Australian Government
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International Agricultural Research

ENHANCING KEY ELEMENTS OF THE VALUE CHAIN FOR PLANTATION GROWN WOOD IN LAO PDR

Wood waste reduction and waste utilisation

An investigation on the various uses of wood waste and off-cuts for the Lao wood processing and manufacturing industry

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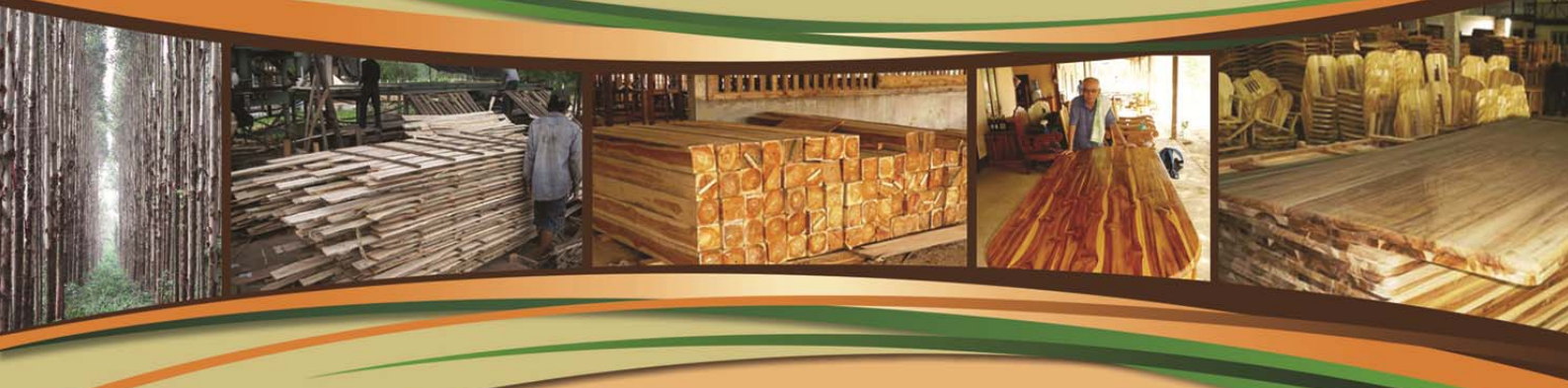


VALTIP2

ບົດຄັດຫຍໍ້

ການປັບປຸງປະສິດຕິພາບໂຮງງານອຸດສາຫະກຳໄມ້ ແມ່ນເປັນເລື່ອງທີ່ສັບສົນ. ໂດຍລວມແລ້ວ ການສົນເສຍວັດຖຸດິບແມ່ນເກີດຢູ່ໃນຂອດການຜະລິດ ແລະ ບໍ່ມີວິທີໃດ ທີ່ຈະສາມາດແກ້ໄຂໄດ້ແມ່ນໄວວາ ແລະ ງ່າຍດາຍໄດ້. ຢ່າງໃດກໍ່ຕາມ, ອົງໃສ່ປະສົບການແລ້ວ ຜົນສຳເລັດຂອງການປັບປຸງປະສິດຕິພາບໂຮງງານອຸດສາຫະກຳໄມ້ ແມ່ນຕ້ອງອົງໃສ່ໂອກາດຄວາມອຳນວຍ, ດ້ານເສດຖະກິດດີ ແລະ ມີປະສົບການ ຫຼື ວິທີການດຳເນີດທຸລະກິດດີ.

ການຫຼຸດຜ່ອນການເກີດໄມ້ເສດໃນການຜະລິດ ຫຼື ການນຳໃຊ້ໄມ້ແບບຍືນຍົງນີ້ຖ້າຍາກປັບປຸງປັນຫານີ້, ສິ່ງທີ່ຄວນເອົາໃຈໃສ່ອັນດັບໜຶ່ງເພື່ອເພີ່ມປະສິດທິພາບໃນການຜະລິດຂອງໂຮງງານແມ່ນການຫຼຸດຜ່ອນການເກີດໄມ້ເສດເປັນເປົ້າໝາຍຫຼັກ. ການຫຼຸດຜ່ອນການເກີດໄມ້ເສດນີ້ສາມາດເຮັດໄດ້ຫຼາຍວິທີໂດຍເລີ່ມຈາກການເລືອກຂະໜາດ ຈົນຮອດສະຖານທີ່ການເກັບມ້ຽນ. ອີກສິ່ງໜຶ່ງທີ່ສຳຄັນໃນການຫຼຸດຜ່ອນການເກີດໄມ້ເສດນີ້ແມ່ນການອອກແບບທີ່ດີ.

ອີກສິ່ງໜຶ່ງທີ່ສຳຄັນໃນການອອກແບບກ່ອນທີ່ຈະດຳເນີນການປະຕິບັດງານໃໝ່. ຄຸນນະປະໂຫຍດ ຫຼື ຜົນໄດ້ຮັບຂອງການຫຼຸດຜ່ອນການເກີດໄມ້ເສດນັ້ນມັນຂຶ້ນກັບການຕິດຕັ້ງເຄື່ອງຈັກ. ໂຮງງານ ຫຼື ຜູ້ດຳເນີນກິດຈະການສາມາດຫຼຸດຜ່ອນການເກີດໄມ້ເສດອີກຕື່ມວິທີໜຶ່ງນັ້ນກໍ່ຄືການຝຶກອົບຮົມໃຫ້ເໝາະສົມເພາະການຫຼຸດຜ່ອນການເກີດໄມ້ເສດເປັນການເພີ່ມທາງດ້ານເສດຖະກິດ. ໃນຂັ້ນຕອນນີ້ການປະສານງານກັບຄົນງານເຮັດວຽກກັບເຈົ້າຂອງໂຮງງານເປັນສິ່ງທີ່ຈຳເປັນທີ່ສຸດ.

ຄຸນນະພາບຂອງວັດຖຸດິບ ແລະ ອຸປະກອນໃນການຜະລິດເປັນສິ່ງທີ່ສຳຄັນອີກສິ່ງໜຶ່ງ. ການນຳໃຊ້ວັດຖຸດິບທີ່ຖືກຕ້ອງນັ້ນເປັນອີກທາງເລືອກໜຶ່ງໃນການຫຼຸດຜ່ອນໄມ້ເສດ ແລະ ຈະໃຊ້ເວລາປະຢັດໃນການຜະລິດ. ອີກຕື່ມປະການເພື່ອປັບປຸງຂັ້ນຕອນການຜະລິດແມ່ນການນຳໃຊ້ວັດຖຸດິບແບບຍືນຍົງ, ລະບົບໃນການວັດແທກ. ການຄວບຄຸ້ມຄຸນນະພາບນີ້ກໍ່ເປັນວິທີໜຶ່ງທີ່ງ່າຍ ເພາະຖ້າມີການຄວບຄຸ້ມ ແລະ ນຳໃຊ້ເຄື່ອງຈັກຖືກຕ້ອງຈະຊ່ວຍເພີ່ມປະສິດທິພາບການຜະລິດ. ຈາກການສຳຫຼວດຂັ້ນຕອນການຜະລິດແມ່ນຍັງເຫັນວ່າໄມ້ເສດຍັງມີຫຼາຍ ແລະ ຄວນຕ້ອງມີການປັບປຸ່ງຕາຕະລາງການບຳລຸງຮັກສາເຄື່ອງຈັກ.

ເຖິງຢ່າງໃດກະຕາມ, ເຖິງແມ່ນວ່າຂັ້ນຕອນການຜະລິດຈະເຮັດໃຫ້ເກີດໄມ້ເສດຫຼາຍ. ໃນກໍລະນີເຮົາສາມາດປ່ຽນຈາກໄມ້ເສດເຮັດໃຫ້ເກີມມູນຄ່າ ແລະ ເປັນບັນຫາທີ່ສຳຄັນ. ຖ້າຫາກເຮັດຕາມກິດຈະກຳ ແລະ

ນຳໂຍບາຍທີ່ແນະນຳຂ້າງເທິ່ງນີ້ກໍສາມາດເພີ່ມມູນຄ່າຈາກໄມ້ເສດ,
ປະສິດທິພາບໃນການຜະລິດໃຫ້ກັບບັນດາຫ້ອໜ່ວຍທຸລະກິດ

Foreword

The present document has been developed to assist the Lao wood processing and manufacturing industry with wood waste reduction and waste utilisation. At present, wood recovery and productivity in wood manufacturing companies are low and a substantial amount of waste is generated. In 2008, the Government of Laos (GoL) started implementing policies for small and medium processing industries using domestic raw materials, in order to increase value adding and competitiveness of exports in international markets. The Ministry of Industry and Commerce, responsible for harvesting and processing forest resources in Lao PDR, established the following priorities:

- Raise factory productivity and value addition to raw materials with emphasis on wood;
- Upgrade technologies and skills of the wood processors in Lao PDR;
- Minimise production waste and utilise bi-products;
- Promote the sustainable use of natural resources and the protection of the environment;
- Develop Lao standards of wood processing to conform to regional and international standards;
- Promote growth and strengthening of the private sector and the creation of wood processing association;
- Trade promotion for finished products in domestic, regional and international markets.

Most of these priorities can be related in one way or another to the development of a wood waste reduction and waste utilisation plan. Consequently, understanding and improving the efficiency of the manufacturing process of plantation-grown wood is vital for achieving these national goals. Following a wood recovery assessment in manufacturing companies, the present document tries to address questions such as:

Which practices and value-added manufacturing technologies would increase the value recovery of small dimensions, inferior quality plantation wood and facilitate early improvements from dry feed stock to marketable products?

Which strategies can be applied to improve productivity and quality in wood processing and manufacturing to improve competitiveness in global markets?

As a result, a detailed plan for the waste reduction has been developed for Lao wood manufacturing companies to provide recommendations on:

- ✓ How to use timber more efficiently and reduce the amount of off-cuts;
- ✓ How to develop efficient systems for waste collection at different production stages;
- ✓ How to segregate and use waste created;
- ✓ How to improve the use of quality components and products which will result in reduction of rejects;
- ✓ Which value-added technologies suitable to immature wood and utilisation of wood waste and off-cuts could be used.

Executive summary

Improving wood manufacturing efficiency is complex. Material loss is occurring all along the process chain and obtaining sustainable results requires determination. There are not many quick solutions. Nevertheless, the more is achieved usually the more opportunities open up and good economic and business practices can be observed as those improvements are sustained.

Developing a wood waste reduction and waste utilisation plan to prevent or minimize the production of residues should always be one of the first targets when trying to improve manufacturing efficiency. Waste minimisation and resource maximisation for manufactured products can be done everywhere from design stage to the inventory management and storage. Having the right design and using optimised cutting patterns can help avoiding situations such as over-processing raw material.

Once the designing step is optimised it is possible to start implementing new practises. The degree of benefit that results from implementing waste reduction opportunities is highly dependent upon the operations. Business can usually minimize the amount of waste through proper education and training while improving their economic viability. At this stage, good communication with the entire workforce in a company is essential for a successful implementation.

The quality of raw material used and the equipment at your disposition are others elements which require attention. Using better raw materials generally reduces the production of waste because it does not require as much time to sort it out and process it. Another key element in any successful improvement process is a sustainable, practical measurement system. Quality control is a simple way to know if what has been done the right way or not. Quality control is a simple tool to increase productivity and reduce waste. Monitoring a manufacturing process can ensure that the number of reject batches is kept to a minimum and help develop and maintain a maintenance schedule.

Nonetheless, even the best manufacturing process creates wastes. In this case, turning wastes into valuable wood products becomes the main focus. The following pages aim to provide information on the best practises and strategies for long term business growth and increase wood manufacturing efficiency.

Contents

Introduction

Wood waste is usually an indicator of inefficient use of raw materials and resources. Improving wood manufacturing efficiency by reducing the amount of waste created is a complex subject and there are very few quick solutions. Managing the yield on solid wood is difficult notably because material loss is occurring all along the process chain. Finding sustainable results takes focus and determinations mainly because it is a continuous process. However, usually the more you achieve the more opportunities open up and as you sustain those improvements, your financial numbers will improve as well, justifying the efforts put into the process.

Waste hierarchy

According to Wikipedia, the basic concept behind waste management is the waste hierarchy, where the preferred and usually most effective approaches to managing waste are at the top (Figure 1). The aim of the waste hierarchy is to extract the maximum benefits from raw material or resource and to generate the minimum amount of waste. It gives priority to preventing waste in the first place because if waste is not produced then it has not to be disposed of. When waste is produced, it gives precedence to preparing it for reuse, then recycling, then recovery, and last of all disposal.

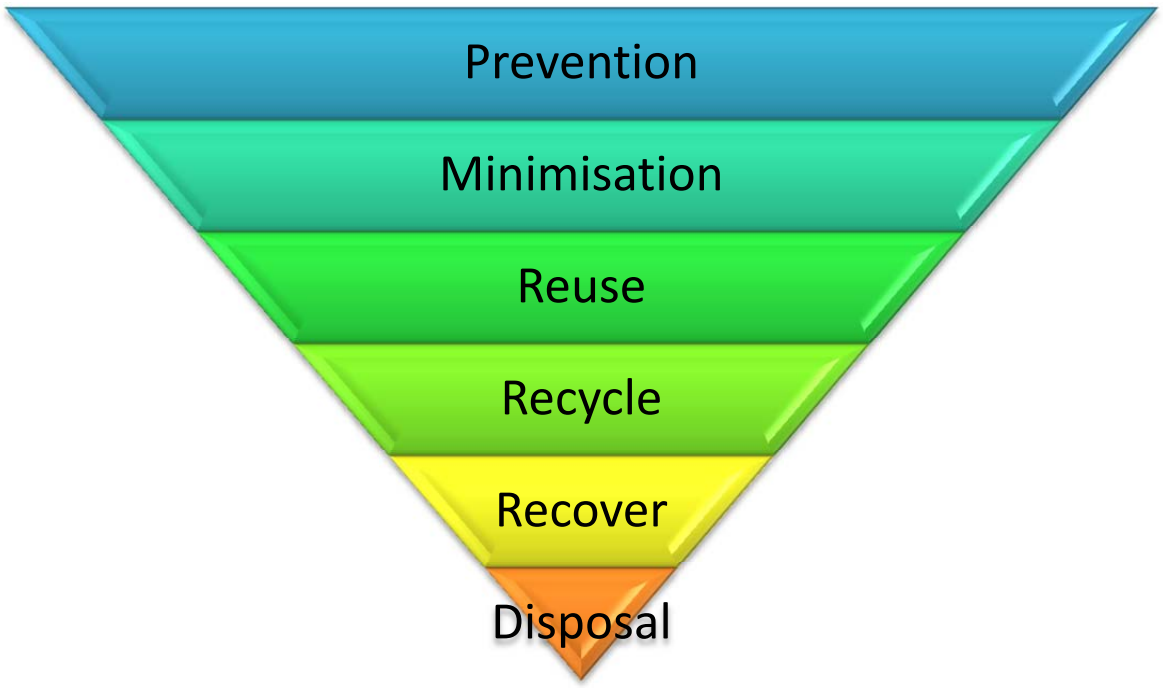


Figure 1 The waste hierarchy (Adapted from Wikipedia)

Prevention

The prevention of waste is the most vital point in the waste hierarchy. Prevention minimizes the generation of waste products in the first place and results in the least environmental and economic costs because it requires no collecting or processing of materials. Prevention also typically produces significant benefits in terms of production efficiencies and the use of resources. It involves using less material in design and manufacture and using less hazardous materials.

Minimisation

Waste minimisation requires knowledge of the production process and the composition of the waste. It involves designing products or processes to reduce the creation of waste. Waste minimisation and resource maximisation for manufactured products can most easily be done at the design stage by reducing the number of components used in a product or optimizing the cutting patterns (Wikipedia).

> *Optimizing the product for operational purposes will increase the productivity, reduce the space requirements and reduce the process times normally required. A further benefit is reducing the complexity of data to be managed.*
>
> Gmeiner (2015a)

Reuse

The reuse of waste is any operation where products or materials that are not waste are used again for the same purpose for which they were intended. Reusing waste might requires collection of material but relatively little or no processing. It usually involves checking, cleaning, repairing, and/or refurbishing entire items or spare parts.

Recycle

Recycling of waste is any activity that includes the collection of used, reused, or unused items that would otherwise be considered waste. Recycling involves sorting and processing the recyclable products into raw material and then remanufacturing the recycled raw materials into new products.

Recover

The recovery of waste is separated into two categories: the recovery of materials and the recovery of energy. Whichever of these choices is better for the environment and human health is the preferred option. The recovery of materials is most often preferred and includes activities such as recycling and composting. These management activities generally require a collection system and a method of material processing and conversion into a new product. The conversion of non-recyclable waste materials into usable heat, electricity, or fuel is done through a variety of processes. Recovery of energy, such as incineration, is usually the less preferred option.

Disposal

The last resort is disposal and is only considered once all other possibilities have been explored. Disposal is any operation that involves the dumping and incineration of waste without energy recovery. Before final disposal, a considerable amount of pre-treatment may be necessary to change the characteristics of the waste in order to reduce the quantity or harmfulness of the waste and that may include physical, thermal, chemical, or biological processes. Landfills are the most common form of waste disposal and the final disposal option.

Benefits of waste prevention and minimisation

Waste minimisation can protect the environment and provide good economic and business practices. Combining technological changes, good operational practices and recycling measures can reduce wood waste by more than 50% (Eshun et al. 2012). It can also help improving:

- ✓ Production practices by achieving more output of product per unit of input of raw materials.
- ✓ Economic returns by reducing costs of purchasing new materials.
- ✓ Public image by reflecting a proactive movement towards environmental protection.
- ✓ Quality of products produced by introducing new innovation and technological practices.
- ✓ Environmental responsibility by minimising or eliminating waste generation which makes it easier to meet targets of environmental regulations, policies, and standards.

Elements to remember!

- *Prevention results in the least economic and environmental costs since it requires no collecting or processing of materials.*
- *Waste can be minimised and resource maximised more easily at design stage.*

Wood wastes and residues definitions

Below are the definitions of some of the most commons wastes.

Coarse residues

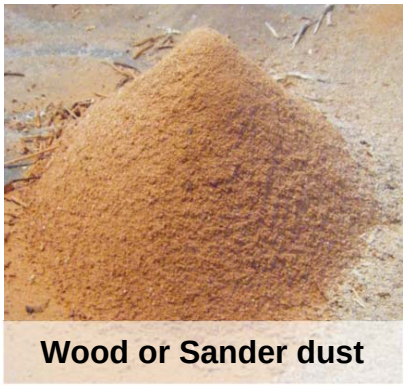
Coarse residues comprise off-cut, edging and trim, usually in the form of coarse or chippable residues generated from large pieces during lumber manufacturing.

Sawdust

Sawdust is generated from sawing, trimming, and edging lumber.

Shavings

Shavings are generated from planing or thicknessing dressed lumber to final dimensions and smoothness.



Wood or Sander dust

Wood or sander dust is the fine powder generated from sanding equipment.

Waste and lean manufacturing

According to lean manufacturing methodology, waste is not just the waste found in our waste bins but rather all types of waste (Wikipedia). Lean manufacturing identifies seven types of waste which will be further discussed in the following pages:

Overproduction	Making more parts than you can sell or ahead of demand.
Delay	Waiting for processing or parts sitting in storage.
Transporting	Moving parts to various storage locations or from process to process.
Over-processing	Doing more work to a part than is required, sometimes because of poor tool, product design, or defects within raw material.
Inventory	Committing money and storage space to parts not sold.
Motion	Moving parts more than the minimum needed to complete and ship them.
Defective parts	Creating parts that cannot be sold '*as is*' or that must be reworked.

Lean manufacturing is the continuous improvement in the operation to reduce any of the seven types of waste.

Detailed plan for wood waste reduction and waste utilisation

The next section has been structured to reflect the waste hierarchy priorities. Ideas for prevention and minimisation of wood waste will be introduced first because they result in the least economic and environmental costs. The upcoming section covers reusing, recycling, and recovering waste. An example of waste reduction program is also provided in Appendix 1.

Preventing and minimising wood wastes in your manufacturing model

Most of the improvements listed below are through process improvements, organizational improvements, capital investments and skills development. But first, where to start? Gmeiner (2015b) proposes three steps to start a wood waste reduction and wood utilisation plan.

Where to start?

- *Set goals and objectives*

  The first step is usually setting the goals and the objectives. The more you can quantify and specify this goal the better. Establish where you are (i.e. current situation, baseline), and then look at your objectives (i.e. where you want to be).

- *Develop your gap analysis*

  As you compare the objectives to the current situation you develop your gap analysis. This gap analysis describes what needs to be done. By clearly understanding your starting point and by defining where you want to end up - possible solutions are already shaping up.

- *Map your process*

  The process mapping defines how the production is organized, scheduled, and controlled. A simple but effective exercise is to map the processes and ask questions such as:

  - ✓ *How is it done?*
  - ✓ *Who is doing what?*
  - ✓ *What information is received from where?*
  - ✓ *What decision needs to be made?*
  - ✓ *What is the output and where is the next step?*

  This exercise can get really interesting if you ask different people about the same questions. The managers and the employees who are actually performing the tasks might have a substantially different version in their mind. If there is more than one person performing the same task, you might also get different versions. When you find these discrepancies you realize the benefits of this exercise. Having a good manufacturing model is all a matter of planning, executing and maintaining. An example of waste reduction plan is included at the end of this document.

  (adapted from Gmeiner 2015b)

According to Gmeiner (2015c) t*he focus should always be on the current process. As the current process is drawn it is possible to start questioning why the processes are designed in a specific way. Secondly, it is important to start modifying the process by eliminating obsolete steps and streamline the others.* ***Easily achievable improvements should also be targeted and implemented first. Good communication with all process holders is essential for a successful implementation****. A process map is also a good tool for teaching a new process to existing and new employees. Unless it is well documented, you usually cannot claim that you know your processes.*

And then…

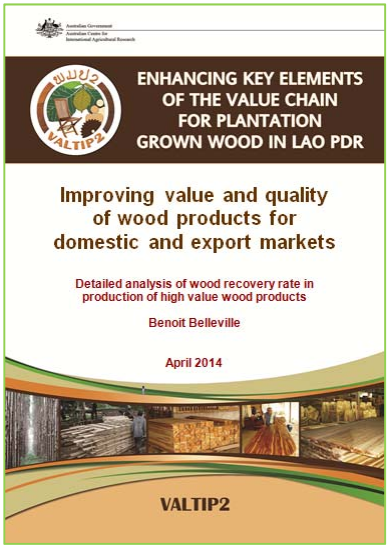
- *Assess wood recovery*

A wood recovery is a detailed analysis of the current wood recovery rate in production (Belleville 2014a). It is a good starting point because it helps determining how much wood is actually recovered or how much is actually wasted. The main objective of a wood recovery is to improve manufacturing process by:

1. Assessing the efficiency of every manufacturing steps;
2. Ranking priorities and elements to focus on;
3. Implementing recommendations based on observed results;
4. Reassessing the manufacturing process to confirm whether or not the recommendations helped improving the efficiency of the manufacturing process.

Assessing each machine/station it will help ranking priorities and start working on those that require an immediate intervention. Focus should be on machines or stations producing and/or wasting the biggest volume of wood.

A documented data collection procedure is available in the Valtip2 report *Improving value and quality of wood products for domestic and export markets* (Belleville 2014a).



Planning

Product design and product specification

A huge proportion of waste factor can be determined and avoided during the design and specification process. Waste minimisation and resource maximisation at the design stage suggests reducing the number of components used in a product or optimizing the cutting patterns. Having the right design will help avoiding situations where you are over-processing raw material. Designing the product with the most abundant material available in mind will cut down on waste and subsequently on cost. Reductions in raw material variety will also reduce inventory levels.

Additionally, research on what constitutes value from the perspective of customers will help to minimise wasted resources. Usually, increase quality of the products will translate in growth to the business long term. Producing products consistently at or above the customer expectation will grow the business. Knowing where the business is falling behind will make a difference to get where the company wants to be.

A simple strategy to improve customer satisfaction is to run a quick survey of the company's last ten consumers. It is important to ask them simple questions such as *what they appreciated from dealing with you* or *what they didn't like*. This easy exercise can be very useful to understand the market when the company doesn't have much time or money to spend on marketing.

The cutting problem

The cutting stock problem is the issue of how to cut out required wood components from raw material with minimum trim-loss and waste. Many practical and industrial aspects may affect the optimisation of wood recovery and the solution strategy. Usually, a cutting pattern for a wood component should be established at the product design stage. Decisions should be made based on raw material and equipment available as well. Below are other aspects worth including at the product design stage.

Purchased grade

Price should not be the only decision factor when buying raw material because the overall cost needs to be considered as well. If buying one quality level requires sorting and selecting the best for a product, the question remains; what to do with the pick over product? If there is a use for it - great! However, if the company starts to accumulate this material to return it to the supplier with restocking charges or use it in place of lower grade (less expensive) then the material is considered a waste. It is possible to calculate whether starting with a more expensive grade selection would be more cost effective or not with all the facts. Depending on the variables, the result may be completely different. Buying higher grade might translate in less defects and this could help avoiding situations where over-processing raw material. Using better raw materials generally reduces the production of waste.

Oversized cutting

It is a common practice to cut pieces slightly larger than required. The extra varies from one company to another. Obviously, the smaller the final piece, the more the extra size impacts the overall wood consumption. Reviewing the minimum requirement and reducing the length oversize will reduce wood consumption. On the down side, going too far will result in rejects going up and losing more. Any millimetre of sustained saving will add up to an overall saving.

Extra quantity

During big batch production, adding a few extra pieces has minimal impact. On the other hand when the batches are small one extra for a quantity of 20 pieces is 5% of your production. To mitigate this problem it is possible to keep them in stock and use them the next time. Sounds good - but the chance that these parts become obsolete, get damaged or lost, or have discoloured by the time we need them again is high. Extra quantity adds substantially to the waste. Reviewing the manufacturing model and applying some basic manufacturing principals will bring results.

It is important to keep in mind that a company commits money and storage space to parts not sold. This also involves moving parts to various storage locations and risking damaging the manufactured pieces in the process. Those parts might even end up sitting in storage for ages and get lost in the inventory.

Examples

Below is an example of a situation observed in a Lao wood manufacturing companies during assessment visits where planning product design and cutting pattern could substantially improve wood recovery and reduce the production of wood waste.

The case was observed in a manufacturing company producing workbenches. To make 400 mm-wide workbenches the company used three 150 mm-wide boards. At the last manufacturing step of the process, a 35 mm-wide section was rip-sawed from the glued-laminated panel to reach final dimensions. When analysing the overall wood recovery for each board, it was found out that only 56% of the last board (i.e. the board on the right side in Figure 2) was used, meaning that 44% of the initial raw material ended up as pure waste. Having designed the product properly, the company could have used narrower boards initially and potentially saved 44% of their raw material acquisition costs. The same concept could also by apply for the length of the boards since more than 15 cm was usually cross-cut from each board to reach the required workbench dimensions. Another alternative to reduce consumption of raw material is ordering pre-cut to the required size for your specific production to minimise timber off-cuts and wastage on projects.

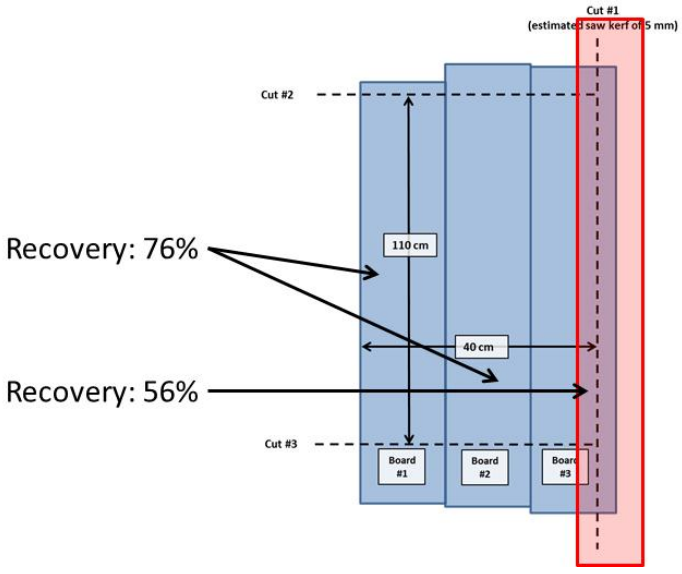


Figure 2 Impact of material selection on wood recovery.

Executing

Inventory management and storage

Significant cost and effort goes into adequately drying the lumber and therefore it is important to protect it (Figure 3). Dried lumber that is exposed to the weather and potentially damaging yard activities can change quality lumber to waste wood. If not immediately used, kiln dried lumber needs to be stored in an enclosed dry shed where it is protected from the weather. Also, if the lumber is stored long term (several months), a controlled environment is recommended to prevent deterioration. The inventory should also be identified (location, label).

Figure 3 Kiln dried lumbers stored in an enclosed dry shed and covered with a waterproof tarpaulin will prevent deterioration.

Arrange lumber delivery to minimize inventory and storage time

The longer that delivered lumber stays in the lumber yard or warehouse, the more chance of degradation resulting from exposure to the environment or damage (breaking, cracking, etc.) from inadvertent contact with equipment or other lumber (Figure 4). Sometimes, excessive quantities of lumber are purchased because of lower prices, however the money saved up front can be lost through damaged lumber that is eventually wasted. It is important to plan carefully so that lumber in the yard maintains the desired quality and is utilized efficiently (US Environmental Protection Agency 2015).

Figure 4 Inappropriate storage can damage lumber and cause production delay while reducing storage space.

Inspect, sort, and separate lumber on reception or as soon as possible

Lumber can be shipped in packages with a random mixture of lengths and it is recommended that the incoming lumber be inspected and sorted (i.e. by length, thickness, width, and quality) based on the needs to reduce wood waste. Lumber that is received below the quality grade requested, or is poor quality, can be identified promptly and returned to the supplier or used appropriately.

Also, yard space can be utilized more efficiently by the elimination of large voids in the packages resulting from mixed board lengths. Mixed lengths will also cause improperly supported stacks and potentially damaged lumber caused by the movement of lumber packages with protruding boards. Sorting can be done by hand and will result in generating less waste which will more than offset the cost of sorting (Figure 5).

Figure 5 Once lumbers have been inspected, sorted and separated on reception they should be stored and identified.

A close partnership with suppliers which encourages more shared responsibility and trust is also recommended. This partnership can eliminate costly, non value-added steps such as inspection and reshuffling materials. Quality programs which document out-of-spec materials will give both the supplier and the customer the facts to measure and improve performance. Suppliers should be trained in the same way as the company's own inspectors would be trained so that they know and meet the particular company's needs. Pre-shipment inspections and "custom" shipments that are one length, one grade, etc., should be considered so that costly additional steps after receiving are avoided (US Environmental Protection Agency 2015).

There should be a place for everything and everything should be in its place (Figures 6-7). All the unnecessary material should be eliminated and only the essential kept (Figure 8).

Questions which should be asked regarding the storage area

- *How old is the oldest material on the shop floor?*
- *Is there obsolete material mixed in the inventory?*
- *Are the corners full of old material?*

Figure 6 Organising tools will prevent searching them and increase productivity.

Figure 7 Sorting and segregating off-cuts will allow using them the next time.

Figure 8 Improper storage of wastes with raw material will affect productivity and increase financial costs.

Quality control

Quality control is a simple tool to increase productivity and reduce waste. Quality control and process monitoring steps can be taken to ensure that the number of reject batches is kept to a minimum. This can be achieved by increasing the frequency of inspection and the number of points of inspection (e.g. by installing automated continuous monitoring equipment to identify production problems).

Glued-up panels should not be rejected because one strip was out of spec (Figure 9). One bad strip in a full size panel discovered after it has been planed down reduces dramatically the wood yield because a big portion of this bigger panel is now waste. Having a quality control system in place to prevent this will save wood and labour. Setting standards and training the operators on these expectations can maintain a higher yield level.

Figure 9 Finished panels where one strip is out of spec because of decay.

A key element in any successful improvement process is a sustainable, practical measurement system. Quality control is a simple way to know if what has been done is right or wrong. It takes management commitment but can be one of the best management tools. When establishing a quality control plan, the first thing consists in establishing a few things that are not quite right. Select what is important. Each measurement selected should have a valid reason for being selected (Figure 10). A good starting point is the bottleneck or the processing step consuming the largest volume of material.

What to measure?

Almost anything can be measured with almost unrestricted units of measure: volume per time (e.g. pieces per day, shift, hour…), productivity (e.g. output vs input, volume per labour hour), quality (e.g. reject rate), or safety (number of incidents). When collecting data on a daily basis these still need to be processed and displayed in a bigger time frame (weekly, biweekly or monthly measures are usually the best practical reporting cycles). More important than the actual measurement is the trend over a period of time. Everyone in a group (employees, supervisor, and manager) should understand what the goals are and how their group is performing. For this reason, it might be useful to create different levels of reporting: shop floor level regarding quality and on-time measurements; manager level for recovery or productivity. This reporting should become part of a daily or weekly work routine.

Figure 10 Measuring the pieces after a processing step to assess variation and make sure that the machine is calibrated will increase productivity and reduce wood waste.

How to measure?

Measurements for output(s) and offcut(s) are function of the processing steps (Belleville 2014a). This means that we should only measure the dimension(s) that is affected during a specific processing step. For example, only measure thickness of output(s) after a planing step (three measures per sample recommended) because this step only affects thickness and has no effect on width or length. The width and length of a blank after planing are supposed to remain the same before (input) and after (output). Same principle applies for a cross-cutting step where we only measure length (One measure per sample recommended) or for an edging processing step where we only measure width

(three measures per sample recommended). The only exception here would be if a processing step affects two or three planes. In this case, all affected planes would need to be measured. The concept behind measuring at three different places is to determine if there is variation within a piece (Figure 11). According to Gmeiner (2015), implementing quality control system can increase productivity gains of 10-15% within the first year not because of the measurements themselves but rather because the focus is now being put on what is declared as critical.

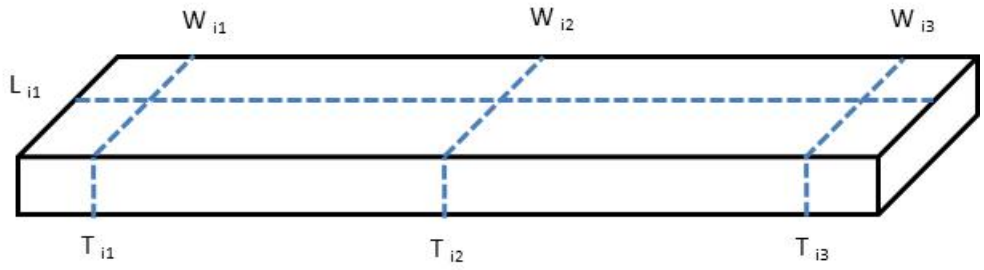


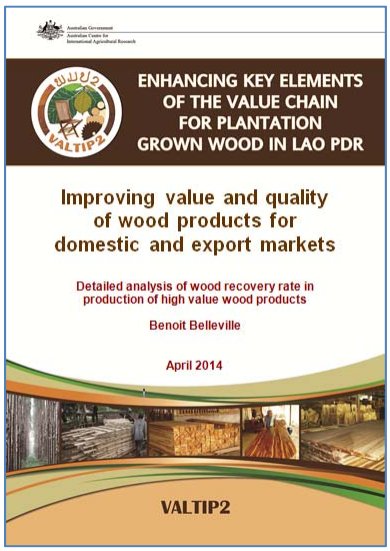
Figure 11 Method for measuring input. Length (L_{i1}), width ($W_{i\ 1\ to\ 3}$) and thickness ($T_{i\ 1\ to\ 3}$).

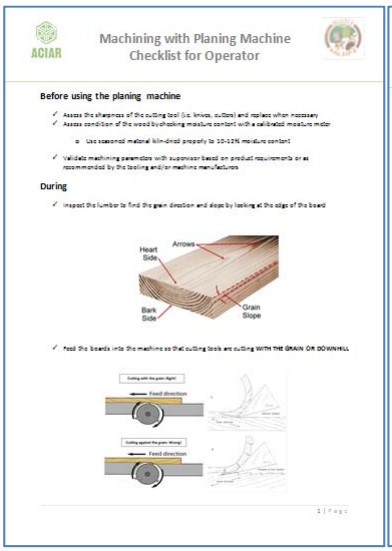
How much measuring is required?

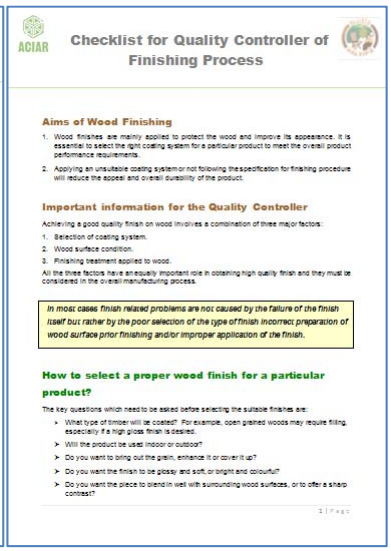
A short answer would be to keep it to a minimum (Gmeiner 2015d). Any measurement costs something to collect, to tabulate, to analyse, and to archive. If you do nothing with the data it is a waste of resources. If you already have sufficient control, and a deep understanding of your operation, you might not need many measures. Remember that what you measure gets attention and what gets attention will improve.

Tools to help implementing a quality control program

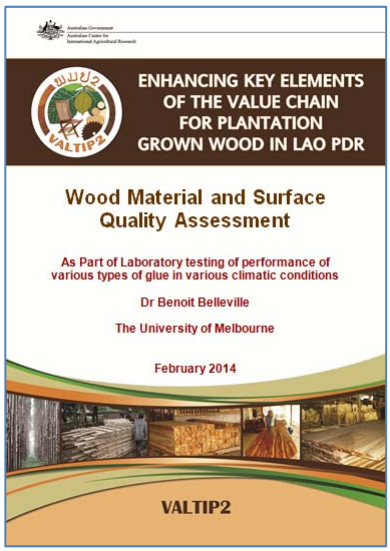
Additional information on wood recovery and implementation of a quality control program can be found in the Valtip2 report *Improving value and quality of wood products for domestic and export markets* (Belleville 2014a). A user-friendly manual on quality control methods used in wood processing and manufacturing applicable to SMEs in Laos is also in press (Ozarska and Belleville 2015). The manual will include checklists to assist workers and quality controllers on multiple wood manufacturing steps.







Information on surface quality assessment as part of a quality control program can be found in the Valtip2 report *Wood Material and Surface Quality Assessment* (Belleville 2014b).



Equipment and technology

The age of the equipment is not as important as it is to see if the machines are the right machines to do the job. In industries, using more efficient manufacturing processes will generally reduce the production of waste because it will translate in fewer defects and avoid you situation where you are over-processing raw material. Making defective parts that cannot be sold 'as is' or that must be reworked is another example of waste according to lean manufacturing principles.

Using the wrong glue can also result in wasted material and time. Some glues (e.g. thermosetting glues) are non-reversible, once they are cured, they cannot be liquefied again. If the desired quality of the bond is not achieved, the material may end up in the scrap pile. The shelf life (check expiration date) and pot life of glues vary. It is important to know the shelf life before purchasing or catalysing large quantities as they could end up as waste. Applying too much glue is also a waste which increases the operational costs (Figure 12 A and B).

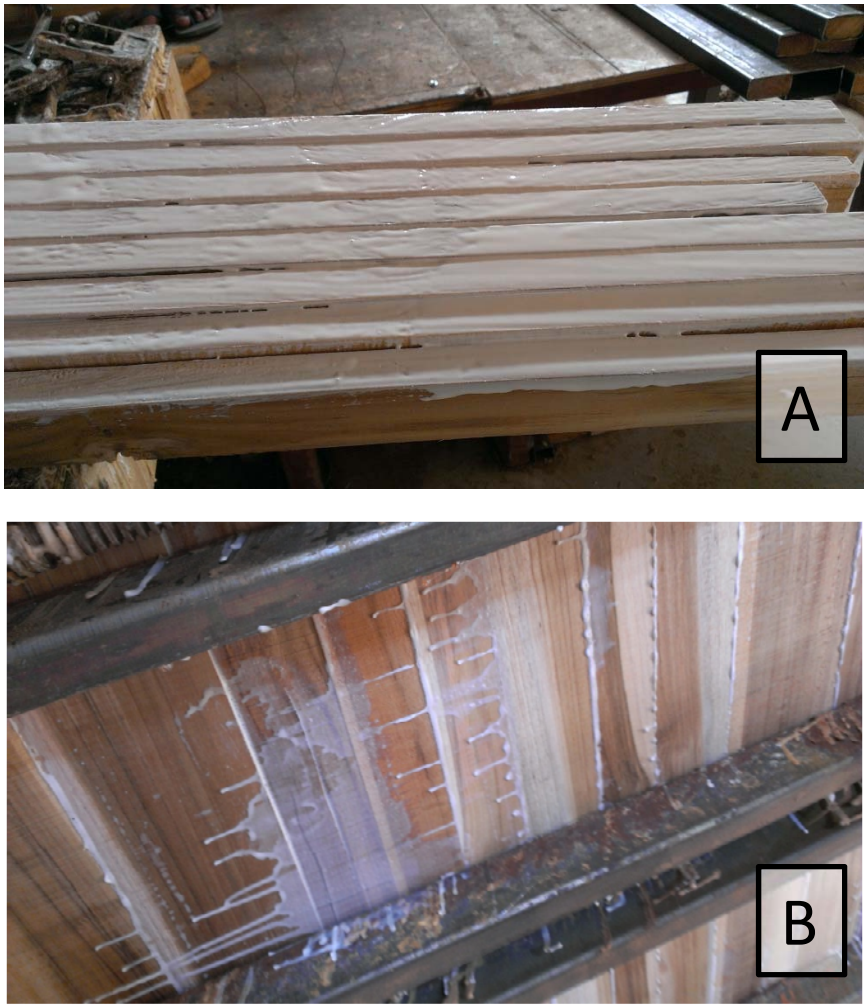
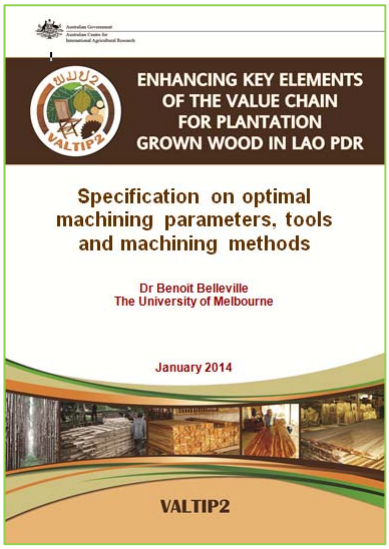


Figure 12 Applying too much glue is wastage of raw material (A) that will increase the processing costs because more glue will be needed and extra time will be wasted to scrapped the excess (B).

Tooling

The width of the saw kerf has an impact on the wood yield when cutting wood. It is important to talk with tool supplier regularly for new tooling products or there may be loss on some improvements. Thinner kerf saws will reduce the proportion of timber that becomes sawdust.

More detailed recommendations on machining procedures for high-quality wood products can be found in the Valtip2 report *Specification on optimal machining parameters, tools and machining methods* (Belleville 2014c).



Packing and shipping

Opportunities for waste reduction in packing and shipping include evaluating damage history (thus reducing product damage and waste) and packaging water resistance. Inadequate packaging can result in furniture being damaged in transit and subsequently disposed in some cases, thereby creating a larger environmental problem than the packaging. The opportunity presented here is to minimize the damaged furniture waste by improving packaging. Records should be collected of what goods are damaged. These records should be evaluated periodically to determine sources of packaging problems. What caused the piece of furniture to be damaged? Would a different packaging approach provide protection from such incidents? Develop methods of improving packaging to eliminate or minimize these problems.

Furniture pieces are typically sensitive to water damage, therefore, most packages must be carefully protected from exposure to water. Unfortunately, there are many cases where boxes are exposed to blowing rain or snow at loading docks, leaks in trailers and extremely high humidity. In these cases, it is important that the basic packaging materials be water resistant (Figures 13-14).

Figure 13 Wrapping finished products will reduce the risks of degrading them prior shipping.

Figure 14 Wrapping finished products will reduce the risks of degrading them prior shipping.

Education and Involvement of workforce

As mentioned previously, a successful implementation process needs good communication with the entire workforce in a company. The degree of benefit that results from implementing waste reduction opportunities is highly dependent upon the operations. Business can usually minimize the amount of waste through proper education and training while improving their economic viability. Key factors for a successful implementation include visible commitment from facility leadership, program ownership and support by all employees, multi-functional participation, establishment of waste reduction goals, management systems for tracking the types and amounts of materials, wastes and associated costs, and the measurement and celebration of progress (Figure 15).

Figure 15 Good communication with the workforce can include advertising the weekly production reports and other relevant information inside the factory such as quality control.

A well-documented process mapping will also be a very good tool for teaching actual and new processes to existing and new employees to make sure that everyone knows the processes and implications regarding your wood waste reduction plan.

Question which should be asked regarding the wood waste reduction plan and the workforce:

- *Do employees relate and understand the meaning of the key performance indicators for the wood waste reduction plan?*

Maintaining

Maintenance is an extremely efficient simple tool to increase productivity. Here are a few simple questions which should be asked regarding working environment and maintenance:

- Is the factory clean and tidy?
- Are workplaces, tools and inventory identified (location, label, sorted)?
- Does the factory appear to be cleaned on a regular basis?
- Are the machines cleaned and free of debris (Figure 16)?
- Are current maintenance schedules posted?
- Is the material stored properly to prevent deterioration and damage?
- Are there practical work instructions or checklists on the different work places?

Figure 16 A clean and tidy factory is one of the first steps when implementing a wood waste reduction and utilisation plan.

Keeping a workplace clean and tidy is a good exercise to achieve culture change and install an atmosphere for improvement. If the changes are not achieved in this area it is not advisable to start the next and more difficult project.

A systematic approach to preventive maintenance will have a big influence on the operations performance.

- ✓ Check equipment daily for proper set-up and needed adjustments to minimize waste
- ✓ Perform regular inspections of application performance
- ✓ Perform preventive maintenance

Small batch size is usually more sensitive to machine and tooling breakdowns, which impact the operation flow. These problems may have always been there, but they are more visible when batch size is small.

Wood dust management

Wood dust is an issue that can threaten no only product quality but also workplace health and safety. Wood dust can cause serious health problems from irritation, allergic reactions and asthma, and dust from certain wood species is even considered carcinogenic. It is also a potential explosion, fire and health hazard (Figure 17).

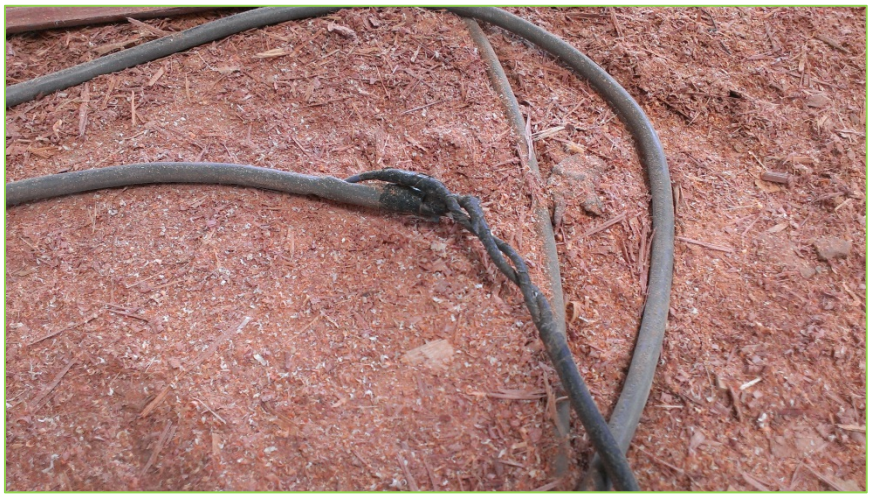


Figure 17 Damaged electrical wires in contact with wood dust is a potential fire hazard.

Dust build up in a shop will lower the quality of everything produced to varying degrees depending on the severity of the problem (Figures 18 and 19). Cleaning sanding belts, saws, and other cutting tools will preserves tool life (e.g. resin build-up) and decrease maintenance by keeping dust away from machinery. In the case of sanding belts, it will also improve sanding efficiency by preventing dust from becoming embedded in the belt.

Figure 18 Wood dust adds an extra step in the process because components need to be cleaned before finishing otherwise this will affect the quality of the finish and subsequently of the wood product.

Figure 19 Chip marks are the result when a machine's exhaust system isn't capable of clearing debris from the cutterhead. This will require additional sanding and increase your processing costs.

Dust management can be an opportunity that will not only make for happier and healthier employees but also improve product quality both in production and finishing. If it is dealt with properly it will save money via fewer rejects, better finishes, energy savings, longer tool and machine life and reduced employee absenteeism. Dust collectors and accessories for collection and mitigation go from small and portable systems at individual machines and workstations to large installations depending on company's needs (Figure 20). A metal detector at the beginning of the process line will also preserve tool life and product quality (Figure 21). Additional information and a review of the strategies and practices top prevent and minimise wood waste is available at the end of the document (Appendix 3).

Figure 20 Having an exhaust system will not only provide a safe and healthy working environment but also simplify maintenance and increase productivity and product quality.

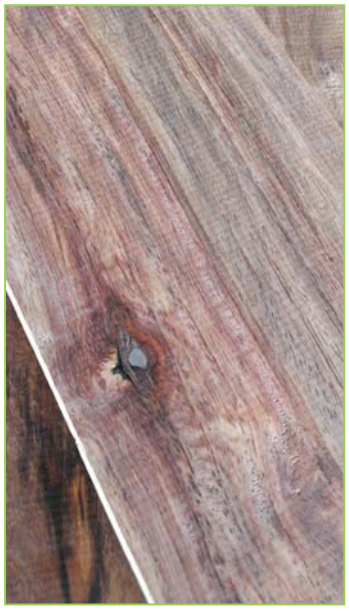


Figure 21 Installing a metal detector at the beginning of the process line will preserve tool life and product quality.

Reusing, recycling, and recovering wood wastes

The target for each company should always be to prevent or minimize the production of residues but in some situations even the best manufacturing process will create wastes. In this situation, turning wood waste into valuable wood products should be the main focus. Obviously, higher the value of the wood product obtained from residues, higher the profits will be.

Reusing, recycling and recovering usually involve sorting, separating, and/or segregating all types of wastes to avoid contamination. Waste streams should never be combined (i.e., mixing sawdust, wood chips, end pieces, etc.) as it may inhibit secondary use. Storage conditions of wastes are also extremely important to avoid contamination with non-wood material (e.g. dirt, grease, sand, etc.).

As mentioned before, the reuse of waste is any operation where products or materials are used again for the same purpose for which they were intended. It often requires collection but relatively little or no processing. It involves checking, cleaning, repairing, and/or refurbishing, entire items or spare parts. Recycling involves sorting and processing used, reused, or unused items that would otherwise be considered waste and remanufacture it into new products. Recovering material and energy generally require a collection system and a method of material processing and conversion into a new product.

Reusing wood wastes

The following list involves options where little of no processing is required. Most of those products are already available on the market and would require little or no research and development (R&D) prior commercialisation. The technology or market is seen as mature and only involve capital investment in most cases.

- ✓ Mulch (for gardening and decorative purposes)

- ✓ Bio-filters and absorbents for organic material (e.g. animal bedding)

Recycling and recovering wood wastes

The following list involves options where sorting and processing the recyclable products into raw material and then remanufacturing the recycled raw materials into new products are required. These generally require a collection system and a method of material processing and conversion into a new product. Most products are already available on the market and would require little or no research and development before commercialisation. The technology and markets are seen as mature and would only involve capital investment in most cases.

- ✓ Parquetry, decking, and outdoor furniture (Figures 22-23)

Figure 22 Wood off-cuts can be used for outdoor furniture and decking to create unique geometric patterns of parquet flooring.

Figure 23 Wood off-cuts can be used for outdoor furniture and decking.

- ✓ Bricks (made using sawdust, Figure 24)

Figure 24 Brick made from sawdust (www.sourceable.net).

- ✓ Small wooden objects for practical or decorative domestic purposes (e.g. toys, handle for tools)

- ✓ Finger jointing or laminating: Finger jointing is the joining of two short sticks end-to-end to form a longer one resulting in less waste and better material utilization (where laminating involves gluing pieces side by side). The pieces are joined and glued end-to-end by a finger joint. Any piece ten cm or longer can be used. There is equipment available that can machine the joints, apply the glue and press the pieces together. For circumstances where areas are not exposed in the final product, the finger jointing process can provide significant increases in material utilization, and thus less wood waste.

- ✓ Wood pellets and briquettes: Made from already kiln-dried offcuts and sawdust for renewable biomass energy to displace coal fired electricity. Asia-Pacific represents the largest and fastest growing global thermal power market (Source: FierceEnergy), EU target 15% of its energy from renewable sources by 2020 (Source: Carbonbrief), the U.S. also has the potential to become the world's second largest user of renewables after China (Source: POWER Magazine).

  Note: Burning treated or coated wood can release regulated hazardous air pollutants!

- ✓ Absorbents for heavy metals and chemicals (e.g. industrial adsorbents, Figure 25)

Figure 25 Activated carbon is an adsorbent for gaseous contaminants in many industrial applications.

The following list **involves options where sorting and processing the recyclable products into raw material and then remanufacturing the recycled raw materials into new products are required**. Most of those products are already available on the market but would require additional research and development before commercialisation. The technology and markets are seen as mature and would only involve capital investment in most cases.

- ✓ Particleboard and fibreboard (MDF/HDF)
- ✓ Wood-Cement or wood concrete panels

The next section lists potential areas for research and development and the development of high-value wood products from wood wastes. Generally, these ideas would involve significant R&D prior the development of commercially ready products since there is not much information (i.e. technology, parameters, and processes) available for Lao wood species such as teak and *Eucalyptus camaldulensis*.

- ✓ Wood foam as insulation material: The green building materials market, valued $106.32 billion in 2012, is expected to reach $234.77 billion by 2019. Insulation application-segment was estimated as the largest segment with 21% of the total market share in 2012. The rising demand for cellulose for insulations is projected to show a healthy growth in near future (Source: Environmental Management & Sustainable Development News).

- ✓ Packaging material: To potentially replace petrochemical-based material expanded polystyrene. The demand for sustainable packaging is a global market projected to hit $244 billion by 2018 (Jackson 2014).

- ✓ Wood-plastic composite
  - Plastic lumber and composite decking products (approximately 90% weight made from wood flour)
  - Moulding and trim apps

- ✓ Wood composite panels
  - Partitions
  - Ceilings
  - Flooring
  - Doors
  - Furniture
  - Acoustic or sound absorbing construction materials
  - Heat-insulating construction materials
  - Cladding

Additional information on product ideas for wood waste utilisation is available at the end of the document (Appendix 2).

Conclusion

Wood wastes are usually an indicator of inefficient use of raw materials and resources. Improving wood manufacturing efficiency by reducing the amount of waste created is a complex subject and there are very few quick solutions. Finding sustainable results takes focus and determinations. Usually the more you achieve the more opportunities open up and as you sustain those improvements.

Understanding and improving the efficiency of a manufacturing process is vital for achieving good results. The present document tried to address which practices and value-added manufacturing technologies would increase the value recovery of small dimensions, inferior quality plantation wood and facilitate early improvements from dry feed stock to marketable products. The strategies listed in the document can be applied to improve productivity and quality in wood processing and manufacturing to improve competitiveness in global markets.

The Government of Laos should also offers incentives for waste minimisation, which focus on the environmental benefits of adopting waste minimisation strategies. Government and fire regulations could also help addressing the issue of wood dust with regulation policies.

Appendix 1 - Example of waste reduction program

- Establish the program
  - ✓ Executive level description
  - ✓ Policy statement
  - ✓ Consensus building
- Organise the program
  - ✓ Name task force
  - ✓ Set goals and objectives
  - ✓ Communicate plan and vision to the workforce
- Do a preliminary assessment
  - ✓ Collect data
  - ✓ Review sites
  - ✓ Establish priorities
- Write program plan
  - ✓ Consider external groups
  - ✓ Define objectives
  - ✓ Identify potential obstacles
  - ✓ Develop schedule
- Do detailed assessment
  - ✓ Name assessment team(s)
  - ✓ Review data and site(s)
  - ✓ Organise and document information
- Define options
  - ✓ Propose options
  - ✓ Screen options
- Do a feasibility analysis
  - ✓ Technical
  - ✓ Environmental
  - ✓ Economic
- Write assessment report
- Implement the plan
  - ✓ Select projects
  - ✓ Obtain funding
  - ✓ Install and/or train
- Measure progress
  - ✓ Acquire data
  - ✓ Analyse results
- Maintain program

Appendix 2 - Product Ideas for Wood Waste Utilisation

15 Product ideas for wood waste utilisation	Comment(s)	Off-cuts	Sawdust	Shavings	Wood dust
Segregate and store off-cuts to reuse them later	• Involve sorting and processing	√			
Mulch	• Require a collection system		√	√	
Acoustic or sound absorbing panels • **Partitions** • **Ceilings**	• Involve sorting and processing • Require a collection system • Require R&D			√	
Sand concrete[1] and wood-concrete composite[2,4]	• Involve sorting and processing • Require a collection system • Require R&D		√	√	√
Heat-insulating/acoustic construction material[3]	• Involve sorting and processing • Require a collection system • Require R&D			√	
Industrial and environmental adsorbent[5,6,7,10]	• Involve sorting and processing • Require a collection system • Require R&D		√	√	√
Bricks[8]	• Involve sorting and processing • Require a collection system		√		√

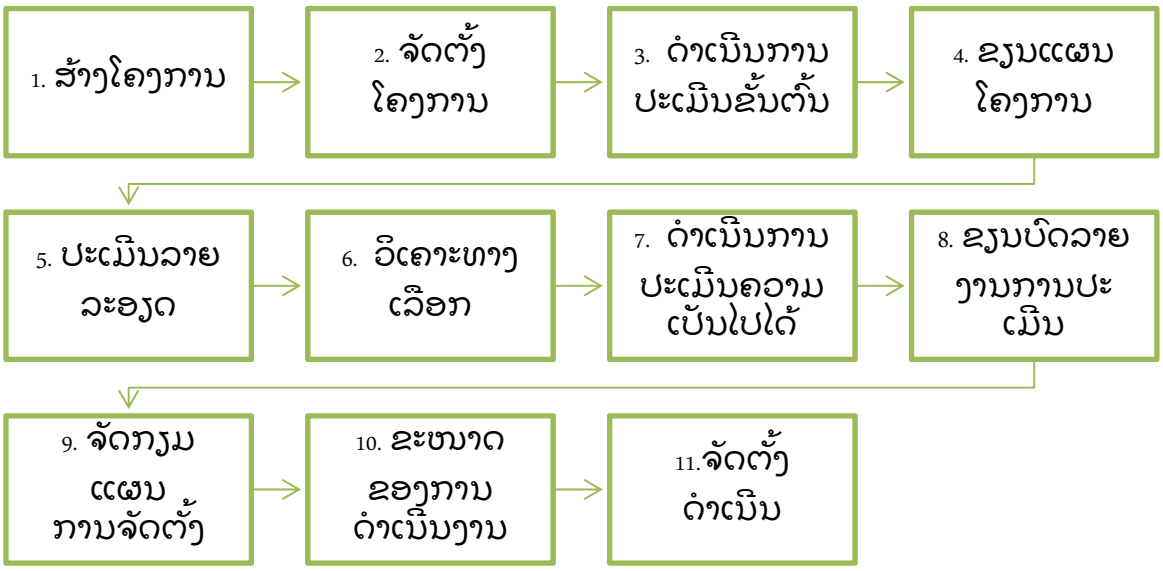
	• Require R&D				
Wood-plastic composites[9] • **Lumber and decking products**	• Involve sorting and processing • Require a collection system • Require R&D		√		√
Parquetry, decking, and outdoor furniture	• Involve sorting and processing	√			
Small wooden objects (e.g. toys, handle for tools)	• involve sorting and processing	√			
Finger jointing or laminating	• Involve sorting and processing	√			
Wood pellets and briquettes	• Involve sorting and processing • Require a collection system • Require R&D	√	√	√	√
Particleboard and fibreboard	• Involve sorting and processing • Require a collection system • Require R&D		√	√	√
Packaging material	• Involve sorting and processing • Require a collection system	√	√	√	
✓ **Wood composite panels** • **Flooring** • **Doors** • **Furniture** • **Cladding**	• Involve sorting and processing • Require a collection system • Require R&D	√	√	√	

Appendix 3 - Strategies and Practices to Prevent and Minimise Wood Waste

20 Strategies and Practices to Prevent and Minimise Wood Waste

- Develop and document your process mapping
- Assess your wood recovery
- Conduct a product design exercise for all your products
- Develop cutting patterns for each product
- Survey your latest customers about their buying experience with you
- Calculate if the grade you're buying is cost effective for you
- Review your minimum requirement and reduce your length oversize if possible
- Inspect, sort and separate lumber on reception
- Develop quality control and process monitoring programs
- Use efficient manufacturing processes to reduce rejects
- Use the right glue and right application methods
- Discuss with your tool supplier for new tooling products
- Develop methods of improving packaging to eliminate or minimize damages and claims
- Communicate with your workforce
- Show visible commitment in your waste reduction goals and support employees
- Check equipment daily for proper set-up and needed adjustments to minimize waste
- Perform regular inspections of application performance
- Perform preventive maintenance
- Post maintenance schedules and work instruction/checklists on each work place
- Install dust collectors and accessories for collection and mitigation

ແຜນວາດທີ1 - ຮູບແບບຕົວຢ່າງວິທີການນຳໃຊ້ໄມ້ເສດ



- ສ້າງໂຄງການ
  - ✓ ພັນລະນາກ່ຽວກັບຂັ້ນຕອນໃນການນຳເນີນງານ
  - ✓ ສະຖານະຂອງນະໂຍບາຍ
  - ✓ ສ້າງຄວາມຄິດເຫັນ

- ຈັດຕັ້ງໂຄງການ
  - ✓ ຊີ່ຂອງຫນ້າວຽກ
  - ✓ ຕັ້ງຈຸດປະສົງຂອງທີ່ແນ່ນອນ
  - ✓ ປຶກສາຫາລືກ່ຽວກັບແຜນການ ແລະ ທັດ ສະນະຄະຕິກ່ຽວກັບຫນ້າວຽກ

  - ✓ ດຳເນີນການປະເມີນຂັ້ນຕົ້ນ
  - ✓ ເກັບກຳຂໍ້ມູນ
  - ✓ ທົບທວນຂອບເຂດ
  - ✓ ຈັດລຽງລຳດັບ

  - ✓ ຂຽນແຜນໂຄງການ
  - ✓ ຄວນພິຈາລະນາປັດໃຈພາຍນອກ
  - ✓ ຄັດເລືອກຈຸດປະສົງ
  - ✓ ວິເຄາະປັດໃຈທີ່ເປັນໄປໄດ້
  - ✓ ປັບປຸງແຜ່ນງານ

  - ✓ ປະເມີນລາຍລະອຽດ

- ✓ ຫົວຂໍ້ທີ່ຈະປະເມີນ
- ✓ ທົບທວນ ແລະ ຂອບເຂດ
- ✓ ການຈັ່ງຕັ້ງ ແລະ ຂໍ້ມູນທີ່ກ່ຽວຂ້ອງ
- ✓ ວິເຄາະທາງເລືອກ
- ✓ ເປົ້າໝາຍຫຼັກ
- ✓ ທາງເລືອກທີ່ເປັນໄປໄດ້

- ✓ ດຳເນີນການປະເມີນຄວາມເປັນໄປໄດ້
- ✓ ເຕັກນິກ
- ✓ ສະພາບແວດລ້ອມ
- ✓ ເສດຖະກິດ

- ຂຽນບົດລາຍງານການປະເມີນ

- ✓ ຈັດກຽມແຜນການຈັດຕັ້ງ
- ✓ ການເລືອກເອົາໜ້າວຽກ
- ✓ ກຳນົດທຶນ
- ✓ ດຳເນີນ ຫຼື ປະຕິບັດກິດຈະກຳ

- ✓ ຂະໜາດຂອງການດຳເນີນງານ
- ✓ ຂໍ້ມູນທີ່ມີຢູ່
- ✓ ປະເມີນຜົນໄດ້ຮັບ

- ຈັດຕັ້ງດຳເນີນ

ແຜນວາດທີ່ 2 - ແນວຄວາມຄິດໃນການນຳໃຊ້ໄມ້ສົດແບບຍືນຍົງ

15 ສິນຄ້າສຳລັບການນຳໃຊ້ໄມ້ສົດ		ຄຳຄິດເຫັນ	ໄມ້ສົດຈາກການຕັ	ຂີ້ເລື່ອຍ	ສົດໄມ້ນ້ອຍ	ໄມ້ສົ
			ດ			ດ
ແຍກໄມ້ອອກເປັນກຸ່ມ ເກັບມ້ຽນໃຫ້ເປັນລະບຽບ	ແລະ	• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດ	√			
ສົດໄມ້ນ້ອຍ		• ການເກັບຂໍ້ມູນທີ່ຈຳເປັນ		√	√	
ແຜ່ນໄມ້ທີ່ສາມາດເກັບສຽງ • ຝາ • ເພດານ		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ຄຳແນະນຳ ແລະ ຂໍ້ມູນ			√	
ຂີ້ລາຍ ຄອນກຣິດ[1] ແລະ ໄມ້-ຄອນກຣິດ[2,4]		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ຄຳແນະນຳ ແລະ ຂໍ້ມູນ		√	√	√
ເຄື່ອງເຮັດຄວາມຮ້ອຍ/ວັດຖຸເຮັດໂຄ້ງສ້າງເຄື່ອງດົນຕີ		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ຄຳແນະນຳ ແລະ ຂໍ້ມູນ			√	
ອຸດສາຫະກຳ ແລະ ສຳພາບເງື່ອນໄຂສິ່ງແວດລ້ອມ[5,6,7,10]		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ຄຳແນະນຳ ແລະ ຂໍ້ມູນ		√	√	√
ດິນຈີ[8]		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່		√		√

		ຈຳເປັນ • ການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ຄຳແນະນຳ ແລະ ຂໍ້ມູນ				
ໄມ້-ປະລາສະຕິກ[9] • ຜະລິດຕະພັນຢາງພາລາ ແລະ ວັງປະຕູ		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ຄຳແນະນຳ ແລະ ຂໍ້ມູນ		√		√
ປະເກ້, ວັງປະຕູ ແລະ ເຟີນິເຈີພາຍນອກ		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ	√			
ໄມ້ເສດນ້ອຍ(ຕົວຢ່າງ ເຄື່ອງຫຼິ້ນ, ອຸປະກອນໃຊ້ສອຍຕ່າງໆ)		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ	√			
ການຕໍ່ໄມ້ ຫຼື ເຮັດໄມ້ບາງ		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ	√			
ຖ່ານໄມ້ ແລະ ໄມ້ກ້ອນ		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ການເກັບຂໍ້ມູນທີ່ຈຳເປັນ ຄຳແນະນຳ ແລະ ຂໍ້ມູນ	√	√	√	√
ປະຕິເກົ່ານອດ ແລະ ໄຟເບີນອດ		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ຄຳແນະນຳ ແລະ ຂໍ້ມູນ		√	√	√
ການຫຸ້ມຫໍ່ອັດຖຸດິບ		• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ການເກັບຂໍ້ມູນທີ່ຈຳເປັນ	√	√	√	

	• ຄຳແນະນຳ ແລະ ຂໍ້ມູນ			
✓ ໄມ້ທີ່ຜະລິດ • ປະເກ້ປູພື້ນ • ປະຕູ້ • ເຟີນິ້ເຈີ • ກ້ອງໃສອັດສະດຸ	• ແຍກເປັນກຸ່ມ ແລະ ຂັ້ນຕອນການຜະລິດການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ການເກັບຂໍ້ມູນທີ່ຈຳເປັນ • ຄຳແນະນຳ ແລະ ຂໍ້ມູນ	√	√	√

ແຜນວາດທີ 3 - ນະໂຍບາຍ ແລະ ກິດຈະກຳເພື່ອຫຼຸດຜ່ອນໄມ້ເສດ ແລະ ການປ້ອງກັນ

20 ນະໂຍບາຍ ແລະ ກິດຈະກຳເພື່ອຫຼຸດຜ່ອນໄມ້ເສດ ແລະ ການປ້ອງກັນ

- ປັບປຸງແຜ່ນການຜະລິດ ແລະ ອັບເດດຂໍ້ມູນຂ່າວສານ
- ປະເມີນການນຳໃຊ້ໄມ້
- ຮອບຮ່ອມກິດຈະກຳການຜະລິດທຸກໆສິນຄ້າ
- ປັບປຸງການຕັດຂະໜາດຂອງແຕ່ລະຜະລິດຕະພັນ
- ສຳຫຼວດຄວາມຄິດເຫັນຂອງລູກຄ້າກ່ຽວກັບຜະລິດຕະພັນ
- ຄຳນວນລາຄາກັບຜະລິດຕະພັນ
- ກວດສອບຄືນຂະໜາດ ແລະ ຫຼຸດຄວາມຍາດຂອງໄມ້ທີ່ຈະຜະລິດວ່າຖ້າເປັນໄປໄດ້
- ກວດສອບ, ແຍກ ແລະ ຈັດມ້ຽນໄມ້ແປຮູບໃຫ້ເປັນລະບຽບ
- ປັບປຸງການຄວບຄຸ້ມຄຸນນະພາບ ແລະ ສຳຫຼວດຂັ້ນຕອນການຜະລິດ
- ນຳໃຊ້ເຄື່ອງມືທີ່ທັນສະໄໝເພື່ອຫຼຸດຜ່ອນໄມ້ເສດ
- ນຳໃຊ້ກາວ ແລະ ການຕິດກາວໃຫ້ຖືກຕ້ອງ
- ປຶກສາຫາຫຼືກັບຄົນນຳໃຊ້ອຸປະກອນເພື່ອການນຳໃຊ້ເຄື່ອງມືໃໝ່
- ປັບປຸງວິທີ ໃນການທີ່ເຮັດໃຫ້ເກີດມີໄມ້ເສດ
- ຝຶກອົບຮົມໃຫ້ກັບກຳມະກອນ
- ສະແດງໃຫ້ກຳມະກອນ ເຫັນນວ່າໄມ້ເສຫດມີຄວາມສຳຄັນ ແລະ ວ່າງເປົ່າໝາຍວ່າການຫຼຸດຜ່ອນໄມ້ເສດເປັນສິ່ງສຳຄັນ
- ກວດສອບເຄື່ອງຈັກເປັນປະຈຳ ແລະ ຕິດຕັ້ງໃຫ້ຖືກວິທີ
- ສ້າງກົດລະບຽບໃນການນຳໃຊ້ເຄື່ອງຈັກ ແລະ ການເຮັດວຽກ
- ຕິດຕັ້ງຄຳແນະນຳໃນການຮັກສາເຄື່ອງຈັກ
- ຕິດຕັ້ງຕາຕະລາງການນຳໃຊ້ເຄື່ອງຈັກ ແລະ ການເຮັດວຽກຂອງເຄື່ອງຈັກໃນແຕ່ລະສາຍງານ
- ຕິດຕັ້ງເຄື່ອງດູດຝຸ່ນເພື່ອເກັບມ້ຽນຂີ້ຝຸ່ນ

References

1. Bederina et al. (2007) Effect of the addition of wood shavings on thermal conductivity of sand concretes: Experimental study and modelling. Construction and Building Materials. 21: 662-668.
2. Taoukil et al. (2013) Moisture content influence on the thermal conductivity and diffusivity of wood–concrete composite. Construction and Building Materials. 48: 104-115.
3. Fukuta et al. (2010) Development of Low-Density Wooden Molding Mat Using Bicomponent Fibers. Forest Prod. J. 60(7/8): 575–581.
4. Eboziegbe and Mizi (2013) Development of Wood-Crete building materials from sawdust and waste paper. Construction and Building Materials. 40: 361-366.
5. Dulman and Cucu-Man (2009) Sorption of some textile dyes by beech wood sawdust. Journal of Hazardous Materials. 162: 1457-1464.
6. Memon et al. (2008) Sawdust: A green and economical sorbent for thallium removal. Chemical Engineering Journal. 140: 235-240.
7. Sciban and Klasnja (2004) Wood sawdust and wood originate materials as adsorbents for heavy metal ions. Holz Roh Werkst. 62: 69-73.
8. Raut et al. (2011) Development of sustainable construction material using industrial and agricultural solid waste: A review of waste-create bricks. Construction and Building Materials. 25: 4037-4042.
9. Piao et al. (2014) Dimensional stability of wood–plastic composites reinforced with potassium methyl siliconate modified fiber and sawdust made from beetle-killed trees. Eur. J. Wood Prod. 72: 165-176.
10. Gupta and Suhas (2009) Application of low-cost adsorbents for dye removal – A review. Journal of Environmental Management. 90: 2313-2342.
11. Eshun et al. (2012) Wood waste minimization in the timber sector of Ghana: a systems approach to reduce environmental impact. Journal of Cleaner Production. 26: 67-78.
12. Gmeiner S (2015a) Operational excellence starts with a plan. Website accessed on January 2015. http://www.woodworkingcanada.com
13. Gmeiner (2015b) Stop doing the same thing, embrace change. Website accessed on January 2015. http://www.woodworkingcanada.com
14. Gmeiner (2015c) The importance of process mapping. Website accessed on January 2015. http://www.woodworkingcanada.com
15. Gmeiner (2015d) Defining the right metrics for your company. Website accessed on January 2015. http://www.woodworkingcanada.com
16. US Environmental Protection Agency (2015) Wood Furniture Industry - Waste Reduction Opportunities. 144 p.

Valtip 2 reports (available on request for Valtip 2 members)

1. Belleville B (2014a) Improving value and quality of wood products for domestic and export markets - Detailed analysis of wood recovery rate in production of high value wood products. ACIAR International Cooperative Project FST/2010/012 Enhancing key elements of the value chains for plantation-grown wood in Lao PDR. Australia. 18 p.
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4. Ozarska B and Belleville B (2015) User-friendly manual on quality control methods used in wood processing and manufacturing applicable to SMEs in Laos. ACIAR International Cooperative Project FST/2010/012 Enhancing key elements of the value chains for plantation-grown wood in Lao PDR. Australia.