Concern on Wood Waste Utilization: Environment and Economic Evaluation

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Abstract This chapter highlights the concern on wood waste utilization regarding on environment and economic evaluation. Wood waste is the part of the effluents that can comprise discarded wood, whole trees, stumps, or clipped branches. Wood waste is also derived from downstream (sawmills) to furniture, boards, and moldings. Forest waste (waste from deforestation) and residues from wood processing plants are also two types of wood waste associated with sawmill operations. Wood waste can be decreased without negatively impacting the world's forests by improving the productivity of primary wood consumption and using raw wood resources produced from sustainable forest management [1–5]. Due to the defects in the felled trees, the production of sawn timber is considered wasted. Only about 47% of the logs that reach the sawmill are converted into salable timber. The remaining residue containing 33% wood chips, 7% sawdust, 8% shavings, and 5% bark should be discarded or otherwise used [6]. The timber industry is an important industry in Malaysia. At the same time, the timber industry has a significant impact on the environment in general (air, water, and soil) and in particular on land and resource management. So, we must give emphasis to the solution. For example, the adoption of cleaner technology and waste minimization (Krajnc and Domac in Energy Policy 35:6010–6020, 2007). The main factors of environmental degradation are recognized as:

- Inefficient use of timber creates excessive waste and leads to the over-clearing of forests and plantations.
- Burning of branches and treetops in forests and plantations.
- Open burning of wood waste from industry on-site or off-site.
- Inadequate or unlicensed on-site incinerators
- Illegal disposal of waste (especially sawdust) into rivers, wastelands, and so on.

The vast amount of waste generated from wood processing operations in many countries presents challenging opportunities for utilizing wood waste. Consequently, the timber sector is anticipated to see both timber costs and waste disposal costs rise. Subsequently, wood waste is it is anticipated that wood waste will gradually become

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a valuable resource. Wood waste is a sustainable, inexpensive, and widely accessible source of energy that has the potential to replace fossil fuels in a variety of uses, made up of heat, power, and biofuels. The expanded use of agricultural biomass can aid agriculturally based countries in achieving energy security and providing jobs without contributing to environmental damage [1, 4, 7, 8].

1 Wood Waste Resource

A better understanding of the content and element of wood waste is essential. Wood waste is also classified into two types: industrial waste generated from industries and final waste generated after the products have been used [3, 4]. The following categories make up wood waste:

Types of wood waste:

1. Bark
2. Slabs
3. Long offcuts (Trimmings)
4. Short offcuts (Short ends)
5. Peeler cores
6. Sawdust
7. Shavings
8. Sander dust
9. Rejects.

However, the wood waste can be divided into groups:

1. Bulk wastes, which include all larger wastes, are easily segregated.
2. Particle wastes (also known as silo wastes) are a mixture of tiny and fine wood particles resulting from various processes and normally collected in a silo via dust extraction system. These wastes are more difficult and expensive to separate.

Wood waste should be seen as a dynamic and changing material flow rather than a homogenous product. The largest producer of wood waste is the construction and demolition sector. Wood fraction accounts for 20–40% of construction and demolition waste in Europe. Additionally, the furniture business is a significant contributor to waste. Packaging accounts for a lesser part of total production. Wood recycling typically implies the reduction of the material to small particles (chips, fibers, etc.) that can be repurposed in the manufacturing of engineered wood products. Table 1 provides a categorization of wood wastes based on their source [3, 8, 9].

Table 1 Classification of wood waste according to its origin [9]

Origin	Type	Class
Packaging	Pallets and boxes (untreated, no MDF)	1–2
	Pallets and boxes (with MDF/treated wood)	3
Construction/demolition	Wood from construction and rebuilding (untreated, no MDF)	1–2
	Old wood from demolition and rebuilding (with MDF/treated wood)	3
Furnitures	Furniture (untreated, no MDF)	1–2
	Furniture (with MDF/treated wood)	3
	Furniture, upholstered	3
Others	Impregnated wood (wood treated with CCA, creosote or PSP)	4
	Composite building materials from demolition	3
	Miscellaneous (items made from plastic, glass, metal, carboard)	3

2 Potential Usability of Wood Waste

Wood waste can be recycled into several products such as wood composites, power production (heat and electricity), composting, and animal manure. These low-cost, unused feedstocks have the potential to boost the viability of wood waste. As a result, the wood pellet sector has grown to capitalize on the potential given by the rising demand for renewable energy sources, creating long-term value for the bioeconomy [3, 6]. It is anticipated that bioenergy in British Columbia could generate over 1600 MW of heat and/or electricity and produce 3.2 million tons of wood pellets. The entire capacity of BC wood pellet generation in 2017 was 2.4 million tons, accounting for 66% of total Canadian wood pellet capacity but falling far short of the county's maximum manufacture [6].

Wood waste is a type of rubbish that comprises waste wood from several sources, like wood packing, destruction, and construction, the wood-based sector, private dwellings, and rail systems [1]. This garbage can be used as a secondary source of raw materials to produce energy and a wide range of new goods, such as chemicals, biofuels, and organic materials [2]. Lipophilic and hydrophilic residues in wood bark can be turned into high-value items like cosmetic chemicals and medications [3]. Yang et al. [4] reported that bio-oil derived from waste wood works well as an extender and modifier for petroleum asphalt binder in asphalt payment. Biofuel production and wood composites might be used as additional wood waste applications with a significant added value. In addition, minimizing wood waste could aid the timber industry in decreasing its environmental effect while simultaneously satisfying the rising wood demand without further deteriorating the world's forests [5]. Consequently, forest-based companies should highlight on reduce, recover, and increasing the usage of wood waste from harvested and processed wood.

A large variety of essential industrial goods can be produced from leftover wood and the leftovers of wood-based industrial operations. Sawmills collect 1 ton of sawdust, shavings, slabs, and edgings for every 1000 board feet of timber produced; almost 75% of this useless material is composed of wood, and 25% is bark [7]. It can be utilized for energy and non-energy purposes. The generation of energy from wood waste includes burning, cogeneration, pellets, and briquettes, while non-energy uses include the production of composite boards, surface products, compost, and cement board [8]. Multiple study has uncovered a few value-added strategies for transforming wood waste into profitable goods. For example, a study conducted in Finland identified several emerging markets for wood products (textiles, chemicals, biofuels, and alternative plastics) [9]. A study conducted in Zimbabwe found that most offcuts and chips from wood-based companies are used as fuel by local people to generate steam for kiln dryers in commercial sawmills [10]. Another Japanese study reported that furniture manufacturers generate 15 million cubic meters of wood waste, over 90% of which is recycled into processed wood and fuel [11]. Virgin wood from Paulownia fortuniei, a fast-growing species, meets the minimum standard EN 300 Type 1 (1997) for General Purpose Oriented Particleboard (OSB) panels for use in dry environments [13].

There is a heated debate about even if burning wood instead of coal can help reduce greenhouse gas emissions (GHG). Proponents argue that the carbon dioxide emitted when trees are felled and burned is captured by new trees that sprout in their stead. So, there are no GHG emissions as carbon is part of the sustainable cycle. Biofuels can also help with energy security and job creation. Wood fuel is more location and climate-independent, easier to store, distribute, and most importantly transport over greater distances than other renewable energy sources like photovoltaic (PV) and wind. It is also less location and climate dependent than other renewable energy sources like wind and solar. Critics contend that encouraging wood fuels may lead to a global logging boom that damages forest biodiversity. For instance, biofuel advancement in Europe may have made a significant contribution to deforestation in the Eastern United States, Western Canada, and Southeast Asia [6, 12].

Forests are a vital component of the global ecosystem. In addition, they contribute to national economies through the production of forest products such as timber and non-timber forest products. According to DFRS [20], 40.36% of Nepal's land area is classed as forest, while 4.38% consists of other woody regions, for a total of 44.74%. Recent years have seen around 3,4 million m^3 of stem wood harvested from Nepal's forests, as estimated from forest stumps [1, 13]. A significant amount of this is utilized as lumber and poles, with the remainder as fuelwood. Pandey et al. [13], reported that annually, approximately 4.8 million people might be employed in the sustainable production of 900,000 m^3 of timber and 1.2 million m^3 of fuelwood.

The particleboard sector is currently the principal user of recycled wood. The inclusion of utilization of wood waste from building and demolition into the inner layer of medium-density fiberboard. In 2019, particleboard usage in Europe was 37.07 million m^3 [7]. Particleboard contains varying amounts of recycled wood depending on the country. Italy has a 100% rate, Belgium, the United Kingdom, and Denmark have a 50% rate, Germany, France, and Spain have a 15–30% rate, while Switzerland has a 0% rate. [4]. There looks to be space for improvement in several European nations. The fabrication of waste wood plastic [8–11] and waste wood concrete composites are considerably smaller-scale advances pertaining to the cascade use of waste wood [9].

In industrial countries, pulp and wood-based panel sectors utilize an ample proportion of logging and wood processing leftovers. Alternately, wood processors and power plants chop and burn residues to generate steam and electricity. This development is largely explained by strict environmental restrictions for waste management, the requirement to reduce forest fire risks, and the high recreational value of many northern kinds of wood (for which logging leftovers are a detriment). However, the desire to rationalize and maximize efficiency may be the strongest motivating factor.

In terms of usability, the wood wastes fall within 2 broad uses:

1. As power generation resources such as:
    - Boiler for kilns drying, wood conditioning, lacquer-curing, and so on.
    - Co-generation plant fuel.
    - Commercial firewood (brick baking, noodle production, tobacco curing, and steam generation).
2. As secondary raw material such as for:
   Within the wood-based industry:
    - Medium density fiberboard
    - Particleboard
    - Blockboard
    - Laminated board
    - Charcoal briquettes
    - Parquet
    - Pallet manufacturing.

   Outward wood-based industry:
    - Compost and mushroom cultivation
    - Livestock litter/bedding
    - Low-volume wood goods, e.g., in Cottage Industry
    - Pulp and paper industry.

3 Economic Evaluation

Wood biomass is a significant renewable energy source, particularly in nations that have historically relied on forestry resources. Wood biomass can have various good socioeconomic and environmental consequences in these nations. Wood offers numerous advantages regarding the bioeconomy and cyclical economy. It's a naturally occurring, biodegradable material with remarkable mechanical and thermal qualities. In comparison to comparable materials made from inorganic or fossil source elements, wood materials often have substantially less of an impact on nature during the manufacturing and final phases [1]. In addition, unlike agricultural resources, wood is not in competition with food. Consequently, the utilization of wood for advanced purposes (energy production, construction materials, etc.) has increased since the beginning of the twenty-first century [2].

A study indicates that by 2030, Europe's wood supply may not be sufficient to meet demand [1]. The increase in wood use is sustained by a rise in the generation of waste wood from wood-based products that have reached the end of their useful life. Thus, recycling this vast deposit might provide copious and inexpensive raw materials to produce new materials. Wood is a natural substance, but reclaimed wood usually contains additives (adhesives, varnishes, paints), various impurities (wood treatment products and heavy metals), and contaminants (glass, plastic, metals, etc.). This diversity makes the recycling process rather difficult. Therefore, current wood waste management solutions are primarily based on landfill, energy recovery, and materials recovery [3]. Although more difficult, the second salvage option should be pursued as it is based on recycling by creating new materials and involves "cascading" use. According to [9], cascading utilization is "the efficient use of resources through residual material use and material recycling to increase the overall availability of biomass within a given system." As a result, the cascading effect makes it possible to delay the release of carbon in the form of CO_2 when the material is used as an energy source at the end of its life [9].

Utilizing woody biomass from forest land could increase rural community economies, boost carbon dioxide discharge mitigation from sustainable wood low-grade wood, attract private investment, and protect the environment. Small-diameter wood and harvest wastes that could be utilized for bioenergy and bioproducts are available for utilization in quantities of 210 million oven-dry tons. Their estimated economic value is $5.97 billion (109). The review of current U.S. laws, regulations, and directives affecting the use of forest biomass, as well as the identification of barriers, challenges, and potential opportunities connected to the use of woody biomass from public lands, are necessary to achieve this utilization target supporting the U.S. Department of Agriculture's implementation. The use of forest biomass for bioenergy and bioproducts might, however, expand with better coordination of public policies (regulatory legislation, public subsidies, and support programs) at different levels of government. Covers the definitions of major biomass terminology used in various initiatives encouraging the utilization of forest biomass for bioenergy and other bioproducts. Standards for renewable fuels may encourage the utilization of forest biomass from lands [10, 12].

There are considerable regional differences in the use of biomass, bioenergy technologies, market dominance, and research concerns in these fields. However, in most countries, the socioeconomic advantages of using bioenergy can be emphasized as a key element in the expansion of bioenergy's share of the world's energy supply. Indicators of the economy like employment and financial gains are used to quantify the socioeconomic effects of biomass production and use, but the research also considers social, cultural, and environmental considerations. Despite their potential importance at the local level, these latter aspects have historically been left out of most impact analyses since they are not necessarily amenable to quantitative study. Types of technology, regional economic structure, social characteristics, fabrication processes, and common resources are only a few examples of the factors that may affect the local socioeconomic effects, which are diverse and will vary [7].

Research conducted by the Slovenian Forest Institute and the Croatian Energy Institute Hrvoje Pozar has shown that the method of socioeconomic analysis that is most likely to provide the optimal combination is the level of local bioenergy/renewable energy turned out to be highly dependent on energy development [7]. There are very few reference plants in Croatia and Slovenia, for example, basic modeling is required to aid project construction including technical and political demands. In contrast, there are countless excellent examples of initiatives in Sweden and Austria that are ready for further evaluation. Therefore, it is improbable that a single model applies to all countries. Another critical issue is the biomass resources used to generate energy. Unlike in any other country, wood fuels and biomass in general are primarily produced from forests in Slovenia and Croatia. Croatia and Slovenia are transformational countries (countries in central, eastern, and southern Europe that transitioned to market-oriented democracies in the 1990s and hence have distinct economic and social characteristics [7].

4 Wood Waste Management

In terms of environmental and economic implications, timber harvesting is often a significant portion of forest activities and administration. According to a considerable body of information, forest harvesting operations in Sabah, Malaysia can damage up to 50% of the residual stand, and potentially up to 60% [8]. Damaged and damaged trees significantly contribute to logging residues. As previously stated, two-thirds of logging residues in Terengganu, Malaysia, consist of trees injured or destroyed during road construction, logging, and extraction. Lesser logging rates lessen the damage, and in the preceding section's figures, it was assumed that just half of the logging residues are made up of injured trees. However, it is evident that minimizing the impact of forest harvesting might lead to a considerable reduction in logging waste. When compared to traditional logging, using reduced impact logging (RIL) techniques might likely minimize damage by around half save soil and biodiversity, and help preserve the productive potential of the leftover forest products [8].

Wood waste can be used to make a variety of materials, but the government must implement appropriate waste management rules to maximize the usage of wood waste resources. On the upstream side, the volume of wood waste can be kept to an absolute minimum through proper management. The following measures are advised:

- **Reduce**: By using better design equipment, enhancing the skills of the personnel and/or changing the production process to increase the recovery rate or maximize the raw material usage.

- **Reuse**: By returning the "as received" waste to another process or a downstream process.
- **Recycle**: By resizing the waste to become secondary raw materials or to be resource fuel.
- **Recover**: By returning scrap waste to be used as fuel wood.

Proper wood waste management is crucial to saving the environment. In general, each sector should:

- Minimize wood wastage by proactive planning of wood utilization based on resource.
- Access the possibilities for internal utilization of wood waste.
- Keep track of and evaluate the development of wood waste types and volumes relative to production growth.
- Evaluate the viability of recovering energy from wood waste for personal energy needs.
- Evaluate the viability of selling recovered energy to nearby clients or the national power system.
- Survey the possible uses of wood waste within 50–150 km.
- Evaluate the viability of using wood waste for purposes other than energy recovery.
- Evaluate the possibility of wood waste management collaborative ventures between surrounding wood-based companies.

Currently, the demand for and supply of wood waste varies significantly from region to region.

It is considered, however, that the development of a specialized organization of sufficient size is economically possible.

5 Conclusions

Examining and evaluating the employability function of bioenergy and socioeconomic factors is a time-consuming and difficult undertaking. There are various models that explore bioenergy systems, but none of them generate these kinds of output results. They are essentially techno-economic models that provide cost and efficiency data to assist developers in making decisions about the design and technique for project developments. And, while they do give specifics on expenses and profits, they don't include revenue information [7, 12–15].

If the recycling idea is to be developed further, waste wood must be seriously considered as a resource material, as it contains a few metals that can be easily claimed and sold. Existing equipment allows for the processing of both waste wood and bark. However, two further requirements must be fulfilled for this to be profitable. First, waste companies must deliver both materials in a recyclable state. At the time of collection, wood, and bark must be separated from other garbage; if the notion of recycling were more commonly accepted, this separation would occur automatically.

Second, prospective clients must be willing to purchase the process material and, if necessary, modify their equipment to accommodate it. There is reason to be positive about the future of wood waste and bark recycling as both requirements are currently being met in some capacity. Charcoal manufactured from waste wood is an innovative and growing use. Bark, a previously unusable byproduct of the forestry industry, is recognized as a high-quality raw material. Bark can be crushed in the same machinery that processes waste wood to generate higher quality fertilizer and useful organic mulch for horticultural and agricultural applications. The processor's cost accounting is very positive [16–18].

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