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FROM RECYCLED POST-CONSUMER WOOD TOWARDS PRIME QUALITY PARTICLEBOARD

This paper gives an detailed review of literature concerning the problems of wood waste management in Ukraine, and, in particular, the effects of treatment of hazardous wastes as well as the issues of recycling post-consumer wood (PCW) in Ukraine as alternative raw material resource for manufacturing particleboard (PB). Today recycling is the most environmentally friendly method of managing wood waste. A large proportion of the wood waste generated consists of used furniture and other constructed wooden items, which are composed mainly of PB, a material which can potentially be reused. The rising cost of raw materials, ever more restrictive and tough legislation about waste disposal, and the fierce competition between PB manufacturers has led to the increasing use of recycled wood. It is possible to use any source of recycled wood to reduce raw material costs by between 40-70 % and the resulting boards will have even surfaces and post-soft formable core layers. Recycled wood has a moisture content of around 20 % compared to the 60-70 % moisture in virgin wood, so it makes economic sense to buy recycled wood chips, also, it has longer service life and consumes less energy during processing operations. Technological advances in wood recycling equipment and machinery have also increase processing efficiency and made it more economic. The latest wood shredders are capable of processing over 30 tons an hour, and are often fitted with over-band magnets, eddy current separators and trammel screens. A great deal is being done currently to identify and remove contaminants to further improve the quality of the recycled chip. It was found that boards will be lighter, have excellent mechanical properties, be easier to process and that wood and glue consumption will be greatly reduced. There are advantages apart from the obvious one of being a sustainable alternative to using virgin timber. The increasing cost of raw materials and the escalation of competition in both quality and price of wood- based panels oblige board manufacturers to rapidly introduce this innovative technology.

Keywords: post-consumer wood, recovered wood, waste wood, particleboard, wood preparation, recycling, waste management, assignment waste wood, wood-based panel manufacture.

Introduction. The demand for wood composites from waste wood has been increasing as timber resources in natural forests decline. The use of renewable biomass as a raw material in composites production was one approach and the use of renewable biomass may result in several benefits such as environmental and socioeconomic (fig. 1).

Today renewable biomass are mostly accepted as waste materials and are mostly ploughed into the soil or burnt in the field. According to the end uses of wood-wastes and their possible reuse products, PB has found typical applications as flooring, wall and ceiling panels, office dividers, bulletin boards, furniture, cabinets, counter tops, and desk tops, and it seems that the manufacture of PB from recycled wood-based wastes is the most common way to reuse such waste materials. The PB is a panel product manufactured under pressure from particles of wood or other lignocelluloses materials and an adhesive. PB has been widely used throughout the world for furniture manufacture and house construction, including flooring systems, etc. Recently, the demand for the PB has continued to increase for housing construction and furniture manufacturing.

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A literature search was conducted to establish the "state-of-the-art" with respect to the use of recycled furniture waste to provide second generation building materials. Unfortunately a search of such a specific nature often results in few articles pertinent to the topic, but will provide considerable associated information; such was the case with this search. As can be appreciated the types of materials used in construction within the furniture industry are very diverse and include metals, plastics, textiles, plaster and wood based materials. Science likewise has a wide range of waste materials but it is only the wood based panels that we are concerned with in this current research. Our search disclosed numerous articles relating to the application of waste materials for use in producing panel products. However, very few of these articles refer to panel waste or waste furniture recycling. We will mention briefly the current situation regarding some uses of waste paper and waste wood as resource materials for the production of panel products. This literature is vast and varied our comments will be a "cameo" merely to put our search in perspective.

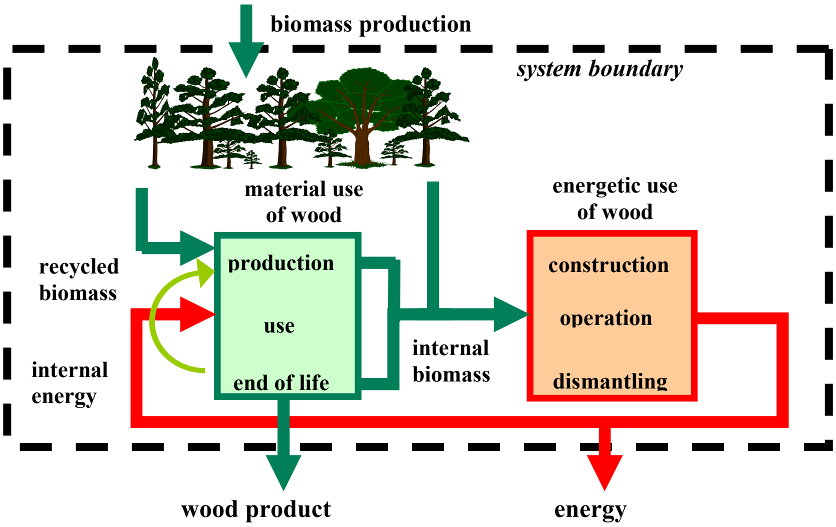

Fig. 1. Recycled biomass

Literature Search – the need to recycle wood. The word "waste" projects a vision of a material with no value or useful purpose. However, technology is rapidly evolving that holds promise for using waste wood and waste paper to make an array of high-performance composite products that are in themselves potentially recyclable. Today's rapid technological growth has led to dangerous degradation of the environment, which constitutes a serious threat for upcoming generations. Environmental pollution, the reduction in natural resources and the general disturbance of the ecological balance constitute problems that should be taken into serious consideration by our society [29]. The increase in CO_2 and CH_4 emissions, resulting from the over-consumption of fuel, from forest fires and from the decomposition of waste, are, to a large extent, responsible for the 'greenhouse phenomenon' which involves overheating of the planet and extreme meteorological and climatic events [20].

In order to prevent such events, many countries from all over the world agreed to sign the Kyoto protocol, with the result that by the year 2010, there should be a decrease in greenhouse gas emissions of 8 % compared with 1990 levels [28]. Apart from the factors already mentioned, the carbon balance on earth is also considerably influenced by photosynthesis. Forests, via photosynthesis, absorb large quantities of CO_2 from the atmosphere and as a result they constitute an enormous natural carbon reservoir with an important role in regulating the "greenhouse phenomenon" [24]. The crucial contribution of forests to the ecological balance also arises from the fact that they facilitate water storage, they are great recreation areas and, of course, they provide wood, a valuable raw material used in the manufacture of furniture and many other products [19]. Changes in economic and demographic growth, combined with the many advantages of wood compared with other construction materials, have resulted in an increase in demand for wood worldwide combined with an increase in the generation of wood waste (fig. 3). Nevertheless, wood waste can potentially constitute a valuable resource for the production of various materials and products [13, 40].

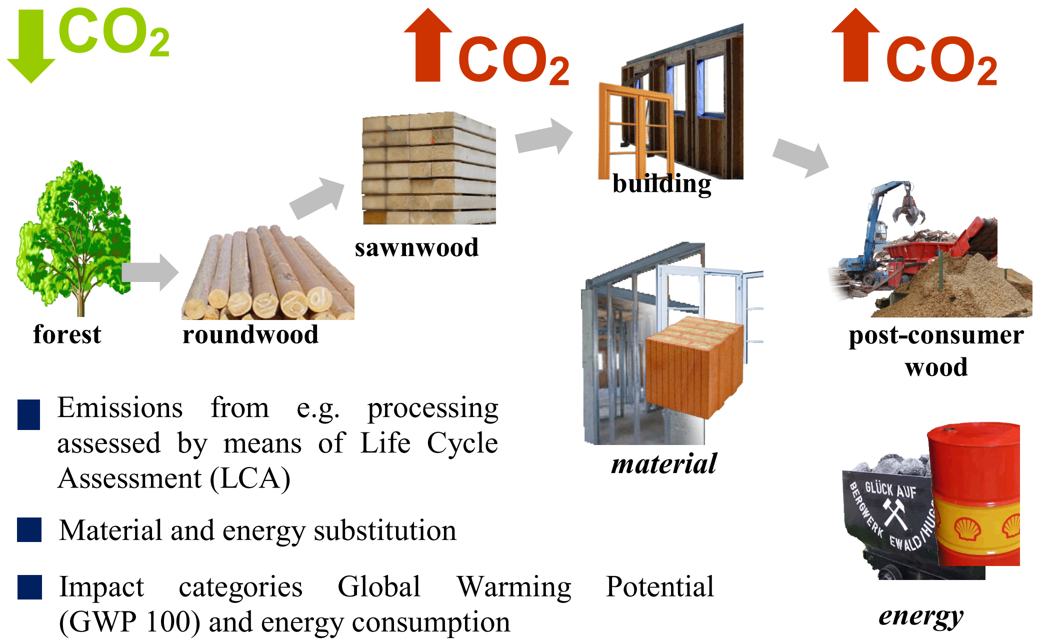

Fig. 2. Substitution effect due to wood utilization

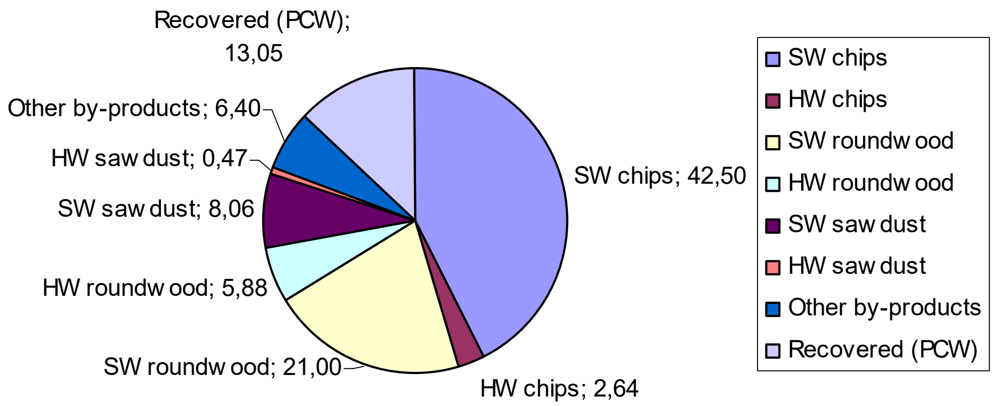

Fig. 3. Raw wood consumption of the European particleboard industry, %
(13,6 mio. dry tones under bark within selected countries, 2010)

In the Ukraine, about 13 mio. tons waste wood and over 5 mio. tons are either discarded or diverted from recycling by burning or some other low value use [20, 18, 14]. Other wood waste from new construction and demolition projects amounted to 0.6 and 2.0 tons, respectively [13, 15]. Taken collectively, these materials represent a significant resource base from which many different composite products can potentially be made. The most relevant achievements of this research were reached in the following areas of interest: management of recovered wood; amounts of recovered wood; quality aspects of recovered wood; energy generation; market aspects of recovered wood; greenhouse effects of recovered wood; design of wood products. The most interesting results gained during research a amount of PCW in Ukraine (assumption, 2009) is about 2.6 mio. t/a which corresponds to about 13 % of the annual round wood consumption of 10.5 mio. t/a and about 39.0 PJ/a (10.8 TWh/a) or 6.0 % of the current annual primary energy consumption in Ukraine of about 162 TWh in 2009 year.

These are several advantages to using recovered materials for various composites. First, the use of these materials in products made by the forest products industry will contribute greatly to long-term sustainable development and forest ecosystem management, and it will allow markets for wood-based composites to grow while minimizing the use of virgin timber. Secondly, wood-based composites of varying types are opaque, colored, painted or overlaid. Consequently recovered fibers used for composites do not require extensive cleaning and refinement to remove adhesives, inks, dyes, etc. Thus, composites provide an unusually flavorable option for the recycling of waste wood and paper.

The recycling of wood products. The current strategies in managing wood waste and their impact on the environment are presented in table 1 [5]. Landfilling of organic material leads to CH_4 emissions, which result in greenhouse gas potential 21 times higher than that of CO_2 [6]. Furthermore, Risholm-Sundman and Vestin [38] reported that during the combustion of PB it is important to have the appropriate conditions; otherwise incomplete combustion can result in the formation of toxic compounds. Other researchers have also stated that the alternatives to incineration or the disposal of wood waste in landfills constitute low-profit solutions that can also be hostile to the environment [25] in contrast with recycling, which causes less harm to the environment. On the other hand, the growing shortage of low-price wood, in combination with the continuously rising cost of raw materials, creates considerable problems for wood-based panel manufacturers. As a result, they are seeking alternative sources of raw material and they are turning to the option of wood waste recycling [16, 18, 44, 45].

Table 1. Wood waste management techniques and results for the environment

	Environmental impacts		
	Air	Water	Soil
Landfilling	CO_2 and CH_4 emissions (greenhouse gases) Unpleasant smells	Toxic compound pollution of subsoil water	Build up of hazardous substances in soil, land take up
Incineration	Emits CO_2. CH_4. SO_2. NO_x, HCl, dioxins	Fallout of hazardous substances into surface water	Dumping of incinerator ashes and smoke – cleaning residues
Recycling	No such environmental impact		

A large part of wood waste is composed of old wooden constructions, including furniture, which, when they have outlived their usefulness, are available for exploitation [23]. The above constructions are mainly manufactured from urea-formaldehyde (UF) bonded PB and medium density fiberboards (MDF). Since these boards consist of at least 90 % wood, the recovery and recycling of wood from used wood-based panels in the production of new ones constitutes the most rational means of wood waste exploitation [12, 15].

Various researchers have dealt with the possibility of recycling wood-based panels as well as re-using board production residues. Sandberg [40] and Pfleiderer Unternehmensverwalt [34] have presented methods which make possible the re-use of board residues, after steaming, in the production of PB or other wood-based material. In a related patent published by Moeller [43], a method for the recycling of wood products and waste containing wood is described. The application of the method includes mechanical handling of waste followed by processing for the production of by-products or end-products. Roffael [39] presented a method for re-using wood particles and fibers derived from waste panels bonded with tannin-based adhesive. The formaldehyde required to crosslink the tannin was generated by the hydrolytic decomposition of adhesives of the waste boards during hot pressing. Boehme and Michanickl [2, 3] presented a method with which it is possible to recover particles and fibers from waste containing wood, old furniture and other wood-product residues.

The wood waste is comminuted and is then impregnated with a solution consisting of urea, ammonia and soda. After this impregnation, the wood products are heated in order to dissolve the adhesive bonds between the fibers and particles. A project named "Envirofiber" was introduced by Fibersolve Ltd proposing the hydrothermal pulping of waste wood panels in order to recover wood fibers that could be used as raw material for the production of medium density fiberboard [36, 37]. Related work has also been conducted by Sandison [41] who presented a patent for the recovery of wood particles from waste PB and MDF using a vacuum prior to the heat treatment.

A patent related to the recycling of wood products published by Hesch [26] relates to a method that uses an apparatus for breaking down wood products such as used furniture into usable individual components such as chips and fibers. In USA the wood resource used in the manufacture of PB and MDF is still primary wood residuals. It has been estimated that between 80 and 90 per cent of the wood fiber used is sawdust, wood savings, green chips and other residuals [30]. In Australia a higher use of round logs is used, especially for MDF manufacture. The social/environmental push is placing a higher priority on using recycled feedstock. The use of municipal waste is possibly the most reported area of research [21, 22, 31] and certainly considerable progress has taken place with glass, metals and paper. To help address this need the Nationality university of forestry and wood technology Ukraine (NUFWT of Ukraine) – Department of technology of products from wood (Ministry of education, science youth and sports of Ukraine) has a project centred on housing using home components made from recycled material and include roof, wall and floor systems [1,18, 16].

The word "recycling" conjures up visions of curb-side collections. Considerable attention has been paid to these post consumer waste materials, while until recently, the recycling of solid wood waste has received little attention [17]. Demolition projects, new construction and even land clearing can produce millions of tons of wood waste every year and it is this resource that is now being addressed [8]. As well as the use of this wood waste in traditional panel products (PB and MDF) using adhesive systems, due consideration is being given to other binder systems. Cement PB panels are receiving much attention [1] especially as the wood waste, even if treated with chemical preservatives, can still be used in cement boards [1, 10]; but such treated waste still presents major challenges in organic adhesive bonded products. The research literature identified which actually addresses the use of waste panels or waste furniture is indeed limited [10, 23].

As indicated above large quantities of waste from primary processing from sawmilling is currently recycled into panel production, as is the case with primary processing in the metals and plastics industries. However, less efficient utilization is made of waste from secondary processing, for example in the furniture industry which is currently measured in millions of tonnes per annum globally [13, 14, 15]. Some recent work in Canada [27] has demonstrated an effective process to generate fibers from waste MDF. The process is based on the fact most resins used in MDF production are from within urea-formaldehyde (UF) and melamine fortified UF (MUF) systems.

The chemical bonds formed in these situations are unstable at high temperature and high humidity and thus can be reversed to de-bond the fibers within the panel making them available for recycling back into panel products. Europe, and in particular Germany, is being forced to address the problem of industrial waste as legislative measures require recycling of wood based panels to be stepped up in order to reduce the volume of boards to be disposed of as organic waste [9, 32, 33, 39]. Therefore, intensive research work is conducted now in many countries in Europe on how to reutilize PB. Thermal utilization is considered an attractive solution by many experts.

However; there is some reservation concerning toxic compounds formed during combustion [32]. Disintegration of PB and fiberboards and their reuse as the raw material for second generation panels totally or in part has been investigated in many laboratories [22, 32, 33]. The results reveal that UF and PF (phenol/formaldehyde) bonded PB can be prepared from recycled products using conventional technology for PB manufacturing. Although the research work from the various laboratories have demonstrated that waste panel products can be broken down, by reversing the chemical bonding, the energy required and the extra processing would suggest that the process is not able to compete economically with the current production of PB and MDF.

Our approach will be to mechanically disintegrate the panel waste and attempt to reconstitute by current processing methods. It is envisaged that the materials produced will have lower performance levels as damage will result as the particles and fibers are broken apart. The objective of our research is to use simple low cost processing to recycle low volumes of panel waste into existing processes or new products.

Methodology. A Scientific Advisory Group (SCAG) – Department of technology of products from wood in NUFWT of Ukraine was set up to bring together representatives from the Ecological economics department teachers, ***Department of Light Industry of the Ministry of Industrial Policy of Ukraine (DLIMIP of Ukraine)*** and industry. It's objective was to produce a technical report setting out the process and controls necessary to determine when PCW ceases to be waste. To do this, the SCAG: identified the major markets and end uses for processed wood; identified the current legislative framework that governs the production, handling, storage, transportation and use of PCW; sought analytical data on the composition of material produced; reviewed available standards and specifications; assessed relative risks to human health and the environment from using PCW, and any necessary mitigation methods; proposed ways forward for each of the major markets so that certain end uses may be regarded as fully recovered where strictly defined conditions are met [13, 15, 17, 22]; and analysis of management approaches for post-consumer recovered wood (fig. 4).

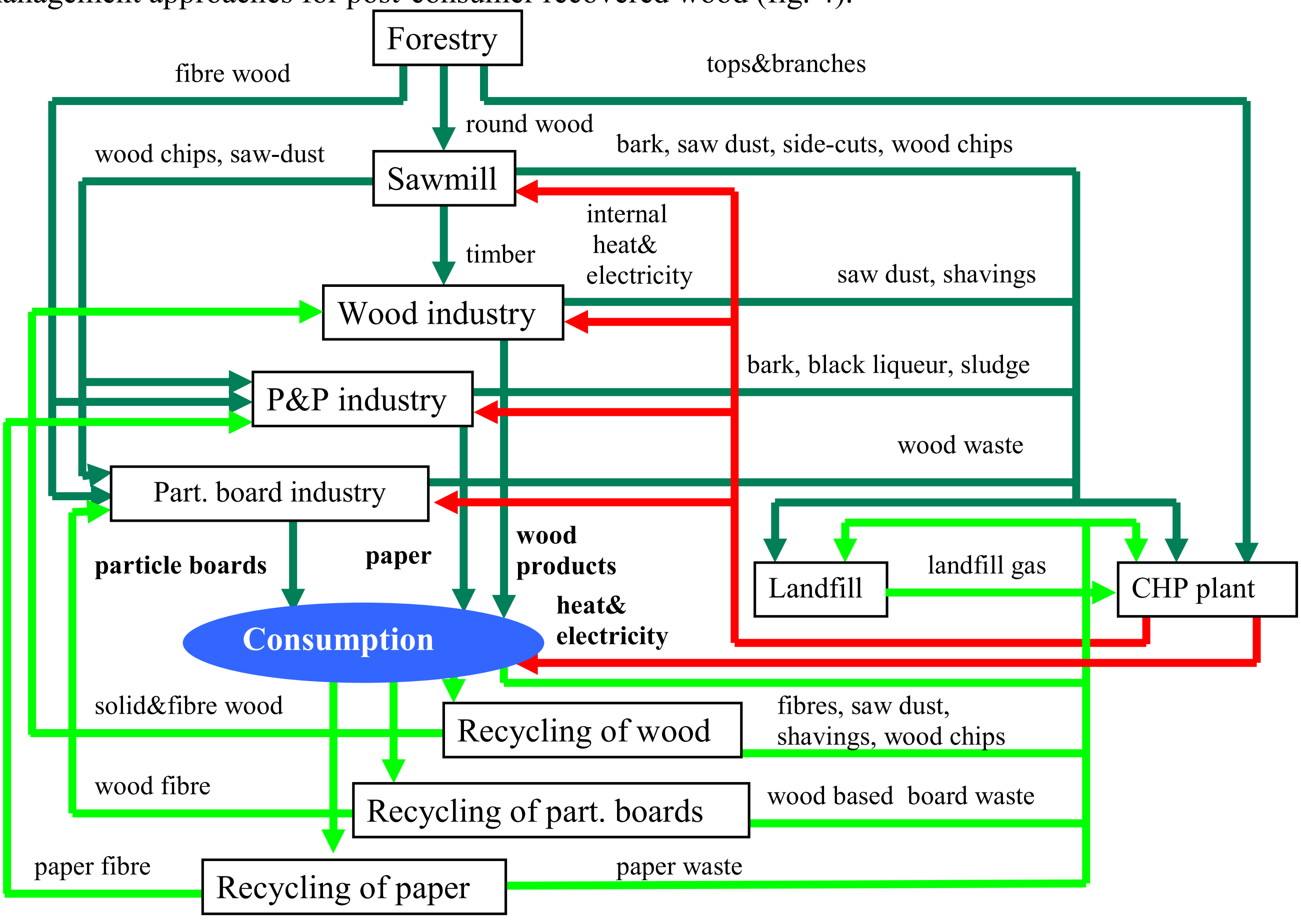

Fig. 4. Waste management options for wooden products

Wood-based Panels Market in Europe and Ukraine

In response to the economic crisis, consumption of wood-based panels grow by 13.5 % in Ukraine and by only 3.7 % in Europe in 2010 (table 2).

Table 2. Wood-based Panel production in Europe and Ukraine (mio. m^3)

Wood-based Panel	Europe			Ukraine		
	2008	2009	2010	2008	2009	2010
Particleboard	40,140	36,790	37,640	1,622	1,316	1,471
Fiberboard	17,770	17,020	18,000	0,115	0,094	0,108
Plywood	3,950	3,620	3,930	0,163	0,108	0,144
Total:	61,860	57,430	59,570	1,900	1,518	1,723

Market characteristics: significantly higher wood raw material costs; worsening wood availability despite higher prices; increased competition from wood-energy sector; PB and MDF producers forced to process more; roundwood instead of sawmill by-products; and downscaling of wood-based panels (WBP) production capacity. Forecast for 2011: trade outlook cautiously optimistic; domestic demand will increase gradually; fierce competition for wood raw materials from; fiber sector will continue to increase PCW; and material costs will increase throughout 2011.

Main markets for PCW The SCAG identified and reviewed the main markets for PCW to establish whether the waste could definitely be used again once it had been processed. For the purposes of this technical report, markets were considered for recycled wood products made from PCW recycled in chipped or pellet form. This PCW may come from: materials recovered from products at end-of-life, for example wood from demolition and packaging (for example pallets); and offcuts and other waste from panel board, furniture and other wood product manufacture, and from building and construction activities.

Market development and growth potential in Ukraine

The PCW recycling industry is relatively small and new, and most of the 2.9 mio. tons (2008) of PCW continues to be landfilled. Nevertheless, the industry and markets are growing rapidly. In 2008, 0.29 mio. tons of PCW were processed and significant growth is projected in the years ahead [13].

There are four main current markets for PCW: the wood based panel industry [11-13, 18, 19, 39-42]; and fuel for renewable energy [15, 17, 20, 22, 40, 46-48].

It should be noted that these current markets are largely existing (rather than new) markets in which PCW competes with virgin wood material on specification, price, delivery and other factors. The wood based panel industry currently takes most PCW which, when clean and dry, has the advantage of low moisture content compared to virgin material. In recent years, efforts have been made by the recycling industry and others to encourage the development of more diverse and value-added markets and to reduce dependence on the wood based panel industry. This has helped to develop the animal, horticultural and landscaping markets. There are other new or potential markets, for example use in products made from wood-plastic composites, glued boards (joiner's plate) and ethanol production. Such markets do not presently exist or are not significant in the Ukraine and further development is uncertain. While continued growth in all markets for PCW is projected, markets are uncertain for various reasons.

These include competition between recycled and virgin materials, competition for clean PCW between the main markets, and international competition with the Ukraine wood based panel industry. Growth will depend on how far barriers are broken down, including negative perceptions towards ‘waste’ materials and the development of infrastructure, technologies and practices for higher levels of recycling (fig. 5).

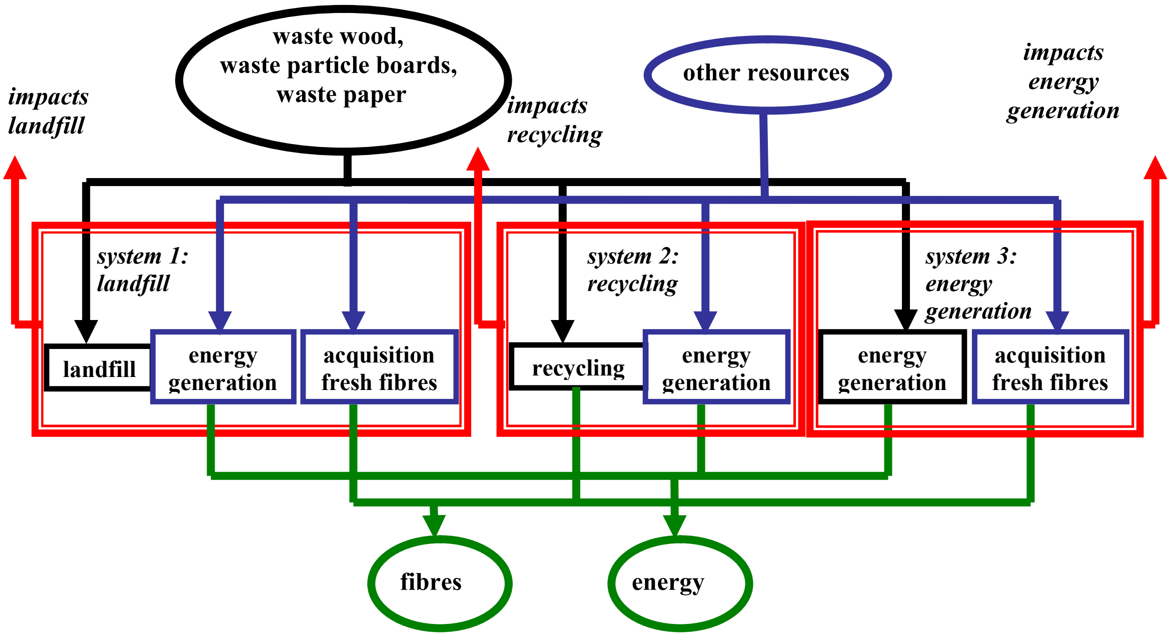

Fig. 5. Waste Wood Treatment Options: Input Related Comparison

One of the criteria for PCW to cease to be waste is 'having a market where it can definitely be used'. However, the nature of the markets for PCW means that generally there is no definite use for PCW material until it has been transformed into a product or there is a contract of supply between producer and buyer. The market with the highest growth potential is using PCW as fuel for energy production in response to demands for renewable energy. The SCAG found that there is also major potential for growth in using treated PCW (the majority of which is currently landfilled) for the energy market. The regulatory position on the use of PCW as a fuel is outlined in [13, 16, 20]. The SCAG did not investigate the renewable energy market further, but emphasised industry desire for a standard to be produced that would bring greater certainty to this market.

Markets and material grade. Markets for PCW may be inhibited by the perception that it is a single commodity and all PCW is contaminated [10]. Confusion is compounded by the many sources and various ways of describing PCW by the way it was originally used (for example furniture), how it was collected (for example civic amenity sites), the type of material (for example plywood) and its potential to become contaminated (for example untreated or treated). Clean PCW is acceptable for all markets. Treated PCW [13, 16, 15] is presently unacceptable for most purposes as it may contain copper chrome and arsenic (CCA) and creosote, although some uses may tolerate residual chemical contaminants [10]. A study carried out by [12, 15, 16, 18, 23] concluded that the only viable use for treated PCW is re-use or recovery via energy from waste. Both animal products and horticultural and landscape products were considered and found not to be viable options.

Current legislative position. The current legislative position was reviewed to clarify: those materials and products which waste regulatory controls apply to; and when in the supply and production cycle waste regulatory controls no longer apply and a waste becomes a product.

All wood waste processing must be carried out at fully authorized sites.

If wood waste is transferred to another site and there is further processing, regulatory controls will continue to apply. These controls may not be directly related to the waste material being accepted, but may be required as a result of the processing activity, for example regulating air emission limits from panelboard manufacture. It should be noted that material containing CCA and creosote is classed as hazardous waste and may not be used in any of the named end uses. The current legislative regime and existing case law indicates that PCW going to the wood based panel industry cannot cease to be waste until it is incorporated into wood based panels. However, as the material entering a wood based panel manufacturer meets a standard, the SCAG decided it would be valid to assess whether the material accepted onto site could be considered a secondary raw material, which was similar to creating woodchip from virgin timber.

Material composition. The SCAG indicated that the main inputs that are processed to derive woodchip for wood based panel products markets are usually limited to clean PCW, consisting of packaging PCW and discarded wood offcuts, with little or no contamination. Clean PCW is defined fully in [10, 13, 23]. All PCW inputs to processing may contain other materials (referred to in this report as contaminants), depending on where they came from and how the material has been collected, segregated and stored. These may include [10]: ferrous and non-ferrous metals; grit and dust; plastics, glass, paper and rags; colouration; resins and glues; coating such as paints and other surface treatments and treatment chemicals, including preservatives and pesticides.

The SCAG 2008 have examined the levels of contaminants in PCW in various studies. These studies have found that where treated PCW has entered processing it may contain one or more of the following treatment chemicals [10, 13, 17]: copper chrome arsenic (CCA); copper organics; creosote; light organic solvent preservatives (LOSP); micro emulsions; paints/stains and varnishes. PCW may also contain pesticide residues, including fumigants. These are generally less persistent than preservatives but whether they are acceptable or not will depend on the material and end product. For example, pesticides are not accepted in chipboard if the material compliant for subsequent burning.

Production process – stages of wood chips for panelboard production

PCW, which enters the site, undergoes some degree of sorting and segregation before entering the production process. Sorting is mainly conducted visually, but, in some cases, spray indicator or other methods may be used to detect chemical (mainly copper) contaminants. The level of segregation and sorting of material could vary from site to site and there are no standard practices in place. The implications of this are discussed in [12, 17, 22]. The level of unwanted contaminated material entering processing, including treated PCW removed by pre-sorting, cannot be defined. In practice, and depending on the source of the wood and level of sorting, physical contaminants such as nails and treated PCW will be present in most PCW sent for processing.

The level of processing subsequently carried out will vary depending on how successful the initial segregation and sorting stage(s) are.

After sorting and segregation, the material accepted on site then enters the production process. In summary, after chipping, physical contaminants are removed by various means, including magnets for ferrous metals and eddy currents for non-ferrous metals. Fig. 6 provides full details of all the potential stages of processing.

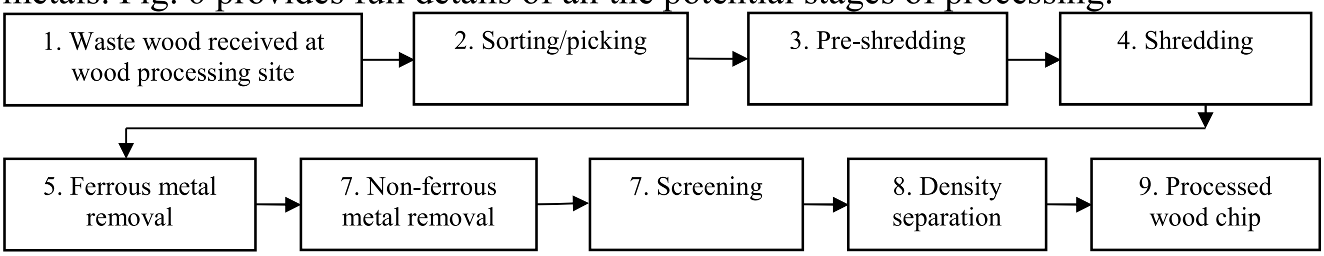

Fig. 6. The main production stages of wood chips for panelboard

After the waste is received at the processing facility and it has been initially sorted and picked, hammer milling or crushing techniques are usually used to process PCW into chips. This first stage reduces and controls the size of the particles and removes larger size contaminants, including ferrous metal. The process may be described as shredding, chipping, milling, crushing or comminution.

The initial objective is to produce a basic wood chip, which is suitable for supplying to the chipboard manufacturing industry. Apart from contamination limits, the main criterion for this basic chip is a maximum particle size of 50 mm in any dimension, and a minimum of 5mm. Many first stage production units do not use the second stage screening normally necessary to achieve the minimum chip size requirement. Instead, they rely on further cleaning capacity, and tolerance on the part of the receiving mill, and exclude potentially dust-producing raw materials such as panel products.

A basic chip would make up some 90 per cent of the product currently processed in the Ukraine and is generally produced by all PCW processors. It is also the specification that most processors would initially offer in response to any enquiries from added value markets, and it has found some success in these markets. However, to fully satisfy the performance requirements of different markets, the basic chip may need to be processed further. Once the wood has been chipped, the quality can be improved by separating the chips into different sizes and removing non-ferrous contamination.

Trommel screens are capable of separating basic woodchip into different particle sizes. The plant will usually be installed in line with the prime mover (shredding machine) and may require conveyors, but no extra loader capacity. As it is only capable of separating one or two chip sizes it is not best suited to producing a range of added value products. Flat screens are capable of separating basic woodchip into several (normally three or four) different particle sizes. They are particularly suited to added value products. The requirement of most panelboard mills to exclude material below five millimetres is best achieved by flat screens where such material is being supplied as a low cost product to some markets. Where non-ferrous (stainless steel, brass, copper, aluminium) metal extraction is required, it would be normal to put an eddy current separator in line with the basic production unit. This unit would normally be static, and electrically powered, although such capability is now available built into a mobile shredder.

Producing weed suppressants and pellets for other markets requires the wood chip to be manufactured further, including: interim storage of raw materials; drying/conditioning; grinding; colouring; pelletising; cooling; screening; storage; and packaging.

On higher value products packaging is used to contain and protect the product, and to carry messages such as branding and safety instructions.

This material is then ready for despatch as an input material to the wood based panel manufacturers market of wood based panel industry.

Wood based panel manufacture. Whilst the same processes are used to produce wood chips for supply to the wood based panel industry, further decontaminating and cleansing processes are carried out at the site of the wood based panel manufacturer. These are integral to the production process as once the PCW chip enters the process, it does not leave until it has been incorporated into a wood based panel.

The manufacture of wood based panelboard is quality controlled and carefully managed to ensure that the end product meets accepted specifications and that air emission limits are adhered to. However, it was found that inputs to wood based panel manufacturing may include wood chips from PCW sources other than clean PCW (for example up to five per cent painted wood) provided they meet the requirements "*Wood recycling in the panelboard manufacturing industry"* and other industry specifications.

Given that the wood based panel industry accepts over 0.29 mio. t of PCW, 5 per cent contamination would equal 14.500 tonnes of wood with some painted surfaces.

Project PB plant with PCW. Fig. 7.

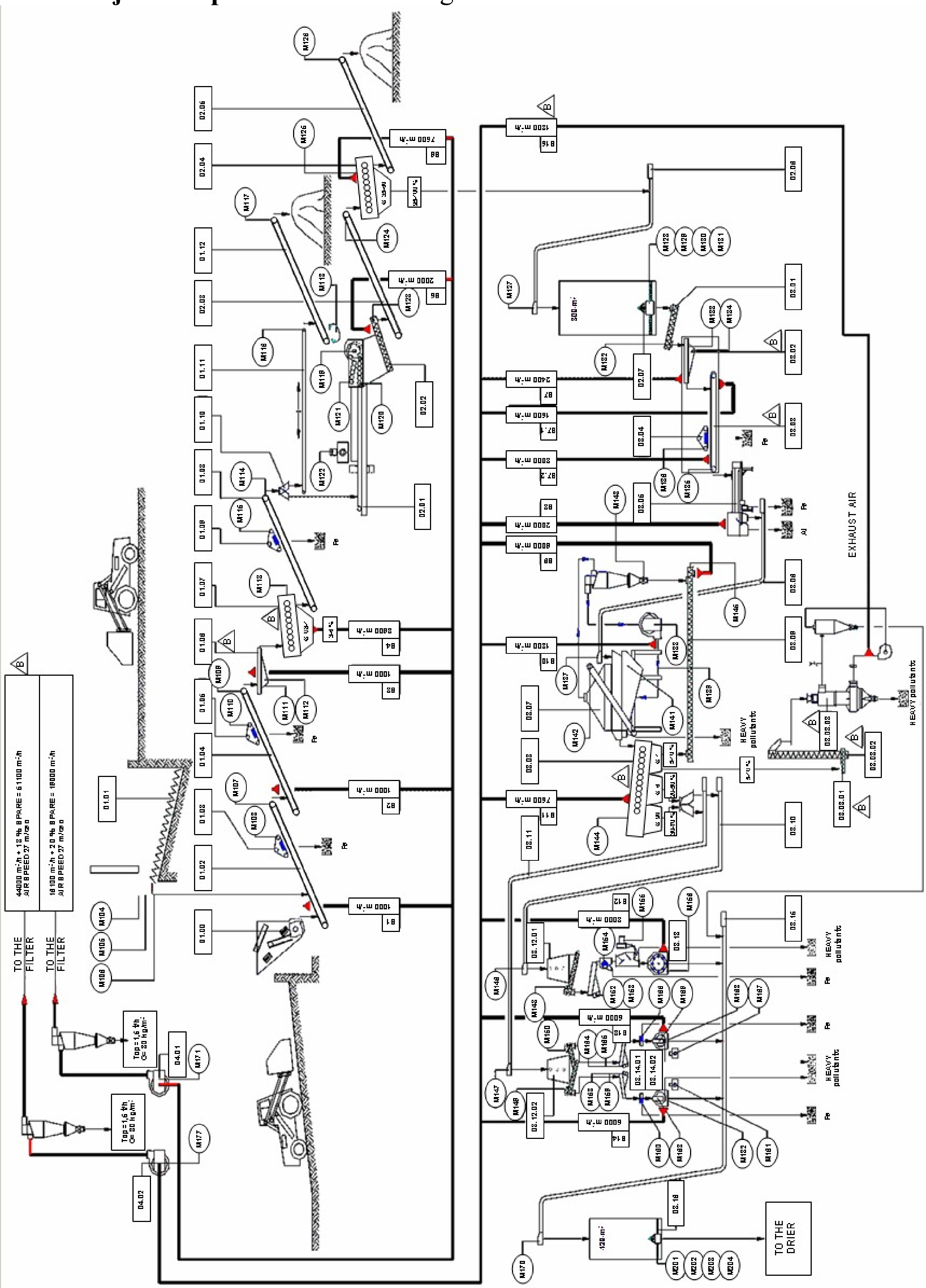

Fig. 7. Flow of wood preparation area of post-consumer wood

“PCW” mills based on recycled wood have had varying success. However there is apparently a growing market from some who want to make an environmental point. Described PCW Panels, as the project PB plant to operate successfully with 100 % recycled post-consumer waste wood. Annual input is 35,000 tons. The mill uses pallets, crates, cable reels, construction and industrial wood. One of the keys is compaction of the residues, such as pallets and reels, to allow more material per truck load and consequent lower raw material transportation costs. Pallets come from within a 200 km radius. Another key is a stringent cleaning process with nine points where debris and metal are removed from the raw material. Fig. 7 shows the project designed and engineered the plant (table 3). Crushing, cleaning, metal and debris removal were by Pal srl of Italy. Drying, conveying, blending and pressing with continuous Berndorf bands and sanding were by Modul Systeme of Germany. Drying is fairly conventional except for two more wind sifters after drying – one for core and the other for surface. Drying costs are lower because the wood is generally at or below 20 % moisture content. The objective is to remove the last bit of ash and other contaminants from the furnish. However, the material requires about 1 % higher resin content. New researches was to separate the dirty steam coming from the refiner, together with most of the volatiles from fiber processing. The dirty steam is condensed and treated in a conventional water treatment plant. The fibers are then conveyed from the steam separator, helped by fresh steam to allow for conventional blow line blending in a secondary blow line ahead of the dryer. Dryer emissions are mainly volatiles from the resin added in the blow line and are managed by control devices such as RTOs.

Table 3. Machinery and Equipment Listing of wood preparation area of PCW

Code	Machinery and Equipment	Purpose
01.00	Pre-crusher	Pre-crushing of recycled wood (PCW)
01.01	Screw conveyor	Transportation of wood chips
01.02	Belt conveyor	Transportation of wood chips
01.03	Overbelt magnet	Deferrization of pre-crushed and/or wood chips
01.04	Belt conveyor	Transportation of wood chips
01.05	Overbelt magnet	Deferrization of pre-crushed and/or wood chips
01.06	Vibrating feeder	Dosing of pre-crushed and/or wood chips
01.07	Dynascreen	To screen pre-crushed and/or wood chips
01.08	Belt conveyor	Transportation of wood chips
01.09	Overbelt magnet	Deferrization of pre-crushed and/or wood chips
01.10	Diverter	Possibility to discharge the flow of material to two different points or to split the flow in two different flows
01.11	Belt conveyor reversible	Transportation of wood chips
01.12	Belt conveyor	Transportation of wood chips
02.00		
02.01	Belt conveyor	Transportation of wood chips
02.02	Screw conveyor	Transportation of wood chips
02.03	Belt conveyor	Transportation of wood chips
02.04	Dynascreen	To screen wood chips
02.05	Belt conveyor	Transportation of wood chips
02.06	Pipeline	Air loading of wood chips
02.07	Bunker, 300 m^3	Intermediate accumulation
03.00		
03.01	Screw conveyor	Transportation of wood chips

03.02	Vibrating feeder	Dosing of wood chips
03.03	Deferrizating unit	Removal from recycled wood chips flow of: a) metals with low magnetic permeability, I.E. some stainless steel; b) ferrous metals
03.04	Overbelt magnet	deferrization of pre-crushed and/or wood chips
03.05	Eddy current separator	Functions a) to remove non ferrous metals from chips flow; b) to remove residual ferrous metals from chips flow
03.06	Pipeline	Air loading of wood chips
03.07	Dry cleaner for chips	To remove heavy pollutants from the chips, such as: stones, ferrous and non-ferrous metals, heavy plastics, etc.
03.08	Dynascreen	To screen wood chips
03.08.03	Windcleaner	To clean fines from f1.1 of dynascreen 03.08
03.09	Screw conveyor	Transportation of wood chips
03.10	Pipeline	Air loading of wood chips
03.11	Pipeline	Air loading of wood chips
03.12	Bunker	Intermediate accumulation
03.13	Hammer-mill	Refining of micro-chips
03.14	Knife ring flakers	Refining of macro-chips
03.15	Pipeline	Air loading of wood chips
03.16	Bunker, 120 m^3	Intermediate accumulation
04.00	Wind sifter for (dry) sl particles	To eliminate heavy pollutants such as sand, stones, etc. From the surface layer material
04.01	Wind sifter for (dry) cl particles	
04.02	Densimat	To eliminate heavy pollutants such as sand, stones, etc. From the material before going to the refiner mill

Quality controls and standards

The SCAG reviewed available standards, codes, specifications and acceptance criteria for input materials for the main products and markets to consider:

- when materials meet a standard and require no further processing; and
- if there is a need for a standard to be produced.

The SCAG reviewed 'standards' in the broad sense, including publicly available national and international standards, codes, industry and company specifications and acceptance criteria.Quality management systems (for example certified to or based on ISO 9001: 2000) should be applied to all management processes and production operations to make sure that processed PCW meets the required specification.

Publicly available specification sets the minimum acceptable standards for wood chip destined for wood based panel manufacturing. The wood based panel industry also follow guidance document *"Guidance for the specification and control of reclaimed wood raw materials used in the manufacture in the Ukraine of wood PB's"* to control the incoming wood materials. The acceptance criteria vary between operators so that they can make sure that the air quality standards for their sites are not exceeded.

The contamination limits permitted in PB as defined by [10, 17] are as follows (Contaminant Mg/kg of finished product): Arsenic 25.0; Cadmium 50.0; Chromium 25.0; Copper 40.0; Pentachlorophenol (PCP) 5.0; Lead 90.0; Mercury 25.0; Fluorine 100.0; Chlorine 1000.0; Creosote 0.5.

Once incoming material enters a panelboard manufacturing site it is subject to inspection, and non-compliant loads are rejected. The process includes further screening of the woodchip to remove physical contaminants. The woodchip then enters the drying stage. Quality management processes are used to make sure that materials and products meet specifications. Visual inspection, laboratory tests and other methods may be used to check that it meets specifications. Depending on the sampling method however, individual samples may exceed specifications due to the localised presence of contaminants. For example, a small piece of copper wire may cause an individual sample to exceed specifications on copper content. Contamination with copper wire does not constitute contamination with chemical treatment. From the point at which it enters the drying stage, the waste-derived woodchip is handled in the same way as woodchip from virgin timber.

Quality assurance. A number of options have been proposed to solve the lack of standardisation in all markets. SCAG has proposed a grading system to categorise PCW with respect to market grade and acceptability based on market suitability. This system is still at the proposal stage, as it has not been accepted industry wide and is presented in [13]. In summary, there are currently no common quality controls applied across the wood recycling industry. It is recognised that the difference in input materials may mean a risk-based approach is needed for quality control measures. However, it is considered that, as a minimum, all PCW recyclers should carry out three quality control measures: classify input materials – identify the source of the material and the types of contamination likely to be present. Sort and segregate treated from untreated timber. Remove physical contaminants by picking; make sure the production process used is fit for purpose. Make sure it removes the types of contaminants present in the input materials well enough to meet the requirements of the end users' specification; and make sure outputs meet an agreed specification. For example, material going to wood based panel manufacture will meet, as a minimum, the specification.

If the above measures are carried out, the SCAG agreed that the output could be clean PCW and acceptable to all markets as a non-waste/waste derived product.

Risk assessment and mitigation. To establish the level of risk which PCW potentially poses to human health and the environment, the SCAG reviewed risks in relation to its production, handling and storage and subsequent use in each of the end uses.

Also, in the present context, the SCAG considered factors which may affect certainty of use, including market certainty and degradability.

The SCAG concluded that if appropriate quality controls are put in place to ensure an output of clean PCW, then risks to human health and the environment are considered to be low. This section focuses on why it is necessary to use clean PCW to ensure a low risk of harm to human health and the environment.

Processing, handling and storage. Any risks to human health or the environment during the production process, as detailed in [13], are mitigated under waste management regulations. The handling and storage of PCW is also mitigated under waste management legislation. However, the SCAG felt that additional mitigation was needed to minimise the risk of fire, degradability and dust nuisance. To minimise the risk of fire associated with stockpiling processed wood chip, and degradability of the material, the SCAG recommended that appropriate mitigation be put in place. It is recognised that the mitigation measures will vary from site to site depending on the size and storage time of stockpiles and level of fire risk. Where material contains fines it is a potential nuisance risk as well as a health risk where there is a high level of exposure.

Dust nuisance can be reduced by storing the material in closed containers and also by pre-selection. This may also help to reduce odour. The risk of chipped material degrading can be reduced by storing it for no longer than six months. This was suggested by the SCAG to allow storage time at the wood recyclers before it reaches the wood based panel industry where it should only be kept for approximately three months. There is possibly a need for paperwork to be completed to state the storage time, although the time to avoid degradation will vary depending on the storage conditions.

Clean PCW. Clean PCW was seen by the SCAG to constitute a very low risk to both human health and the environment. Provided adequate input controls are in place, the SCAG agreed that this material poses no greater risk to human health or the environment than wood chip from virgin timber used for the same purpose. Where the input material contains physical contaminants, processing technologies can remove most of these contaminants. The SCAG recognised that there is a potential risk of treated PCW entering the process through mixing waste streams. However, it considered that if inputs into the chipping plant are adequately monitored and controlled, mixing waste streams will be limited such that 'harm' will not be caused. This would mean that the risk of treated PCW entering the process is low. The process and quality control measures (identified in Appendix E) will further reduce the risk of this occurring. Therefore, using clean PCW that has been appropriately processed to a point where it poses no greater risk to human health or the environment than wood chip from virgin timber used for the same purpose, is seen to pose a low risk.

Treated PCW. No research information has been found on the potential toxicological impacts of using recycled PCW. The Environment Agency has carried out some research on the possible environmental impacts of timber treatment chemicals.

However, this research is limited to reviewing the impacts of using whole treated timbers (for example logs, planks) in aquatic environments and does not consider the potential impacts on soil systems. However, this work indicates that some timber treatments are more prone to leaching than others. Internationally, extensive research has been carried out into leaching from CCA treated timbers. This and the toxic nature of the material have supported banning the use of CCA to treat timber. However, it will still be present in the waste stream for the foreseeable future, as buildings are demolished which contain CCA treated timber. Where stockpiles are uncovered and contain treated PCW, there is a possibility that some leaching may occur and contribute to ground contamination and surface water pollution. The risk of leaching is generally low where chemicals are strongly bonded to the wood, but in subsequent product use chemicals may be released if the wood breaks down. During the further decontaminating and cleansing stages at the wood based panel manufacturers, fines are screened out from the recycled wood they receive. Such material may include a proportion of lead (from paint fragments) and if so, there may be risks to the environment associated with its use. The level of risk could not be quantified. No data was made available to the SCAG on the quantities of lead within the material. However, this material still remains as waste and must be handled in accordance with duty of care regulations. Whilst the definition of clean PCW used within this report specifically excludes treated timbers, the SCAG considered that some material from treated timber may be included in this category.

The SCAG initially noted that it might be feasible to remove treatment chemicals from treated PCW so it could potentially be recycled. Potential processes include: fungal breakdown of contaminants; removing chemicals by oxalic acid, solvents or other chemicals; and physically removing surface layers.

Further consideration suggests that while these processes are technically possible in some cases, they are generally not feasible currently because: technologies are not well developed and are restricted to laboratory or small-scale processes and have not been demonstrated on a commercial scale; and the value of the product in relation to the cost of treatment suggests that these processes are unlikely to be commercially viable.

It considered that further information was needed on how effective these technologies were and on how different timbers take up treatment chemicals to assess the level of risk associated with using processed treated PCW in different end uses.

Until this additional research has been concluded, using treated PCW is seen to be a risk to human health and the environment and should not be used in any of the markets stated. If treated PCW is removed at the input stage, and appropriate processing is carried out to produce clean PCW, the SCAG considers that the risk to human health and the environment is low. However, the outputs produced must also reach an agreed end user specification so they can definitely be used.

Quality Protocol for PCW as fuel. The SCAG found that there were two obstacles to achieving a Quality Protocol for wood as fuel:

- current case law indicates that waste to be used as a fuel normally remains as waste until the energy is recovered by burning; and
- the main area of potential market growth is in the burning of treated wood waste. The Waste Incineration Directive is clear that the only wood waste that can be burned is that which is not contaminated with halogenated organic compounds or heavy metals. The SCAG felt that this zero tolerance to metals in wood is unachievable.

The SCAG agreed that the Waste Protocols Project was not the correct forum for addressing this issue, but felt that there is a need for a standard to be produced for PCW as fuel. The Environment Agency SCAG members felt that this may not be achievable, as energy from waste facilities may require different feedstock qualities due to different technical requirements. A common specification may therefore limit the market.

Quality Protocol for the wood based panel industry

The SCAG considered the options for developing a Quality Protocol for the wood based panel industry but found no apparent benefits for either wood processors or wood based panel manufacturers of changing from the current situation.

Based on the review of acceptance procedures and production processes carried out by wood based panel manufacturers, the SCAG identified three options where waste derived woodchip could be considered to have ceased to be waste:

Option 1: ***When incorporated into panelboard***

This is the current situation.

Option 2 : ***After processing and before entering the drying stage***

After physical contaminants (for example pieces of plastic, metal and grit) have been removed, and before the material enters the drying stage, it may be considered to be the same as producing woodchip from virgin timber.

Option 3: ***Where wood processors have removed the same level of contaminants as the wood based panel manufacturer***

This means where the material meets the industry developed standard "Guidance for the specification and control of reclaimed wood raw materials used in the manufacture in the Ukraine of wood PB" and the level of contaminant removal which is currently carried out on the wood based panel manufacturer site.

In the case of option 2, it was questionable what would be achieved by defining the material as ceasing to be waste, given that it has already entered the production process. This option provides no apparent benefit to the wood based panel industry, as it will not affect the regulation of the production process.

In the case of option 3, there is currently no common standard used by the wood based panel industry to define the levels of processing necessary to reach this point. Whilst the SCAG did not derive costs for implementing this option, from their experience in the industry they felt that the level of investment required to achieve this would be prohibitively high, and its viability is therefore questionable.

In view of these considerations it was found that a Quality Protocol is unlikely to add value to the industry, as it would not be viable to move the point of recovery.

Conclusions

The rising cost of raw materials, ever tighter legislation about waste disposal, and the fierce competition between PB manufacturers has led to the increasing use of recycled wood. It is possible to use any source of recycled wood to reduce raw material costs by between 40-70 % and the resulting boards will have even surfaces and post-soft formable core layers. There are advantages apart from the obvious one of being a sustainable alternative to using virgin timber. Recycled wood has a moisture content of around 20 % compared to the 60-70 % moisture in virgin wood, so it makes economic sense to buy recycled wood chip; it also lasts longer and utilizes less energy during processing.

Technological advances in wood recycling plant and machinery are also increasing processing efficiency and economy. The latest wood shredders are capable of processing over 30 tonnes an hour, and are often fitted with over-band magnets, eddy current separators and trommel screens. A lot of work is also being done currently to identify and remove contaminants to further improve the quality of the recycled chip. The SCAG claims that boards will be lighter, have excellent mechanical properties, be easier to process and that wood and glue consumption will be greatly reduced. The increasing cost of raw materials and the escalation of competition in both quality and price of wood based panels oblige board manufacturers to rapidly introduce this innovative technology.

Recommendations. The SCAG recommends that the DLIMIP of Ukraine produces guidance on when regulatory controls apply that reflects: the low risk of harm posed by using clean PCW provided that quality controls are in place to minimize any potential risk posed by contaminating materials; treated wood waste should remain as waste; and wood off cuts produced as a result of processing virgin wood (for example from sawmill operations or timber product manufacturing) that are free from contaminants and can definitely be used again should not be waste and therefore should not be regulated. There is no evidence that using clean PCW in wood based panel industry creates a significant risk to human health or the environment. The SCAG recommended that these activities are low risk and regulatory controls are not needed. The SCAG recommended that where treated PCW is mixed with clean PCW this will be treated as waste. The SCAG recommended that if the PCW industry can provide evidence that this material poses low risk to human health and the environment, this position should be reviewed. There needs to be clarity on acceptable levels of chemical contaminants and contamination levels in virgin wood. Such data can then be used to compare with contaminants in clean PCW to ensure no additional human health or environmental effects arise from the use of this material.

The SCAG recommend that more research should be done on the effectiveness of technologies that remove contaminants from treated PCW. The ***DLIMIP of Ukraine could*** then consider developing a Quality Protocol for this waste stream.

It is recommended that the ***DLIMIP of Ukraine consider*** further the regulation of PCW as fuel, considering the importance and growth of this market.

Outlook PCW: the global trend for a cleaner environment and recycling of all materials will continue; wood plays a major role in combating climate change – greater use of of wood products will: stimulate the expansion of Ukraine's s forests, and reduce greenhouse gas emissions, by substituting for fossil fuel intensive products. PCW waste will always be generated, even with falling prices for virgin wood; wood recycling helps to decrease the deficit of virgin wood by giving wood a "second" life; positive of world market dynamics and awareness towards a "green" product; naturally, this is process produces a truly "green" product that helps reducing the build-up of landfills and deforestation; recovered wood will gain importance as a raw material for PB, seen the growing competition with biomass energy; avoid massive burning of wood for purely energetic reasons; the cost for PCW waste is considerably lower often free compared to virgin wood; the drying cost is substantially lower due to low initial moisture contents (<20 % (o.d.) average); fiscal incentives such as reduced Value Added Tax for wood products from sustain ably managed; market incentives such as public procurement clauses to encourage the use of wood products such as minimum wood content in public buildings; and future Ukraine and policies should focus on efficient recovery of recovered wood.

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З переробленої вживаної деревини до якісних деревостружкових плит

У статтях наведено детальний огляд літератури з проблем деревних відходами в Україні, та, зокрема, ефект від очищення забруднених відходів, а також питання утилізації вживаної деревини (ВЖД) в Україні в якості альтернативного сировинного ресурсу для виробництва деревностружкових плит (ДСП). Сьогодні перероблення є найбільш екологічно чистим методом управління деревних відходів. Велика частина деревних відходів утворюється з використаних меблевих виробів, які в основному складаються з ДСП, та інших сконструйованих дерев'яних предметів, тобто матеріалів, які потенційно можуть бути використані повторно. Зростання вартості сировини, все більш жорсткі закони про утилізацію відходів і жорстка конкуренція між виробниками ДСП призвели до збільшення використання переробленої деревини. Можна використовувати будь-яке джерело переробленої деревини за скорочення витрат на первинну сировину в межах від 40-70 %, яке в результаті забезпечить якісну поверхню плит з м'яких, частково деформованих стружок. Відновлена деревина має вологість близько 20 %, що у порівнянні з 60-70 % -ною вологістю для первинної деревини, дає економічний сенс купувати перероблену деревну тріску, крім того, вона має тривалий термін служби і споживає менше енергії під час операцій оброблення. Технологічні досягнення в

галузі обладнання та машин для пероблення деревини підвищили ефективність оброблення і зробили його більш економічним. Останні подрібнювачі деревини здатні обробляти більше 30 тонн на годину, і часто оснащені верхньо-стрічковими магнітами, вихровими сепараторами і мережевими екранами. У даний час багато-що робиться для виявлення і видалення забруднень для подальшого поліпшення якості переробленої стружки. З'ясовано, що одержані плити будуть легшими, мати добрі механічні властивості, легше оброблятися, а кількість деревини та витрата клею буде значно скорочена. Є перевага, крім очевидних, що ВЖД буде стійкою альтернативою використанню первинної деревини. Зростання вартості сировини та ескалація конкуренції в якості та ціні деревних плит зобов'язує раду виробників швидко впроваджувати цю інноваційну технологію.

Перспективи ВЖД: глобальна тенденція до чистого довкілля завжди буде зумовлювати перероблення всіх спожитих матеріалів; деревина відіграє основне значення в боротьбі із зміною клімату – більше використання вживаної деревини буде: стимулювати розширення українських лісів та скорочувати викиди парникових газів, заміщаючи викопне паливо альтернативним; ВЖД завжди накопичуватиметься, незважаючи на привабливі ціни первинної деревини; перероблення ВЖД допоможе зменшити дефіцит первинної деревини, якщо цій деревині надати "другого" життя; позитивна динаміка світового ринку і усвідомлення у напрямку до "зелених" виробів; природно, це є процес виробництва дійсно "зелених" виробів, який зменшує накопичення відходів на звалищах та вирубування лісів; ВЖД є важливим сировинним матеріалом для плитної промисловості, який постійно зростає у порівнянні з біомасою, яка йде на виробництво енергії; необхідно уникати масивного спалювання ВЖД, розмірковуючи тільки з енергетичних причин; вартість ВЖД є значно нижчою у порівнянні із первинною деревиною; вартість сушіння ВЖД істотно нижча, завдяки низькому початковому вмісту вологості; фінансова стимуляція, як, наприклад, зменшення ПДВ для підприємств, які використовують ВЖД; стимуляція ринків шляхом заохочування через пропозиції державної закупівлі ВЖД з домашніх господарств; у майбутньому директивні рішення України повинні базуватись на використанні ВЖД.

Ключові слова: вживана деревини, відновлена (очищена) деревини, деревні відходи, деревостружкова плита, підготовка спожитої деревини, перероблення, утилізації відходів, призначення деревних відходів, деревні плитні виробництва.