and nail ability. Methods employed to minimize movement include water proofing by tar or bitumen after installation and designs that allow movement to be taken up within the building. Manufacture is by the same processes as for cement-sand blocks, ranging from hand molding into wooden molds to the use of fully automated block-making machinery.

Wood-fiber-plastic composites.

Using wood-based materials to reduce the cost of thermoset plastics dates to the beginning of the century. Using recycled wood or paper fiber as a reinforcing filler in thermoplastics is a recent innovation. Most commodity thermoplastics, such as low- and high-density polyethylene (LDPE, HDPE), polypropylene (PP), and polystyrene (PS), can be blended with waste wood or paper. Polyethylene terephthalate (PET), used to make soft drink bottles, is generally not used because its melting temperature is greater than the degradation point of wood.

Gypsum Products

Sawdust can be used in the manufacture of gypsum commodities to decrease weight and increase sound and heat insulation qualities. This can also make them porous and soft so they can be nailed and sawn. Such products are used for interior partitions, floor insulation, wallboards, and roofing material. Composition stuccos and plasters also use sawdust as fillers to make them lighter and more porous than normal, able to be nailed, and higher quality insulators. Shavings can also be mixed with limestone during burning to produce lime. The resulting product is said to be of high quality.

Insulation

Sawdust can be used in wall construction--mixed with asphalt and resins, then rolled into sheets and used as insulation on the sides of buildings or floors. Alternatively, it can be packed into a sandwich between corrugated galvanized sheeting, commonly used as roofing for low-cost dwellings, but very hot under direct sunshine. Sawdust serves as an effective insulator in construction of ice-houses, refrigerated trucks, and cold storage sheds. When properly packed it does not add to the fire risk and can be additionally protected against fire and insects by the use of low cost chemicals.

AGRICULTURAL USES

Livestock and Kennel Bedding

Coarsely ground shavings or sawdust make excellent bedding for small animals such as chickens or rabbits. It is cheap, soft, warm, and free from dust associated with straw. It absorbs urine and excreta, and especially from fowl has some fertilizer value. Adding superphosphate and permitting this to rot can produce an even better grade of fertilizer.

Mulch

Mulch is a layer of material laid of top of (or mixed with the top layer of) soil, often around young plants, for the purpose of reducing water evaporation from the soil, controlling surface temperatures (protection from frost or strong sun), or preventing weed growth. Mulches may serve to prevent soil splashing during heavy rainfall and resulting erosion and may improve the rate of water movement into the soils. The action of mulch is physical; organic mulches also break down chemically to provide necessary elements and humus to the soil. Sawdust is considered to be an excellent mulch for fruit orchards, tobacco and similar seedlings, and for soft-

fruit, vegetables, and flower gardens. However, if the sawdust mulch is mixed in with the soil, it is essential that adequate nitrogen be added also.

Soil Conditioners

Wood contains only small amounts of inorganic chemicals valuable as fertilizers: 31 pounds of nitrogen, 21 pounds of phosphate, and 2 pounds of potash per ton of dry material. Only when composted with other materials is the nutrient value of wood waste raised. The principal organic compounds present in wood that are of agricultural interest are cellulose, the pentosans, and lignin (the tough fibers that make a material "woody"). When sawdust is added to soil, bacteria and fungi attack the cellulose and the pentosans most rapidly. The lignin and its degradation products and the residue of microorganisms tend to remain in the soil as humus, the network of fibrous and granular material that is important for improving the physical condition of the soil.

WOOD FLOUR

Wood flour is not the same as sawdust. It is a uniform, fine powder of much smaller grain size. Commercially, it is used as an absorbent, a chemically reacting substance, chemically inert filler, a modifier of physical properties, a mild abrasive, and a decorative material.

Uses of Wood Flour

Wood flour can be used as an absorbent to remove water, oils, or greases from delicate machinery parts, jewelry, and furs. In the manufacture of dynamite, absorbing it in wood flour, thus solidifying the liquid nitroglycerine, can reduce the sensitivity of the explosive.

The chemically reactive property of wood flour is utilized in incense and in the coatings of arc-welding rods where it provides a neutral gas to protect the weld puddle from air. In reaction with polyurethane foaming resins it produces a rigid foam-in-place structure. Wood flour is also used in fireworks intended to burn for a time rather than explode.

As a chemically inert diluting agent or filler, wood flour is used in the manufacture of plastic products. When utilized in this manner it increases impact resistance or toughness, reduces stresses, and minimizes shrinkage on cooling after molding. Wood flour is sometimes added to make transparent plastics opaque. It is also used in the manufacture of patching materials, cements and glues, insecticides, soap powders, and rubber. The natural resins in wood flour are used for their binding properties, notably in linoleum manufacture.

In foundries, wood flour is used as an anti-binding agent to modify the physical properties of an item--for example, to help ease castings out of their molds. In chinaware and firebrick manufacture, it is used as a burnout material to increase porosity. In special paints, it gives sound insulating properties and in electrical equipment, wood flour improves insulation.

As a mild abrasive, wood flour is sometimes added to soaps and is used in cleaning furs. It is also used to polish soft materials such as buttons and for removing the flash (material that sweeps out at the mold joint) from newly molded plastic articles.

Wood flour is also used decoratively in interior decorating. In velvet or raised wallpaper for example, colored wood flour is sprinkled over the sized surface.

Wood flour has also been used in biochemical processes as a culture medium for the growth of bacteria, for example. This produces valuable organic acids such as acetic, lactic, gluconic, and citric.

Manufacture of Wood Flour

Light colored flour is required for many applications. Since bleaching is not practiced, lightwoods such as rubber wood and some fast growing trees are the most desirable. The chief source of raw materials for wood flour is the residue of other wood processing industries. Wood flour can be produced by a variety of method: recovery of dust from sanders; screening, using meshes as fine as 350 to 400; abrasion by corrugated metal discs revolving in opposite directions; cutting and shock, using impact hammer mills; and crushing by passing the material between a moving roll and a stationary surface.

OTHER USES FOR WOOD WASTES

Slabs are strips of wood removed from the outside of the tree trunk before it is converted into planks. They are often about six inches wide and six to eight feet long, with one flat side, and the other covered with bark. Slabs can be used as lumber and the other covered with bark. Slabs can be used as lumber, whenever the finished product does not have to be uniform and tight fitting. Appropriate usages of slabs include animal pens, shed shelves, loose storage bins, or rustic furniture. Slabs will rot quickly if exposed to the ground; to they need to be preserved with creosote. Slabs nailed to posts; with the bark side facing outward has the appearance of rustic fencing. In gentle climates, slabs can be used as roof boards if tarpaper is spread under them. A slab sandwich consists of a layer of slabs, nailed to cross pieces with the bark side down, then a double layer of tar

paper, another layer of slabs, with the bark side up overlapping like shingles. Such a roof is not permanent, but may last about five years, so it is suitable for storage or other temporary uses.

Forest wastes such as leaves make the finest compost, and should be used for this wherever possible. Wood bark protects the tree but it is harmful to many forms of life. Therefore waste bark has in the past, had little commercial value other than for fuel. Chopped bark can be used as animal bedding and in chipboard. Because of its color, however, it may not always be acceptable. Recently composed bark has been used for soil conditioning after processing to remove any danger to plant life.

6. Summary

Wood waste utilization in Thailand mostly moves towards to three appropriate facilities, (a) Bio based energy production and (b) as raw materials to be used by the wood based panel factory and (c) by industries outside the wood industry sector.

Vigorous considerations needed in Thailand before utilize wood waste are the following issues:

6.1 How much waste wood do you generate? This will determine how often collection and transportation are needed and what will be necessary to accomplish this.

6.2 When do you generate wood waste? How consistently do you generate wood waste?

6.3 What types and sizes of wood do you generate? Due to the variety of generation sources, mixed wood makes up the majority of the wood waste stream.

6.4 How clean is your wood? The question of cleanliness is complex because each wood waste processor has its own criteria for accepting wood waste. The cleaner the wood waste, the more management options. This might require some capital investment that influence to economically feasible.

At last, remarkable sentence is raised to propose with respect to this workshop is;

"Wood waste reduction program can conserve natural resources and save money in reduced disposal costs."

Thank You for Your Kind Attentions