GUIDEBOOK

Wood Pellet Heating

A Reference on Wood Pellet Fuels & Technology for Small Commercial & Institutional Systems

Massachusetts Division of Energy Resources

Prepared for the

Massachusetts Division of Energy Resources

By

Biomass Energy Resource Center

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How to Use this Book

This guidebook is intended to be a reference for potential owners of institutional- or commercial-scale wood pellet heating systems. Although developed for the Commonwealth of Massachusetts, much of the information is applicable to similar-scale facilities in other regions.

This guidebook will be useful to the following groups:

- Municipal, state, or federal building owners
- School boards or other school executives
- Business owners
- Developers and owners of newly constructed space
- Any others interested in applying wood pellet heating technology to commercial- or institutional-scale facilities

The guide is both a general and a technical resource. Introductory information is provided under each subject heading and new terms are defined in a glossary on page 22 that can be linked to by clicking on the term. A "back" arrow following each term in the glossary will return the reader to where the link originated.

The How To sections were designed to help building owners with the more technical decision necessary for installing a wood pellet heating system. Technical experts such as engineers or system vendors can assist building owners with the processes outlined in these sections of the guidebook.

Contents

Wood pellets are a common type of biomass. Biomass is any biological material that can be used as fuel—including grass, corn, wood, and biogas as well as other forestry and agricultural residues.

Wood Pellets

A Good Choice for Heating

Many building owners use fossil heating fuels, such as oil or propane, for space heating. These fuels are often expensive and unstable in pricing, and are threatening the global climate and sustainability of communities. Proven alternatives to fossil heating fuels exist and are already in use across North America: Biomass fuels are a local, renewable resource for providing reliable heat.

Wood pellets are a common type of biomass. Biomass is any biological material that can be used as fuel—including grass, corn, wood, and biogas as well as other forestry and agricultural residues.

WOOD PELLETS

One biomass fuel that has gained national attention with rising fossil fuel prices is wood pellets. Wood pellets are compressed by-products from the forest products industry, often woodchips and sawdust. They are a locally available and a cost-effective heating fuel with several advantages over other types of biomass.

Wood pellets are a condensed uniformly sized form of biomass energy, making them easier to store and use than many other biomass fuels. Pellet heating technology is also quite simple, minimizing operation and maintenance requirements. These heating systems can be easy to plan for and install and can save a building owner thousands of dollars in energy costs over time while providing significant local economic and environmental benefits.

ADVANTAGES TO HEATING WITH BIOMASS

Using biomass fuels helps mitigate such environmental issues as acid rain and global climate change. Perhaps the greatest advantage of biomass fuels, however, is that they cost on average 25-50 percent less than fossil heating fuels and are more stable in pricing. It is unlikely that any future carbon or energy taxes will increase the cost of biomass fuels and are more likely to raise the cost of heating with fossil fuels. The technology is becoming well established in the North American market and the choice to heat with biomass fuels can be as simple as choosing a traditional fossil fuel heating system.

In addition, wood pellets:

- are convenient and easy to use, and can be bulk stored in less space than other biomass fuels
- have a high energy content, and the technology is highly efficient compared to other biomass fuels
- are a clean-burning renewable fuel source
- are produced from such waste materials as forestry residues and sawdust
- are price stable compared to fossil fuels

Who Should Consider Wood Pellet Heating?

There are currently about 800,000 homes in the United States using wood pellet stoves or furnaces for heating, according to the Pellet Fuels Institute. Wood pellets are manufactured in the US and Canada, and are available for residential use in 40-pound bags from feed stores, nurseries, and other supply outlets.

Increasingly, heating with wood pellets is becoming common on larger scales—in municipal or federal buildings, educational facilities, housing complexes, office buildings, and other businesses. While the majority of installations of this size are in Europe, a growing number are in North America, including New England. The greater heating requirements of these larger buildings differ from those of residential settings, thus requiring different technology (boilers rather than stoves) and fuel supply infrastructure (bulk wood pellet supply rather than bags).

There are several demonstrations in New England of wood pellet boilers replacing fossil fuel heating systems, reducing reliance on fossil fuels, and saving building owners money.

CANDIDATES FOR WOOD PELLET HEATING

The best candidates for wood pellet boilers are buildings between 10,000 and 50,000 square feet (SF) that use heating oil, propane, or electricity to produce space heat and/or hot water. Natural gas is generally a less expensive fossil fuel for space heat, and wood pellet prices are not always competitive. When natural gas prices are significantly higher than the national average price, wood pellets may be the better alternative. Wood pellet heating systems are also a viable option for new construction.

Other important site characteristics to consider include the layout of the building. It should have—or the owner should plan to convert to—a centralized hot water heat-distribution system. There should be adequate space for the wood pellet boiler and storage silo as well as adequate access to the silo for fuel truck deliveries. The distance between the building and the wood pellet distribution center ideally should be no more than 50 miles since the actual cost paid per ton for bulk wood pellets will include a delivery charge that may make wood pellets less cost effective as the delivery distance—and delivery charge—increases.

WOOD PELLET BOILER TECHNOLOGY

Wood pellet boiler technology is becoming well established in the North American market. There are several vendors with proven track records of reliability and performance (vendors and contact information can be found on page 24) and several demonstrations in New England of wood pellet boilers replacing fossil fuel heating systems, reducing reliance on fossil fuels, and saving building owners money.

Two Case Studies

Harris Center

Hancock, New Hampshire

Heated Space: 10,000 SF
Pellet Storage: nine-ton silo
Annual Wood Pellet Use: 10-15 tons
Average Staff Time: 75 minutes per week (during the heating season)
Estimated Fuel Cost Savings: 45 percent

The Harris Center for Conservation Education is an environmental education organization that provides conservation and environmental education programs for all ages. It also serves as a local land trust.

Started as a project focused on promoting environmental health, installing the wood pellet boiler has generated substantial fuel-cost savings. The facility is an excellent example of how a business approach to sustainability can also make good financial sense.

NRG Systems

Hinesburg, Vermont

Heated Space: 46,000 SF on three floors
Pellet Storage: 30-ton silo (one year's worth)
Average Staff Time: 15 minutes per day
Heating Fuel Offset: 4,735 gallons propane (06-07 heating season)

NRG Systems manufactures wind measurement systems for the wind power industry. The building is a model workplace that embodies the company's values by demonstrating the benefits of the latest renewable technologies. While the building's heat load is not typical of most of this size (it is heated with two large residential-sized 140,000 Btu per hour wood pellet boilers), this application of wood pellet heating technology demonstrates a successful model of using a locally available, renewable, and cost-effective resource to provide reliable heat in an office/manufacturing setting.

Wood Pellet Fuel

Characteristics

Wood pellets are a manufactured biomass fuel. They are made from wood waste materials that are condensed into pellets under heat and pressure. Natural plant lignin holds the pellets together without glues or additives. Wood pellets are of uniform size and shape (between 1-1½ inches by approximately 1/4-5/16 inches in diameter), making them as easy to store and use as traditional fossil heating fuels. Wood pellets also take up much less space in storage than other biomass fuels because they have a higher energy content by weight (roughly 7,750 Btu per pound at six percent moisture content) due to their densified nature and low-moisture content (typically between 4-6 percent moisture by weight).

While wood pellets are typically not differentiated between soft and hardwood sources, there are three grades based on the amount of ash produced when they are burned:

- Premium (ash content less than one percent)
- Standard (ash content between one-two percent)
- Industrial (ash content three percent or greater)

Premium and standard grade pellets are suitable for any wood pellet boiler with automatic ash removal, including most institutional- or commercial-scale applications. Industrial grade pellets, or those with ash content greater than three percent, should be avoided due to the high volume of ash produced.

Availability

For the residential market, wood pellets are sold in 40-pound bags at farm or building supply stores. Small commercial- or institutional-scale applications of the type being discussed here, however, require bulk delivery and storage. Several wood pellet manufacturers (see list on page 24) can deliver in bulk. The customer is charged per ton delivered, the price typically including a per-load fee scaled to the distance of the delivery.

Pricing

When exploring the conversion from fossil fuels to wood pellet heat, an important consideration for building owners is the fuel-cost savings from using wood pellets. Because fossil fuels and wood pellets are sold in different units, a price comparison must be based on the amount of energy—in millions of British thermal units (MMBtu)—delivered by each fuel. The basis for comparison then becomes the cost of producing one MMBtu with each fuel being considered.

Several other factors affecting the true cost of heating with any fuel include the energy and moisture content and the efficiency of the heating system used to burn each fuel. Figure 1 shows the various equivalencies of each fuel after accounting for these factors.

FIGURE 1.

FUEL EQUIVALENCIES

For heating, one ton of wood pellets equals…

- **120 gallons of heating oil**
- **170 gallons of propane**
- **16,000 ft^3 of natural gas**
- **4,775 kilowatt hours (kWh) electricity**

Paying $200/ton for pellets is the same as paying…

- **$1.67 per gallon for heating oil**
- **$1.18 per gallon for propane**
- **$12.50 per (1,000 ft^3) for natural gas**
- **$0.04 per kWh for electricity**

The comparisons above show, for example, that the heat provided by one ton of wood pellets is equal to the heat provided by 120 gallons of heating oil, and paying $200 per ton for wood pellets is the same as paying $1.67 per gallon of heating oil.

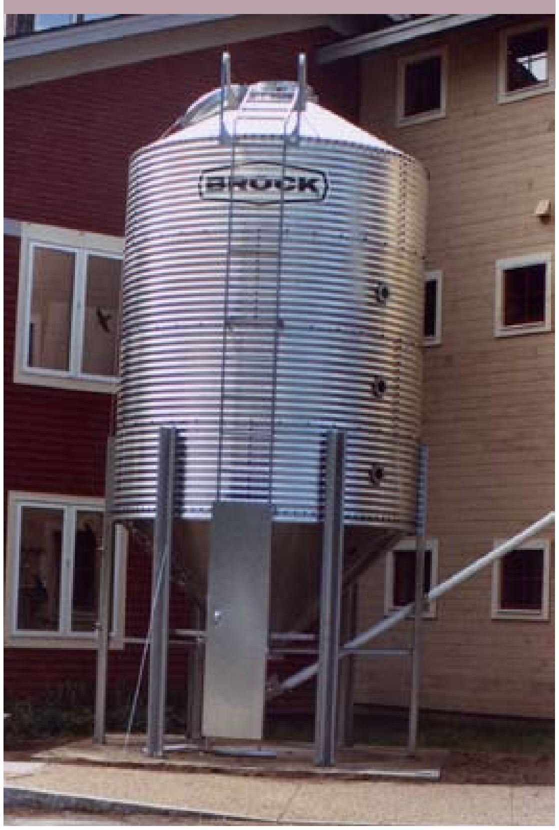
The savings in fuel costs using wood pellets can be figured out by comparing the actual price of the current heating fuel to the price equivalent given in the table. A building owner paying $2.30 per gallon of heating oil would save $.63 per gallon displaced (the difference between $2.30 and $1.67), or 27 percent, representing a yearly savings of $2,700 on a $10,000 annual fuel bill.

In general, space heating with wood pellets is less expensive than with fossil fuels. Natural gas is the only heating fuel that is not always more expensive (on a MMBtu basis) than wood pellets. That is why buildings that currently heat with natural gas are not always good candidates for converting to wood pellet heating.

HOW TO

SIZE A WOOD PELLET STORAGE SILO

A good rule for sizing a fuel storage silo is to choose one that is somewhat larger (maybe 1.5 times) than the capacity of the fuel delivery truck used by your supplier. Since there always will be some pellets remaining in the silo at the time of next delivery, this sizing will maximize delivery efficiency, particularly since delivery charges for wood pellets are often per load rather than being based on the actual quantity. If the supplier uses a 10-ton delivery truck, the silo should be 15 tons or more. Silos should be sized in increments of 10, 15, 25, or 35 tons. For small commercial- or institutional-scale boiler systems, the silo should have a storage capacity of at least 15 tons.



Securing a Fuel Supplier

When selecting a pellet manufacturer (also referred to as "supplier") capable of making bulk deliveries to your area, there are other points to consider in addition to price:

- **Delivery Distance.** Wood pellets are most cost effective when the distance by road between the manufacturer/distributor and the customer is fewer than 50 miles.
- **The Bulk Market.** It is best to go with a supplier that is committed to the development of the bulk market and will favor meeting orders for bulk deliveries over producing bags for residential sale.
- **Guaranteed Supply.** Look for a supplier that guarantees an available and reliable supply.
- **Source Material.** Look for wood pellets that were produced from green woodchips or sawdust and avoid wood pellets that were made from construction and demolition (C&D) waste. The ash produced from burning pellets made from C&D wood waste may not pass Commonwealth of Massachusetts rules on hazardous waste materials. The ash from green woodchips and sawdust, however, is likely to comply with the Commonwealth's solid waste management rules. You can obtain a written statement of the source of wood being used from your pellet manufacturer.

It is important to keep in mind that while the technology is gaining ground in North America, centralized wood pellet heating at the institutional and commercial scales is still a developing market.

Calculating Potential Fuel Cost Savings

STEP 1

To calculate your potential fuel cost savings, you first need to determine the amount of heating fuel you use per year and multiply that by your average price per gallon. This gives your total heating fuel bill for the year, to which you will compare your estimated fuel bill if you were using wood pellets.

For example, if you typically use 1,120 gallons of propane in a year for space heating (excluding any heating fuel that is used for water heaters or cooking) and your average price over the past year for propane was $1.75 per gallon, your total average annual fuel bill would be $1,960.

________________ x $ _______________ = $ _________________

Total Units Price/Unit Total Annual Fuel Bill

STEP 2

The next step is to estimate how many tons of wood pellets your building requires in a year, using the equivalency factors given in Figure 1. In the case of propane, one ton of wood pellets is equal to 170 gallons of propane. Almost 7 tons (6.6 tons) of wood pellets will be needed to heat for one year (1,120 gallons of propane divided by the equivalent 170 gallons of propane per ton of wood pellets).

If the current price of wood pellets is $200 per ton, your estimated fuel bill using wood pellets would be $1,320 (6.6 tons of wood pellets multiplied by $200 per ton).

_________ ÷ _________ = ________ x $ _________ = $ ________

Total Units Units/Ton Tons/Year Price/Ton Total Bill

STEP 3

The dollar savings from switching to wood pellets this year can be calculated by subtracting an estimated fuel bill using wood pellets from your current annual fuel bill. As you project these savings into the future, those prices would change and the gap would increase, since fossil fuel prices will escalate faster than woody biomass fuels.

An important question for potential owners of wood pellet boilers is the extent to which fuel cost savings justify the cost of the project (see Economic Analysis section on p. 16).

Components of a Wood Pellet Heating System

The Technology

Wood pellet boilers are relatively simple systems that are easily installed and operated. The wood pellets are typically stored in a standard outdoor silo. Pellets are delivered in trucks similar to those that deliver grain. Wood pellet fuel is automatically fed to the boiler via auger systems similar to those used for conveying feed and grain on farms. The pellets are discharged from the silo and conveyed to the boiler using automatically controlled augers set to provide the right amount of fuel based on the building's demand for heat.

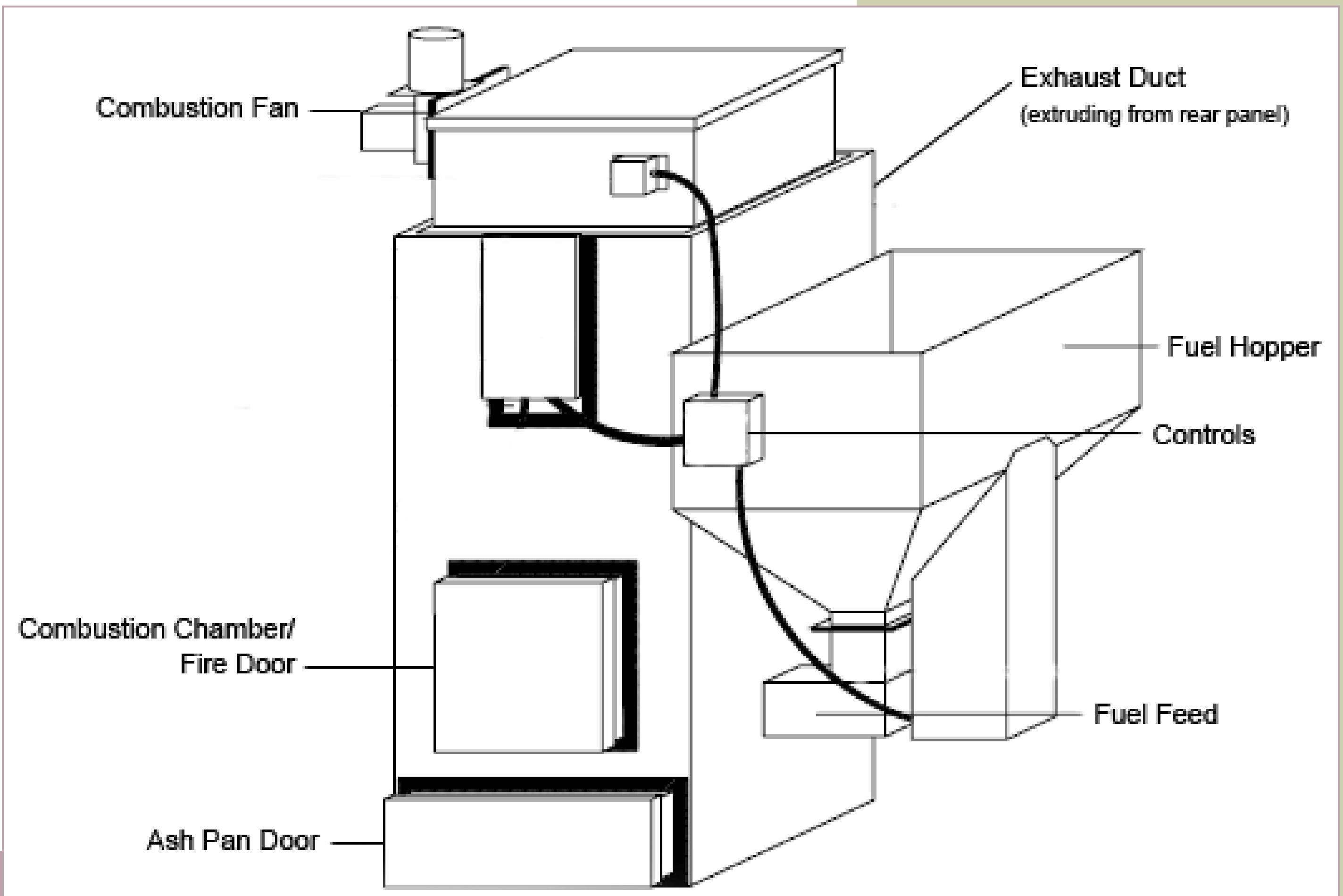
FIGURE 2.

DIAGRAM OF A WOOD PELLET BOILER

A typical system includes a fuel storage silo with an auger system that delivers the wood pellets from the silo to the fuel hopper.

The wood pellets are fed from the fuel hopper through the fuel feed system into the combustion chamber at a rate determined by the control settings. The combustion fan supplies air to the combustion chamber and the exhaust is ducted to the chimney through a port at the rear of the system.

Ash must periodically be removed through the ash pan door.



Explanation of Components

The boiler is usually delivered completely assembled; however, some pieces, like the fuel hopper, may be removed to facilitate the installation of the boiler.

COMBUSTION CHAMBER/FIRE DOOR

The combustion chamber is where the pellets are burned to produce heat. It is accessible for cleaning or maintenance through the fire door.

COMBUSTION FAN

The combustion fan provides air to the fire in the combustion chamber.

PRIMARY CONTROLS

The control unit allows the user to control the flow of wood pellets and combustion air into the boiler based on temperature settings. The unit also gives readings on boiler and exhaust temperatures.

FUEL STORAGE SILO

Wood pellet fuel for the institutional- or commercial-scale market is typically delivered in bulk, where it is stored in the same type of standard outdoor silo used to hold grain or animal feed, or in silos specifically made for fuel pellets.

FUEL HOPPER & FEED SYSTEM

Wood pellets are delivered by automatic conveyors from the storage silo into the fuel hopper. From the fuel hopper, the pellets are delivered into the boiler through the fuel-feed system at a rate determined by the control settings.

EXHAUST DUCT

The combustion exhaust gases are ducted through a port at the rear of the system, which connects to either a new or existing chimney.

Equipment Checklist

When a wood pellet boiler is purchased, the vendor will typically supply not only the pellet boiler, but also the fuel handling equipment, chimney connection and automated controls, and may also supply the fuel storage silo.

The components for a pellet boiler system are:

- Storage Silo
- Fuel Conveyor/Auger System
- Fuel Hopper and Feed System
- Combustion System (Boiler)
- Electronic Controls
- Connection to Existing Chimney
- High Temperature Chimney (if there is not an existing chimney to connect to)
- Plumbing Connections (to the building's hot water heat distribution system)

Optional components:

- Ash Removal System
- Automatic Soot-Cleaning System

Wood pellet boilers are relatively simple systems that are easily installed and operated.

HOW TO

SIZE A BOILER

The wood pellet boiler should be sized to meet the peak heating demands of the building. The boiler should be capable of providing enough heat to keep the building warm during the coldest hour of the year. The peak heating demand depends upon both the efficiency of the building and the climate in which it is located .

A wood pellet system vendor or a mechanical engineer can recommend a system with the right capacity for your building's heating needs. Information useful to have on hand prior to contacting these professionals includes:

- An energy loss analysis for your building to determine its ability to retain heat and quantify its peak heating requirement, if available
- Several years of heating bills showing monthly fuel consumption
- Total fuel consumption in a typical year, with monthly fuel consumption during peak winter months
- Data on your area's climate, such as the number of heating degree days

A mechanical engineer, system vendor, or other design contractor will be able to help you with collecting and analyzing this information and assist you by recommending an appropriate boiler size for your facility's heating needs. Typical engineering and design fees can range from 10-15 percent of the total project cost, although system vendors may not charge directly for this service.

Operation & Maintenance Requirements

Wood pellet boilers are relatively simple biomass heating systems. Because wood pellets are generally uniform in size, shape, moisture and energy content, fuel handling is very straightforward. Nevertheless, there are some ongoing maintenance requirements for these systems.

A wood pellet boiler will take more time to maintain and operate than a traditional gas, oil, or electric heating system. At the institutional or commercial scale, however, many of the maintenance activities can be cost-effectively automated by installing off-the-shelf equipment such as soot blowers or automatic ash removal systems. Some of the typical maintenance activities required for wood pellet systems are:

WEEKLY

- Emptying ash collection containers
- Monitoring control devices to check combustion temperature, stack temperature, fuel consumption, and boiler operation
- Checking boiler settings and alarms, such as those that alert to a problem with soot buildup

YEARLY

- Greasing augers, gear boxes, and other moving parts
- Checking for wear on conveyors, augers, motors, or gear boxes

When considered on a daily basis, the total time required for maintaining the wood pellet boiler system equates to roughly 15-30 minutes per day over the entire heating season.

FREQUENTLY ASKED QUESTIONS

WHAT IS THE DIFFERENCE BETWEEN A WOOD PELLET STOVE AND A WOOD PELLET BOILER?

A wood pellet stove is sized for residential settings. The heating needs of an average-sized home are typically much lower than those of commercial or institutional settings like small schools, municipal buildings, or small businesses. A wood pellet boiler, on the other hand, is sized for these larger commercial heating loads. There are also other differences between pellet stoves and boilers in the degree of automation and fuel storage and handling, based on the different needs of residential and commercial users.

WHAT ARE THE BEST USES FOR A WOOD PELLET BOILER?

While a wood pellet stove is sized and sold for homes (or anywhere a space heater can be used for a small heat load), wood pellet boilers are more appropriate for small commercial- or institutional-sized applications. Examples of successful projects (lists can be provided by system vendors) include greenhouses or other agricultural settings, smaller educational facilities, conference centers, businesses or office buildings, housing complexes, and state- or town-owned buildings. In general, those facilities between 10,000 and 50,000 SF, that have boilers with heat output ratings between .25 and 1.5 MMBtu per hour, and heat with fuel oil, propane, or electricity, are good candidates for heating with wood pellets.

DO WOOD PELLET BOILERS REQUIRE MORE OPERATOR ATTENTION AND DAILY MAINTENANCE?

On average, wood pellet boilers require 15-30 minutes per day of operator attention. The typical general maintenance tasks include emptying the ash bin about once per week and checking the boiler settings. In addition, all of the moving parts and motors need to be greased on an annual basis and checked for wear.

ARE WOOD PELLET BOILERS NOISY OR MESSY AND DO THEY SMELL LIKE BURNING WOOD?

Wood pellet boilers run as quietly as any other furnace or boiler would. Wood debris, dust, and allergens are minimal. Due to the highly efficient combustion, and the well-dispersed exhaust through the chimney, the smell of burning wood is usually undetectable.

HOW ARE WOOD PELLETS MADE?

Wood pellets are made from densified wood waste material, typically from logging, sawmill, or packaging residues. Wet sawdust is pressed into pellets under high heat and pressure. There are no additives in wood pellets, therefore they burn cleanly.

HOW ARE WOOD PELLETS DELIVERED?

Bulk wood pellets are brought to the site in a truck that delivers directly into the storage silo using either compressed air or a pneumatic conveyance system.

HOW MUCH WOOD PELLETS WILL I NEED AND WHERE WILL I STORE THEM?

The amount of wood pellets required—measured in tons—can be estimated based on the amount of fuel currently being used to heat your building. Commercial wood pellet suppliers and other experts can assist with these calculations. The amount of storage space required will be dependent on the amount of wood pellets needed. Typically, wood pellets are stored in a silo (similar to those housing grain) or other type of bin. The storage tank must provide good access for the fuel delivery truck. Wood pellets can be conveniently stored for up to one year. Wood pellet boiler vendors or other experts can assist with determining an appropriate size for your pellet storage (see How To Size a Boilern on previous page).

CAN I CONNECT MULTIPLE BUILDINGS TO ONE WOOD PELLET BOILER?

A small district energy system, connecting several buildings in close proximity to one heating plant, can be a good project. The buried pipe system connecting the buildings to the pellet boiler can be costly to install, however, a larger heating demand can mean a larger potential for savings on heating fuel costs. It is imperative that the boiler be sized to meet the combined heating needs of all the buildings connected to the system.

Environmental Considerations for Institutional- or Commercial-Scale Wood Pellet Boilers

Air Emissions

There have not been any independent emissions tests performed in North America on institutional- or commercial-scale wood pellet boilers, although efforts are underway. While the actual data is not available for wood pellet boiler technology (with the exception of a partial dataset from a Danish system vendor), test results are available for other modern institutional- or commercial-scale wood-burning technologies, particularly school-sized woodchip boilers.

It is well known that the emissions from wood-burning boilers are different than emissions from such traditional heating fuels as heating oil, propane, or natural gas. All heating fuels—including wood—produce particulate matter (PM), carbon monoxide (CO), nitrogen oxides (NO_x), and sulfur dioxide (SO_2) in varying amounts. Burning wood in a modern and well-maintained woodchip boiler, for example, produces more particulate matter than burning any of the fossil fuels, but less SO_2 than oil or propane. As shown in Figure 3, full test data is not available for pellet boilers.

FIGURE 3.

EMISSION RATES FROM WOOD & FOSSIL FUELS[1] (lbs/MMBtu)

	PM10	CO	NO_x	SO_2
Wood Pellet Boiler (Test Report)[2]	n/a	0.51	0.272	n/a
Woodchip Boiler[3]	0.1	0.73	0.165	0.0082
Oil Boiler	0.014	0.035	0.143	0.5
Propane Boiler	0.004	0.021	0.154	0.016
Natural Gas Boiler	0.007	0.08	0.09	0.0005

[1] Without emission control equipment with the exception of PM10. Emissions given on a heat input basis.

[2] Emissions rates, given in pounds of pollutant per MMBtu (million British thermal units), were provided by the Danish Technological Institute and performed on a Danak pellet boiler. PM10 and SO_2 were not tested.

[3] Emissions rates, given in pounds of pollutant per MMBtu, were provided by Resource Systems Group in a report titled, Air Pollution Control Technologies for Small Wood-fired Boilers (2001). These emissions rates characterize wood fuel in general, with a specific focus on woodchips. The emissions from wood pellets may differ from the emissions rates given here.

It is hoped that future emissions testing of wood pellet boiler technology will rely on independent third-party testing (following USEPA-approved testing methodology) rather than emissions testing conducted by wood pellet boiler vendors or other stakeholders in the wood pellet heating industry.

PERMITTING FOR PELLET BOILERS IN MASSACHUSETTS

The Commonwealth of Massachusetts has set regulations on the emissions of the air pollutants discussed on the previous page. Any equipment, such as a boiler, that is a potential source of these emissions needs to have state approval for operation. A boiler that is larger than 3 MMBtu/hour (heat input rating) will be required to obtain an operating permit, issued by the Commonwealth. Wood pellet boiler applications within the size range being considered here (less than 3 MMBtu/hour), however, are not large enough to require an operating permit.

Massachusetts Department of Environmental Protection (DEP) (see contact information on page 26) may require plan approval for the installation of boilers within the size range being considered here. Any building owner who is considering a conversion to wood pellet boiler heating should contact the DEP to determine if plan approval is necesary and, if so, begin the process. Plan approval should be sought prior to purchasing or installing a wood pellet boiler and may require the inclusion of emissions control technology in the system plan.

WOOD PELLETS & GLOBAL CLIMATE CHANGE

Carbon dioxide (CO_2) is an air pollutant currently not regulated by Massachusetts or the federal government despite it being a major contributor to global climate change. Because replacing fossil fuels with biomass for space heating results in a significant net reduction in CO_2 emissions, it is a meaningful way to begin reducing environmental impacts.

Wood fuels are often referred to as "carbon neutral." This refers to the natural carbon cycle where CO_2 emitted when wood is burned continues to be a part of the overall flux of carbon, while burning fossil fuels releases *new* carbon to the atmosphere that had been locked away underground. Trees capture and store (sequester) carbon. Although the carbon is released when the wood is burned, if harvested and burned at the rate it grows in the forest, no net carbon is released. Thus, burning fossil fuels for space heating increases the net amount of carbon in the atmosphere, while burning wood does not.

Ash from Wood Pellet Boilers

One by-product of burning wood pellets is ash, a non-combustible residue. While the ash produced by burning wood pellets is automatically removed from the boiler in the systems of many manufacturers, the container in which the ash is collected must periodically be emptied and disposed of manually.

Massachusetts requires a "beneficial use determination" from the DEP Bureau of Waste Prevention-Business Compliance Division before approving any use of the ash from pellet boilers. While many wood boiler operators use their ash as fertilizer for lawns or athletic fields, there are other useful ways to handle wood ash material, such as composting and amending soil. The ash is not known to adversely affect humans or plant and animal life when dispersed in this way, although, it may over time lead to increased nutrient runoff into streams, rivers, wetlands and other water bodies. A local water-quality regulator with the Massachusetts DEP (see contact information on page 26) can help determine if any potential effects on local water resources may be significant.

This ash can also be disposed of at any state landfill or other permitted solid waste management facility. Massachusetts considers wood ash from commercial or institutional sources to be a solid waste, thus potentially subject to the state's hazardous waste rules. In reality, the only type of wood pellets that may not meet Massachusetts standards are those made from construction and demolition (C&D) waste wood material, thus making it important to obtain a written statement from your supplier verifying the source.

HOW TO

ENSURE THE CHIMNEY IS THE CORRECT HEIGHT

State air quality regulators with the Massachusetts Department of Environmental Protection or an engineer can assist building owners with determining an appropriate chimney height for your site (see contact details on page 26). Such factors as local topography, wind movement patterns, and neighboring buildings should be taken into consideration when sizing a chimney. The chimney should be high enough to disperse the exhaust—and any pollutants it contains—into the prevailing winds.

Economic Analysis of Wood Pellet Heating Systems

A primary advantage to using wood pellets for space heating is the savings in heating costs that are generated by replacing expensive fossil fuels with less expensive wood pellets.

Cost Effectiveness of Wood Pellet Heating Systems

A primary advantage to using wood pellets for space heating is the savings in heating costs that are generated by replacing expensive fossil fuels with less expensive wood pellets. These savings can be calculated on a first-year basis, or the savings can be projected into the future over the expected life of the wood pellet boiler. An important question for potential owners of wood pellet boilers is the extent to which the fuel cost savings justify the cost of the project.

WHEN ARE PELLET BOILER SYSTEMS COST EFFECTIVE?

Life cycle cost (LCC) analysis can be used to inform a building owner's decision to convert to wood pellet heating. In calculating potential fuel cost savings, the LCC analysis considers several economic variables, such as estimates of fuel price and average inflation rates. The LCC analysis compares the projected costs of an existing fossil fuel boiler system to the projected costs of a new wood pellet boiler system, and shows the net present value (NPV) of savings over the life of the system.

Spreadsheet-based LCC analysis tools are available from:

- Biomass Energy Resource Center
- Natural Resources Canada (RETScreen)
- Universities of Wisconsin and Alaska
- Select architects or engineers

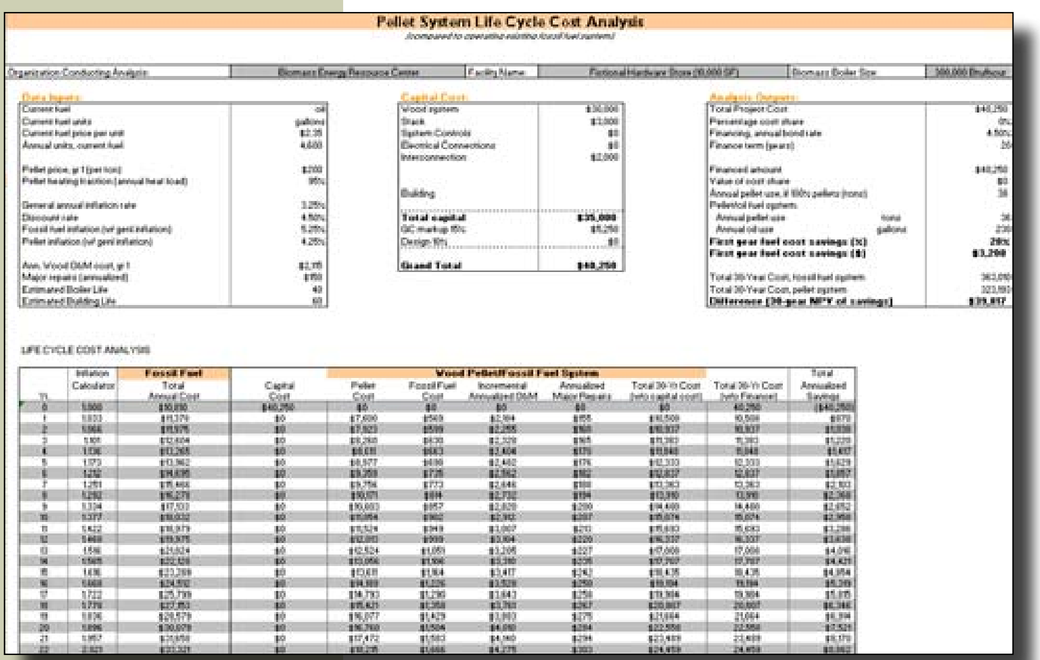


FIGURE 4.

LIFE CYCLE COST ANALYSIS TOOL

A life cycle cost analysis tool takes a number of economic parameters into consideration when calculating the cost effectiveness of installing a wood pellet heating system (see pages 24 and 25 for full-sized screens).

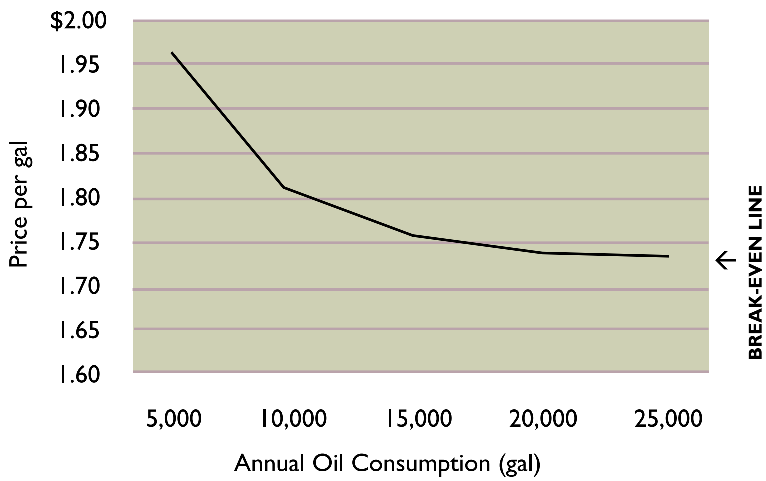
GENERAL INDICATORS OF COST EFFECTIVENESS

The best candidates for heating with wood pellets are buildings between 10,000 and 50,000 square feet (SF) that use heating oil, propane, or electricity for space heat and/or for serving large domestic hot water loads. Electric heat is the most expensive, therefore fuel cost savings generated by switching from electric heating to wood pellets could potentially be substantial, although the costs of converting the electric heaters to hot water heat distribution must be part of the analysis. Propane is typically the next most expensive heating fuel, followed by heating oil. LCC analysis assumes conservative inflation rates for fossil fuels as well as the general inflation rate, and does not take into consideration any additional financial incentives for wood energy, such as possible future taxes on carbon emissions.

The graphs on the following page show the potential for wood pellets to be a cost-effective alternative heating fuel when compared to oil, propane, natural gas, and electric heat. The LCC of a wood pellet heating system was compared to that of each of the fossil fuel heating systems across a range of heat load sizes and fuel prices. On each graph there is a line that represents the "break-even" point, at which the wood pellet system costs just as much as it saves over the life of the system (30 years). At conventional energy prices and consumption rates above the break even line, wood pellets would be a cost-effective alternative heating fuel. At the prices and consumption rates below the break even line, wood pellets are not likely to be cost effective. The farther above or below the break-even line, the clearer the message of the graph. While these graphs give a general idea of cost effectiveness for a range of situations, a site-specific LCC analysis will give more definitive answers.

The best candidates for heating with wood pellets are buildings between 10,000 and 50,000 square feet that use heating oil, propane, or electricity for space heat and/or for serving large domestic hot water loads.

OIL



PROPANE

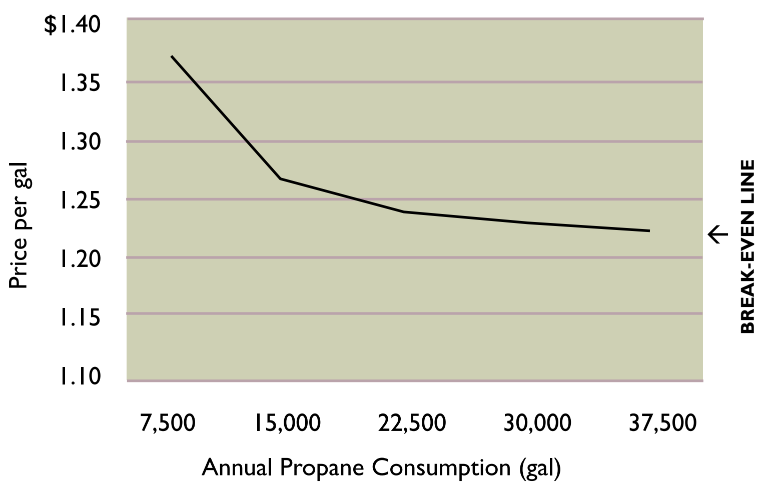


FIGURE 5.

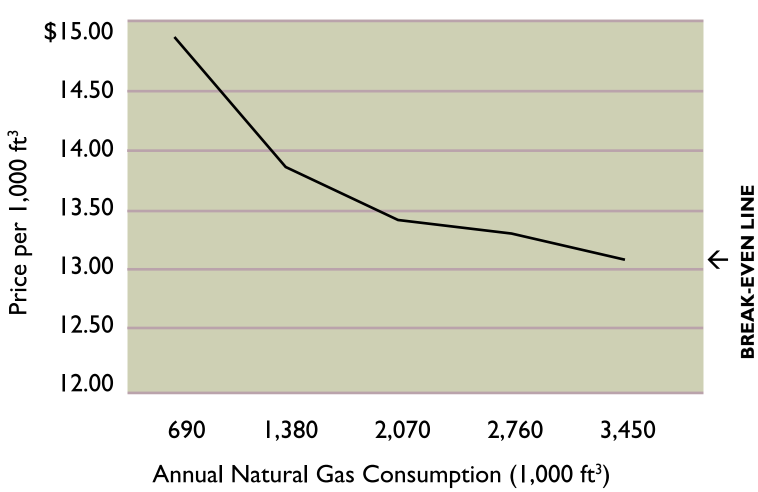
BREAK-EVEN ENERGY PRICES: WOOD PELLETS COMPARED TO OIL, PROPANE, NATURAL GAS & ELECTRIC HEAT

The graphs on this page demonstrate the price points and annual consumption rates above which wood pellet heating is likely to be cost effective. The break-even line illustrates the point for each price and consumption rate where wood pellets would cost the same as heating with the existing fuel. Above the break-even line, wood pellets are likely to be a cost-effective alternative; below the line, they are likely not to be.

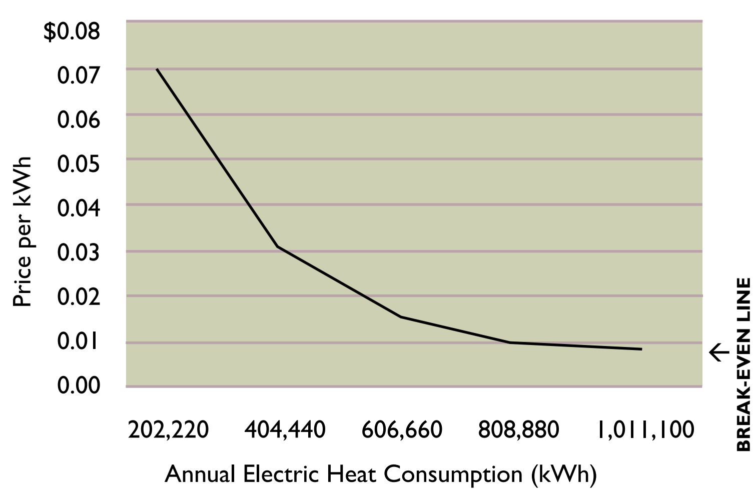
Building owners can input their consumption rate and current fuel price into the appropriate graph to determine whether or not wood pellets would make good financial sense at their site.

For example, a building that uses 15,000 gallons of oil per year for heating where the price is lower than $1.70/gal would be below the break-even point for cost effectiveness, thus it would not be a good candidate for heating with wood pellets. Alternatively, the building might be a good candidate if the oil price was $1.70/gal.

NATURAL GAS



ELECTRIC



How-To Do a Detailed Life Cycle Cost Analysis

DEFINE THE PROJECT & ITS COSTS

Wood pellet boiler systems are one of the least expensive biomass heating options to purchase and install and often do not require any newly constructed space. The full cost of the wood pellet boiler system is dependent on the capacity of the boiler, plus the cost of the equipment associated with it (such as the storage silo). There is also a cost for installing the system, including connecting the plumbing and controls to the existing heat distribution system. Complete wood pellet systems typically cost in the range of $75,000 to $100,000 per MMBtu (measured as heat output). A qualified professional or a wood pellet system vendor can provide site-specific project cost estimates.

Whether contemplating wood pellets for a heating system conversion project or for new construction, a full analysis of the cost effectiveness of any project requires that all costs of purchasing and installing the system, as well as purchasing fuel and operating the system, are considered. Cost components of a wood pellet heating system may include the following:

- System equipment and installation
- Complete fuel storage and handling system, including installation and any optional system components
- Construction (such as building additional boiler room space or a new boiler house, if required)
- Site costs (possibly including driveways for fuel deliveries)
- Chimney equipment and installation, if required
- Emissions permit or control equipment, if required
- Professional fees (such as those for engineering)
- Connection of controls and piping to the existing system

In addition to the cost of purchasing and installing a wood pellet boiler, ongoing costs for operating and maintaining the system need to be included in the LCC analysis. In the same way that a fossil fuel heating system requires general maintenance, a wood pellet boiler will require, on average, 15-30 minutes per day for an operator to keep the system running smoothly. The cost associated with the operator's time, as well as routine parts or service, should be included.

ASSUMPTIONS & DATA REQUIREMENTS

When comparing two heating system options, for example, wood pellet and oil heat, the cost of owning and operating each must be characterized in the same way. The option with the lower LCC will be the better financial investment.

In general, the important parameters for doing a life cycle cost analysis of a wood pellet heating system are:

- Initial system equipment and installation costs, including any construction or site-specific work
- Costs for system design and project management
- The expected life of the wood pellet boiler system
- Estimated costs for any equipment replacements or repairs over the anticipated life of the system
- Costs associated with maintaining and operating the back-up fuel system, including fuel purchases
- The projected volume of wood pellets required each year;
- The projected volume of back-up fuel required annually
- The current price of wood pellets, back-up fuel, and electricity
- The rates of escalation for wood pellet, back-up fuel, and electricity
- Annual general inflation rate, to model the future costs of operation and maintenance
- The projected first-year costs of running the wood pellet system, including costs for electricity, staff time, and routine maintenance
- The projected cost of major repairs on an annual basis
- Financing costs
- Amount of any financial incentives, such as grants or tax breaks, that will offset any portion of the project cost

Fictional Case Studies of Life Cycle Cost Savings

GENERIC HARDWARE STORE

A fictional hardware store is located within 50 miles of a wood pellet distribution center in Massachusetts. The store, including its associated storage space, is roughly 10,000 SF and uses 4,600 gallons of heating oil at a current price of $2.35 per gallon. The annual heating fuel bill at this price is $10,810. Because the store is within 50 miles of the wood pellet depot, the cost of wood pellets is kept relatively low, at $200 per ton, including delivery charges.

In addition to calculating the fuel requirements of this wood pellet heating system and a total project cost of $39,817, the LCC analysis shows that the owners of the hardware store could save about $3,208—or 28 percent—in the first year of operation. These savings are realized after the cost of purchasing fuel and the costs of operation and maintenance have been subtracted from the fuel cost savings. This translates to a net savings of approximately $45,000 (in 2007 dollars) over 30 years after accounting for the rise in costs of operation and maintenance due to general inflation. This building would be a good candidate for heating with wood pellets.

GENERIC TOWN HALL

This fictional Town Hall represents a municipally owned building located within 50 miles of a wood pellet distribution center. It houses a variety of town offices within its 30,000 SF. The entire space is heated by one centralized oil boiler. The price of oil is currently $2.35 per gallon and wood pellets would be available in bulk at $200 per ton.

The LCC analysis shows that the Town Hall would require about 110 tons of pellets per year and estimates the system would cost about $124,200. Fuel cost savings in the first year of operation would be 28 percent. Over the 30-year expected life of the wood pellet boiler, the Town Hall would save a net of more than $211,722 (in 2007 dollars). The Town Hall is a good candidate for a wood pellet heating system.

Sensitivity Analysis

In cases where an LCC analysis shows that a wood pellet boiler system installed at a certain site at current fuel prices would not be cost effective, the tool can be used to determine the point(s) at which the wood pellet boiler system might become cost effective. For example, a wood pellet boiler system may not be cost effective at the current fuel price being used in the analysis; however, if the price were to go up over the next couple of years, the system may become a good candidate for conversion.

In those cases where an LCC analysis shows that a wood pellet boiler system installed at a certain site at current fuel prices would not be cost effective, the tool can then be used to determine the point(s) at which the site would be a good candidate for conversion.

Financial Incentives for Wood Pellet Boiler Systems

MASSACHUSETTS TAX INCENTIVES

The Massachusetts Department of Energy Resources (DOER) website lists several tax incentive programs for renewable energy projects. A professional tax consultant can assist with determining eligibility for and claiming these incentives.

- State Income Tax Credit
- State Sales Tax Exemption
- Local Property Tax Exemption
- Corporate Income Tax Deduction

OTHER COMMONWEALTH INCENTIVES

In addition to the tax incentives listed on the DOER website, there are two other primary sources of financial incentives for wood pellet heating projects in Massachusetts. These can be in the form of reimbursements or financing assistance.

1. Massachusetts School Building Authority offers reimbursement money on a demonstrated need basis to communities that are improving existing schools or constructing new school buildings. An additional two percent is awarded for projects that meet the Massachusetts High Performance Schools criteria (http://www.massschoolbuildings.org/Documents/PDF/MA-CHPS_Green_School_Guidelines_10_20_06.pdf), including the installation of biomass heating systems. (http://www.massschoolbuildings.org/index.htm).

2. MassDevelopment

This finance agency offers loans, guarantees, and bond financing programs to Massachusetts businesses that are looking to grow their operation while supporting local economic development. (http://www.massdevelopment.com/)

FEDERAL INCENTIVES

In addition to Massachusetts-based financial incentives, there are numerous federal-level incentives available to businesses, municipalities, and nonprofits. They are also listed on the Massachusetts DOER website. A professional tax consultant can assist with determining eligibility for and claiming these incentives.

Business Tax Incentive (http://www.energytaxincentives.org/business/commercial_buildings.php)

A tax credit for up to $1.80 per SF is available to building owners, tenants, or federal building designers, for heating system projects that reduce heating costs by more than 50 percent. This program is scheduled to continue through December 2008.

Modified Accelerated Cost Recovery System (MACRS)

The MACRS provisions of the federal tax code give businesses the opportunity to recover investments in renewable energy systems by taking depreciation deductions over an accelerated five-year period.

Tax Incentives for Grants and Subsidies

Funds awarded to projects as part of federal programs may be exempt from taxation.

Grants, Financing Provisions, Production Incentives & Other Programs

Federal agencies such as the Department of Energy, Environmental Protection Agency, and Department of Agriculture periodically offer programs designed to encourage the research, development, and deployment of renewable energy technologies.

GLOSSARY

ACID RAIN: Cloud or rain droplets containing such pollutants as oxides of sulfur and nitrogen, damaging trees, soils, and aquatic environments. ⇦

ASH CONTENT: The amount of ash produced during combustion relative to the amount of fuel fed into the wood pellet boiler. Ash content is one indicator of quality for wood pellet fuel. Ash content for wood pellets should be between 1 and 3 percent. ⇦

BIOMASS: Any biological material, such as wood or grass, that can be used as fuel. Biomass fuel is burned or converted in systems that produce heat, electricity, or both.

BRITISH THERMAL UNIT (BTU): A unit used to measure the quantity of heat, defined as the quantity of energy required to heat 1 lb. of water 1° F. It takes about 1,200 Btu to boil 1 gallon of water. ⇦

CRITERIA AIR POLLUTANTS: A group of air pollutants regulated by the US Environmental Protection Agency and state air pollution control agencies to protect human health and the environment.

ENERGY CONTENT: The total Btu per unit of fuel. For biomass fuels, energy content can be considered on a dry or wet basis, since the amount of energy per pound of fuel is reduced with increasing moisture content. ⇦

FOSSIL FUELS: A group of combustible fuels, such as oil, propane, coal, or natural gas, formed from the decay of plant that animal matter and can be burned to produce energy. Liquid fossil fuels include oil, gaseous fossil fuels include propane, and solid fossil fuels include coal. ⇦

GLOBAL CLIMATE CHANGE: A term that is interchangeable with “global warming” and refers to the warming of the earth caused by the buildup of greenhouse gases (such as carbon dioxide, water vapor, and methane) in the atmosphere. While these gases are naturally occurring, humans are increasing these amounts through burning fossil fuels and other activities. ⇦

HEATING DEGREE DAYS: A measure used to estimate energy requirements for heating. It is calculated by subtracting the average daily temperature in a given area from 65 degrees Farenheit. Yearly totals can be used to compare the severity of the winter in different regions. ⇦

LIFE CYCLE COST: The total cost to purchase, own, and operate a piece of equipment over its entire life. The life cycle costs of several heating system options can be compared to determine which option will be the least expensive to own and operate over the entire expected life of the heating system. ⇦

MILLION BRITISH THERMAL UNITS (MMBTU): The amount of heat energy roughly equivalent to that produced by burning eight gallons of gasoline. ⇦

MOISTURE CONTENT: The total amount of water in a biomass fuel given as a percentage of the total weight of the fuel. Wood pellets, for example, typically have 6 percent moisture content, while woodchips have 40 percent and heating oil has 0 percent. ⇦

NET PRESENT VALUE (NPV) OF SAVINGS: The difference, in current year dollars, between the value of the cash inflows and the value of the cash outflows associated with operating an energy investment. A positive NPV of savings indicates that, from society’s economic perspective, the project is worth doing. A negative NPV of savings indicates that a project is not economically worth doing. ⇦

PARTICULATE MATTER (PM): Extremely small pieces of solid matter (or very fine droplets) ranging in size from visible to invisible. Relatively small PM—10 micrometers or less in diameter—is called PM10. Small PM is of greater concern for human health than larger PM, since small particles remain airborn for longer distances and can be inhaled deeply within the lungs. ⇦

Next Steps

Building owners wishing to install wood pellet heating should begin by taking the following steps:

- Review the four cost-effectiveness graphs provided in this guidebook (page 18) to get a preliminary sense of whether wood pellet heating will make financial sense.
- Undertake a preliminary feasibility study to determine whether the wood pellet heating project will be cost effective. This study will include the preliminary analysis of site-specific data and estimated project costs.
- Tour facilities with existing wood pellet heating systems. Seeing this technology and talking with current owners is extremely valuable in addressing doubts and concerns.
- Identify any potential funding sources or renewable energy incentives that may be available from the Commonwealth of Massachusetts, the federal government, or other sources (see financial incentives on page 21).
- For municipal or public projects, educate the public about the benefits of biomass prior to any vote.
- Learn about the air quality permitting requirements in the area and work with air quality regulators to determine whether an operating permit will be needed before a wood pellet heating system is purchased and installed.

Biomass Energy Resource Center

Pellet System Life Cycle Cost Analysis

(compared to operating existing fossil fuel system)

Organization Conducting Analysis:	Biomass Energy Resource Center	Facility Name:	Fictional Hardware Store (10,000 SF)	Biomass Boiler Size:	300,000 Btu/hour

Data Inputs:

Current fuel	oil
Current fuel units	gallons
Current fuel price per unit	$2.35
Annual units, current fuel	4,600
Pellet price, yr 1 (per ton)	$200
Pellet heating fraction (annual heat load)	95%
General annual inflation rate	3.25%
Discount rate	4.50%
Fossil fuel inflation (w/ genl inflation)	5.25%
Pellet inflation (w/ genl inflation)	4.25%
Ann. Wood O&M cost, yr 1	$2,115
Major repairs (annualized)	$150
Estimated Boiler Life	40
Estimated Building Life	60

Capital Cost:

Wood system	$30,000
Stack	$3,000
System Controls	$0
Electrical Connections	$0
Interconnection	$2,000
Building	
Total capital	**$35,000**
GC markup 15%	$5,250
Design 10%	$0
Grand Total	**$40,250**

Analysis Outputs:

Total Project Cost		$40,250
Percentage cost share		0%
Financing, annual bond rate		4.50%
Finance term (years)		20
Financed amount		$40,250
Value of cost share		$0
Annual pellet use, if 100% pellets (tons)		38
Pellet/oil fuel system:		
Annual pellet use	tons	36
Annual oil use	gallons	230
First year fuel cost savings (%)		**28%**
First year fuel cost savings ($)		**$3,208**
Total 30-Year Cost, fossil fuel system		363,010
Total 30-Year Cost, pellet system		323,193
Difference (30-year NPV of savings)		**$39,817**

LIFE CYCLE COST ANALYSIS

Yr.	Inflation Calculator	Fossil Fuel Total Annual Cost	Capital Cost	Wood Pellet/Fossil Fuel System: Pellet Cost	Fossil Fuel Cost	Incremental Annualized O&M	Annualized Major Repairs	Total 30-Yr Cost (w/o capital cost)	Total 30-Yr Cost (w/o Finance)	Total Annualized Savings
0	1.000	$10,810	$40,250	$0	$0	$0	$0	$0	40,250	($40,250)
1	1.033	$11,378	$0	$7,600	$569	$2,184	$155	$10,508	10,508	$870
2	1.066	$11,975	$0	$7,923	$599	$2,255	$160	$10,937	10,937	$1,038
3	1.101	$12,604	$0	$8,260	$630	$2,328	$165	$11,383	11,383	$1,220
4	1.136	$13,265	$0	$8,611	$663	$2,404	$170	$11,848	11,848	$1,417
5	1.173	$13,962	$0	$8,977	$698	$2,482	$176	$12,333	12,333	$1,629
6	1.212	$14,695	$0	$9,359	$735	$2,562	$182	$12,837	12,837	$1,857
7	1.251	$15,466	$0	$9,756	$773	$2,646	$188	$13,363	13,363	$2,103
8	1.292	$16,278	$0	$10,171	$814	$2,732	$194	$13,910	13,910	$2,368
9	1.334	$17,133	$0	$10,603	$857	$2,820	$200	$14,480	14,480	$2,652
10	1.377	$18,032	$0	$11,054	$902	$2,912	$207	$15,074	15,074	$2,958
11	1.422	$18,979	$0	$11,524	$949	$3,007	$213	$15,693	15,693	$3,286
12	1.468	$19,975	$0	$12,013	$999	$3,104	$220	$16,337	16,337	$3,638
13	1.516	$21,024	$0	$12,524	$1,051	$3,205	$227	$17,008	17,008	$4,016
14	1.565	$22,128	$0	$13,056	$1,106	$3,310	$235	$17,707	17,707	$4,421
15	1.616	$23,289	$0	$13,611	$1,164	$3,417	$242	$18,435	18,435	$4,854
16	1.668	$24,512	$0	$14,189	$1,226	$3,528	$250	$19,194	19,194	$5,319
17	1.722	$25,799	$0	$14,793	$1,290	$3,643	$258	$19,984	19,984	$5,815
18	1.778	$27,153	$0	$15,421	$1,358	$3,761	$267	$20,807	20,807	$6,346
19	1.836	$28,579	$0	$16,077	$1,429	$3,883	$275	$21,664	21,664	$6,914
20	1.896	$30,079	$0	$16,760	$1,504	$4,010	$284	$22,558	22,558	$7,521
21	1.957	$31,658	$0	$17,472	$1,583	$4,140	$294	$23,489	23,489	$8,170
22	2.021	$33,321	$0	$18,215	$1,666	$4,275	$303	$24,459	24,459	$8,862
23	2.087	$35,070	$0	$18,989	$1,753	$4,413	$313	$25,469	25,469	$9,601
24	2.155	$36,911	$0	$19,796	$1,846	$4,557	$323	$26,522	26,522	$10,389
25	2.225	$38,849	$0	$20,637	$1,942	$4,705	$334	$27,618	27,618	$11,230
26	2.297	$40,888	$0	$21,514	$2,044	$4,858	$345	$28,761	28,761	$12,127
27	2.372	$43,035	$0	$22,429	$2,152	$5,016	$356	$29,952	29,952	$13,083
28	2.449	$45,294	$0	$23,382	$2,265	$5,179	$367	$31,193	31,193	$14,102
29	2.528	$47,672	$0	$24,376	$2,384	$5,347	$379	$32,486	32,486	$15,187
30	2.610	$50,175	($10,063)	$25,412	$2,509	$5,521	$392	$33,833	23,770	$26,405
Totals		$789,178		$444,503	$39,459	$108,204	$7,674	$599,839	$589,777	$199,401
30 YR NPV:		$363,010	$37,563	$210,786	$18,151	$52,939	$3,755	$285,630	$323,193	$39,817

Pellet System Life Cycle Cost Analysis

(compared to operating existing fossil fuel system)

Organization Conducting Analysis:	Biomass Energy Resource Center	Facility Name:	Fictional Town Hall (30,000 SF)	Biomass Boiler Size:	1 MMBtu/hour

Data Inputs:

Current fuel	oil
Current fuel units	gallons
Current fuel price per unit	$2.35
Annual units, current fuel	13,800
Pellet price, yr 1 (per ton)	$200
Pellet heating fraction (annual heat load)	95%
General annual inflation rate	3.25%
Discount rate	4.50%
Fossil Fuel inflation (w/ genl inflation)	5.25%
Pellet inflation (w/ genl inflation)	4.25%
Ann. Wood O&M cost, yr 1	$2,550
Major repairs (annualized)	$430
Estimated Boiler Life	40
Estimated Building Life	60

Capital Cost:

Wood system	$100,000
Stack	$5,000
System Controls	
Electrical Connections	
Interconnection	$3,000
Building	$0
Total capital	**$108,000**
GC markup 15%	$16,200
Design 10%	$0
Grand Total	**$124,200**

Analysis Outputs:

Total Project Cost		$124,200
Percentage cost share		0%
Financing, annual bond rate		4.50%
Finance term (years)		20
Financed amount		$124,200
Value of cost share		$0
Annual pellet use, if 100% pellets (tons)		115
Pellet/oil fuel system:		
Annual pellet use	tons	109
Annual oil use	gallons	690
First year fuel cost savings (%)		**28%**
First year fuel cost savings ($)		**$9,625**
Total 30-Year Cost, fossil fuel system		1,089,030
Total 30-Year Cost, pellet system		877,309
Difference (30-year NPV of savings)		**$211,722**

LIFE CYCLE COST ANALYSIS

		Fossil Fuel		Wood Pellet/Fossil Fuel System						
Yr.	Inflation Calculator	Total Annual Cost	Capital Cost	Pellet Cost	Fossil Fuel Cost	Incremental Annualized O&M	Annualized Major Repairs	Total 30-Yr Cost (w/o capital cost)	Total 30-Yr Cost (w/o Finance)	Total Annualized Savings
0	1.000	$32,430	$124,200	$0	$0	$0	$0	$0	124,200	($124,200)
1	1.033	$34,133	$0	$22,801	$1,707	$2,633	$444	$27,584	27,584	$6,548
2	1.066	$35,925	$0	$23,770	$1,796	$2,718	$458	$28,743	28,743	$7,182
3	1.101	$37,811	$0	$24,780	$1,891	$2,807	$473	$29,951	29,951	$7,860
4	1.136	$39,796	$0	$25,833	$1,990	$2,898	$489	$31,210	31,210	$8,586
5	1.173	$41,885	$0	$26,931	$2,094	$2,992	$505	$32,522	32,522	$9,363
6	1.212	$44,084	$0	$28,076	$2,204	$3,089	$521	$33,890	33,890	$10,194
7	1.251	$46,398	$0	$29,269	$2,320	$3,190	$538	$35,316	35,316	$11,082
8	1.292	$48,834	$0	$30,513	$2,442	$3,294	$555	$36,803	36,803	$12,031
9	1.334	$51,398	$0	$31,809	$2,570	$3,401	$573	$38,353	38,353	$13,045
10	1.377	$54,096	$0	$33,161	$2,705	$3,511	$592	$39,969	39,969	$14,127
11	1.422	$56,936	$0	$34,571	$2,847	$3,625	$611	$41,654	41,654	$15,282
12	1.468	$59,926	$0	$36,040	$2,996	$3,743	$631	$43,410	43,410	$16,515
13	1.516	$63,072	$0	$37,572	$3,154	$3,865	$652	$45,242	45,242	$17,830
14	1.565	$66,383	$0	$39,168	$3,319	$3,990	$673	$47,151	47,151	$19,232
15	1.616	$69,868	$0	$40,833	$3,493	$4,120	$695	$49,141	49,141	$20,727
16	1.668	$73,536	$0	$42,568	$3,677	$4,254	$717	$51,216	51,216	$22,320
17	1.722	$77,397	$0	$44,378	$3,870	$4,392	$741	$53,380	53,380	$24,017
18	1.778	$81,460	$0	$46,264	$4,073	$4,535	$765	$55,636	55,636	$25,824
19	1.836	$85,737	$0	$48,230	$4,287	$4,682	$790	$57,989	57,989	$27,748
20	1.896	$90,238	$0	$50,280	$4,512	$4,834	$815	$60,441	60,441	$29,797
21	1.957	$94,975	$0	$52,417	$4,749	$4,992	$842	$62,999	62,999	$31,977
22	2.021	$99,962	$0	$54,644	$4,998	$5,154	$869	$65,665	65,665	$34,296
23	2.087	$105,210	$0	$56,967	$5,260	$5,321	$897	$68,446	68,446	$36,764
24	2.155	$110,733	$0	$59,388	$5,537	$5,494	$926	$71,345	71,345	$39,388
25	2.225	$116,547	$0	$61,912	$5,827	$5,673	$957	$74,368	74,368	$42,178
26	2.297	$122,665	$0	$64,543	$6,133	$5,857	$988	$77,521	77,521	$45,144
27	2.372	$129,105	$0	$67,286	$6,455	$6,047	$1,020	$80,809	80,809	$48,297
28	2.449	$135,883	$0	$70,146	$6,794	$6,244	$1,053	$84,237	84,237	$51,646
29	2.528	$143,017	$0	$73,127	$7,151	$6,447	$1,087	$87,812	87,812	$55,205
30	2.610	$150,526	($31,050)	$76,235	$7,526	$6,656	$1,122	$91,540	60,490	$90,036
Totals		**$2,367,534**		**$1,333,508**	**$118,377**	**$130,458**	**$21,999**	**$1,604,342**	**$1,573,292**	**$794,241**
30 YR NPV:		**$1,089,030**	**$115,910**	**$632,357**	**$54,452**	**$63,828**	**$10,763**	**$761,399**	**$877,309**	**$211,722**

Resources

BULK WOOD PELLET SUPPLIERS

Narragansett Pellet Corporation, E. Providence, RI	(401) 434-4800
Natural Living Innovations, E. Providence, RI	(800) 844-2022
New England Wood Pellet, Inc., Jaffrey, NH	(603) 532-9400

WOOD PELLET SYSTEM VENDORS

AFS Energy Systems, Inc.	(717) 763-8689
Alterrus Bioenergy	(503) 235-5234
Biomass Commodities Corporation	(802) 613-1444
Decker	(204) 764-2861
EnergyCabin	(604) 833-0774
Harman Stoves	(717) 362-9080
Pro-Fab Industries, Inc.	(888) 933-4440
Solagen	(503) 366-4210
TARM USA	(800) 782-9927
Trager/Pinnacle	(866) 967-9777

CONTACT INFORMATION

Massachusetts Division of Energy Resources
100 Cambridge Street, Suite 1020, Boston, MA 02114
(617) 727-4732
www.mass.gov/doer

Massachusetts Department of Conservation & Recreation
251 Causeway Street, Suite 600
Boston, MA 02114-2104
(617) 626-1250
www.mass.gov/dcr/stewardship/forestry/utilmark/index.htm

Massachusetts Department of Environmental Protection
Air & Climate Program
Bureau of Waste Prevention – Business Compliance Division
One Winter Street, Boston, MA 02108
(617) 292-5500
www.mass.gov/dep/air

Massachusetts Department of Revenue
PO Box 701, Boston, MA 02204
(800) 392-6089
www.mass.gov/?pageID=dorhomepage&L=1&L0=Home&sid=Ador

Massachusetts School Building Authority
3 Center Plaza, Suite 430, Boston, MA 02108
(617) 720-4466
www.massschoolbuildings.org

Northeast Regional Biomass Program
www.nrbp.org/

Biomass Energy Resource Center
PO Box 1611, 50 State Street, Montpelier, VT 05602
(802) 223-7770
www.biomasscenter.org

British Columbia's Wood Pellet Industry

JUNE 2011

B.C.'S WOOD PELLET INDUSTRY EMPLOYS ABOUT:

350 workers in the facilities for **PROCESSING & MANUFACTURING**.

400 workers in the operations for **WOODLANDS & HARVESTING**.

350 workers in the area of **TRUCK-DRIVING & TRANSPORTATION**.

= 100 workers.

- B.C.'s wood pellet industry is playing a major role in developing renewable bioenergy sources locally and internationally with growing production and export markets.
- There are currently 11 wood pellet plants operating in B.C. They are located in the communities of Armstrong, Burns Lake, Houston, Kelowna, Prince George, Princeton, Quesnel, Strathnaver, Vanderhoof (two facilities), and Williams Lake.
- The combined production capacity of these 11 facilities is about 1.7 million tonnes per year.
- B.C. is home to seven wood pellet companies: Pinnacle Pellet (which operates five plants), Pacific BioEnergy, Northwest Wood Preservers, Houston Pellet, Princeton Co-Generation, Premium Pellet, and Okanagan Pellets (also known as Viridis Energy).
- Europe is the world's largest market for pellet products. Green energy policies in Europe – where power companies earn carbon credits by replacing coal with renewable wood fuel – have resulted in increased pellet demand. Emerging energy policies in Asian countries are also expected to drive increased pellet demand.
- Practically non-existent a decade ago, this fast-growing industry now contributes about $185 million annually to the provincial economy.
- British Columbia exported 94 per cent of its wood pellet production in 2009. B.C.'s leading markets for wood pellets are Europe (84 per cent of total exports), the United States (eight per cent) and Asia (eight per cent).
- British Columbia represents about 66 per cent of Canada's wood pellet production capacity, far ahead of the Atlantic provinces at a combined 18 per cent, Quebec at 11 per cent, Alberta at five per cent, and Ontario at one per cent.
- In B.C. wood pellets are mainly made from logging residues, timber killed by the mountain pine beetle infestation, sawmilling scraps and waste wood, compacted sawdust, and planer shavings.
- Wood pellet production is a key segment of the bioenergy sector and an important part of the provincial strategy for growing British Columbia's natural energy advantage.

BRITISH COLUMBIA

WOOD PELLET PLANTS OPERATING IN B.C.

- Wood pellets are used to heat the enhanced forestry lab at the University of Northern British Columbia (UNBC). In addition to bioenergy research, UNBC's wood pellet system is a demonstration project for industrial and community heating purposes.

- Wood pellets are burned at an extremely high temperature (1,500 degrees Celsius) and leave very little waste behind. A 40-pound bag of pellets produces only three ounces of ash, making wood pellets one of the cleaner-burning sources of fuel and energy.

- Wood pellets are one way to help fight climate change. They reduce the amount of carbon dioxide released into the atmosphere when they replace a non-renewable source of energy such as coal or oil. Unlike fossil fuels, pellets are carbon-neutral since the wood is part of the current carbon cycle. Wood pellets are also environmentally friendly as they generate heat without contributing particulate to the atmosphere.

For more information about how B.C. is building world-class bioenergy capacity visit the BC Bioenergy Network website at www.bcbioenergy.com

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For more information about wood pellets visit the Wood Pellet Association of Canada website at www.pellet.org

USAID VIETNAM CLEAN ENERGY PROGRAM

CONTRACT NUMBER: AID-486-C-12-00008-00

WOODY BIOMASS FOR ENERGY GENERATION IN VIETNAM
FINAL REPORT

Submitted to

United States Agency for International Development

Submitted by

Winrock International Institute for Agricultural Development

in partnership with

SNV Netherlands Development Organisation

January 2014

This report is made possible by the generous support of the American people through the United States Agency for International Development (USAID). The contents are the responsibility of Winrock International and do not necessarily reflect the views of USAID or the United States Government.

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ABBREVIATIONS AND ACRONYMS

AIST	Advanced Institute for Science and Technology
CDM	Clean Development Mechanism
CIFOR	Center for International Forestry Research
ECN	Energy Research Centre of the Netherlands
ENERTEAM	Energy Conservation Research and Development Center
EU	Europe
FAO	Food and Agriculture Organization
FBC	Fluidized Bed Combustion
FSR	Feasibility Study Report
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit
HAWA	Handicraft And Wood Industry Association
IE	Vietnam Institute of Energy
IEA	International Energy Agency
JICA	Japan International Cooperation Agency
LEAP	Long-term Energy Alternative Planning
MARD	Ministry of Agriculture and Rural Development
MDF	Medium Density Fiberboard
MOEJ	The Ministry of the Environment of Japan
MOIT	Ministry of Industry and Trade
NWFPs	Non-Wood Forest Products
R&D Tech	Center of Research and Development for Industrial Technology – Machinery
REED	Reducing Emissions from Deforestation and Forest Degradation
RIAM	Vietnam Research Institute Agriculture Machinery
SFE	State Forest Enterprises
SME	Small and Medium Enterprises
SNV	SNV Netherlands Development Organization
TBFRA	Temperate and Boreal Forest Resources Assessment
TOE	Ton of Oil Equivalent
US	United States
USAID	United Stated Agency for International Development
VCEP	Vietnam Clean Energy Program
VIAEP	Vietnam Institute of Agriculture Engineering and Postharvest Technology
VNFOREST	Viet Nam Administration of Forestry

1. INTRODUCTION TO THE STUDY

This study provides an overview of the opportunities of woody biomass (residues) for energy generation, including potential future use as well as an overview of the current use. It is prepared as part of the USAID Vietnam Clean Energy Program, funded by the USAID, and with Winrock International as the main implementer.

The main focus of the Vietnam Clean Energy Program, Sub-IR 2.3 is to increase public and private investment in and piloting of renewable energy technologies. This is split into 3 focus areas:

- Result 2.3.1 Developers have economically viable renewable energy projects
- Result 2.3.2 Policy framework for renewable energy facilitates private sector investments
- Result 2.3.3 Off-grid poor communities gain access to renewable energy

Woody Biomass is a high potential source of energy for Vietnam. Wood has several important advantages, mainly related to their characteristics and the fact that it can easily and with high efficiencies (in general) converted to energy, especially when we talk about wood residues as this is a renewable source. Substantial amounts of wood residues (waste) are widely used by households and industries, meanly for cooking and heating on household level whereas industrial applications range from mineral processing, food and agro processing, metal processing, and textiles.

Section 2 and Section 3 provide a general view on the woody biomass exploitation in Vietnam and the energy potential from forestry sector, it also gives an overview of local technology supply. These two sections provide an insight into all form of wood residues which originated from forests harvesting activities (direct wood-fuels) and from other wood processing activities such as sawmills and timber manufactures (indirect wood-fuels).

Section 4 and 5 introduce the current wood energy conversion technologies and equipment used in Vietnam, ranging from densification technologies like pelletizing to large scale industrial use of woody biomass. The woody biomass conversion technologies can be classified into three categories: traditional, state-of-the-art, and emerging technologies.

2. WOODY BIOMASS EXPLOITATION IN VIETNAM

In this chapter background information will be provided, based on existing literature and interviews, on the forestry sector and developments in Vietnam. There is no concistant data available on the forestry sector, and many different reports and sources give (sometimesslightly) different figures on forest sizes, wood collection from forest and other parameters. For this report some key reports have been used, with similar data (but not identical), but in some cases there might be small differences between the data mentioned due to the different sources (MARD, 2012), (MARD, Vietnam Forest Development Strategy, 2006-2020), (FAO, 2009), (FAO, 2002), (SNV, 2012), (VN Forest, 2013) and (Forest Trend, 2013).

2.1 Background on forest development

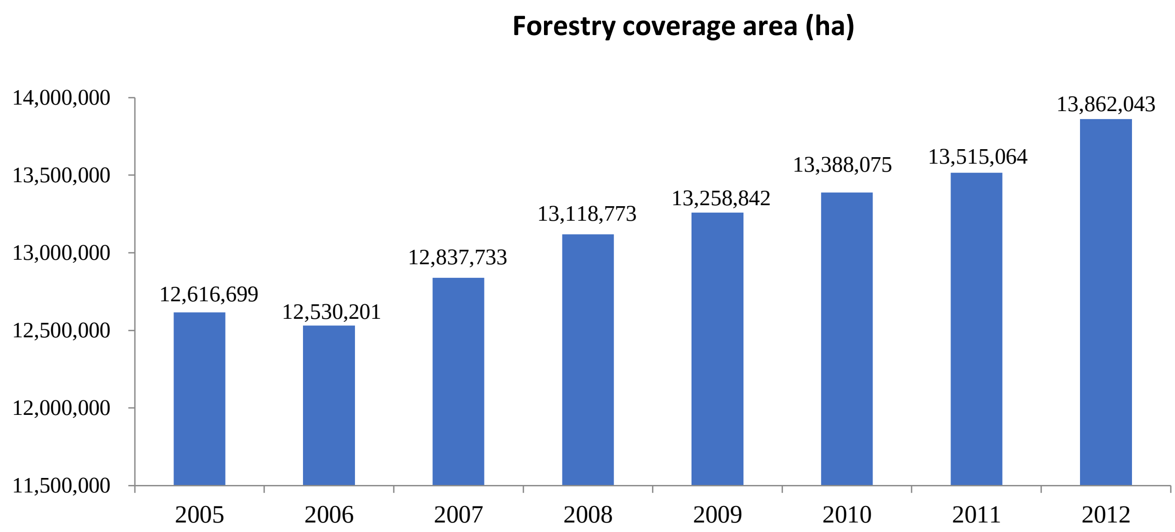
The forests in Vietnam varied over time, in 1943, Vietnam had 14.3 million hectare of forest area, with 43% of forest cover. However, the forest area rapidly decreased in period of 1980 to 1990, losing 100,000 hectare annually, reducing to 9.18 million hectare in 1990 with a forest cover of only around 27%. From 1990 onwards forest area and coverage has been increasing as a result of the forest development strategy launched by MARD in 1995 in combination with a large number of programs to protect forests and increase both the quantity and quality of forests throughout the country[1]. In 2006, forest area in Vietnam was 12,874 million ha (38% forest cover), of which 10.41 million ha were natural forest and 2,464 million ha were plantation forest. According to the latest update of forestry in 2012 by MARD, there is almost 14 million hectare of land covered by forest (41% forest cover), which is mainly natural forest (over 10 million ha). The forest distribution has been indicated in table below.

There are several definitions to label forest areas, it is defined by the situation that resemblances to the condition that would obtain in the complete absence of human intervention. Forests and other wooded land are characterized as natural (undisturbed by man), semi-natural (under some degree of management, or evincing past human intervention) or plantation (under active management) (TBFRA 2000).

TABLE 1: THE FOREST DISTRIBUTION IN 2012 (MARD, 2013)

No	Forest type	Area (ha) Subtotal (ha)	Belong to 3 forest types[2] Special-use forest (ha)	Protective forest (ha)	Productive forest (ha)	Out of forest land (ha)
1	Natural forest	10,423,844	2,021,995	4,023,040	4,415,855	44,641
2	Plantation forest	3,438,200	1,940,309	652,364	2,548,561	155,589
a	Dense forest	3,039,756	81,686	576,764	2,253,215	137,558
b	Yung forest	398,444	9,467	75,600	295,346	18,031
3	**Total**	**13,862,043**	**2,021,995**	**4,675,404**	**6,964,415**	**200,230**

FIGURE 1: THE FORESTRY AREA AND COVERAGE IN PERIOD OF 2005 – 2012

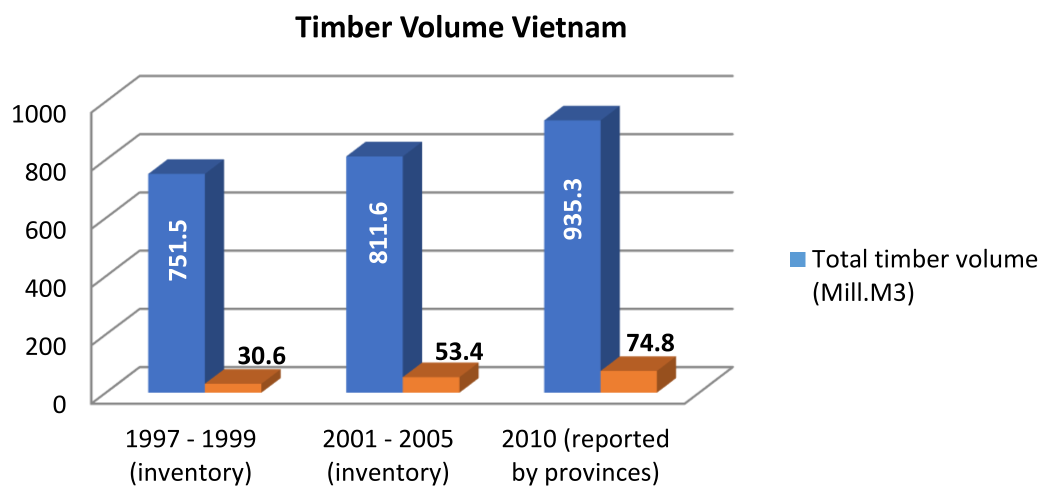


[1] Several large programs have been implemented including The Greening of Bare Land Program (Project 327, 1993-1998), the Five Million Hectare Reforestation Program (1998-2010), the Forestry Extension Program, the National Action Plan for Biodiversity (1995, 2007), the National Action Plan to combat desertification, 2006-2010. On a policy level; National Forestry Development Strategy 2006–2020, Forest Protection and Development Law 2004, The Biodiversity Law 2008

[2] Vietnam categorises forests by designated use (Source: Circulation 34/2009/TT-BNNPTNT, 10 June 2009 of MARD.):
1. protection forest, reserved for watershed and soil protection, prevention of erosion and desertification, and environmental preservation;
2. special-use forest, designated mainly for natural area preservation, ecological diversity, germplasm conservation and scientific research; and
3. production forest, used mainly for timber production in combination with watershed and environmental protection..

The additional attention from the Government, supported by multiple donors have resulted in increasing forest standing stocks. From 751 million m^3 in 1997-1999, to 812 million m^3 in late 2005 of which natural forest accounted for 93.4% and by 2010 the total timber volume of the whole country increased up to 935 million m^3. The average volume of the growing stock of intensive plantation forest was measured to be 40.6 m^3/ha. The stocks of bamboo and rattan (non-timber) were high at around 8.5 billion stems distributed in natural forest and some areas of plantation forest (MARD, 2011).

FIGURE 2: THE COUNTRY FOREST STANDING STOCK (MARD, 2011)



The distribution of the plantation forest is show in the table below. In the Central & Highlands and in Northeast, forest cover is high at over 40%. In the Southeast forest cover is about 20% whereas in the Red River Delta and Mekong River Delta, most of the area is used for agriculture and forest cover is below 10% (VNFOREST, 2011). It is interesting to look deeper into the net rate of forest change, as indicated below in Box 1.

BOX 1: NET RATE OF FOREST CHANGE 2000 - 2005

A 5-year net rate of forest change of almost zero

The REDD and Sustainable Development – Perspective from Viet Nam (SNV, 2010) report shows that the net rate of forest change in Viet Nam between 2000 and 2005 was relatively close to zero, acknowledging that there is a large degree of variation throughout the country. Forest cover changed significantly in parts of Viet Nam, even though increases in some places mask decreases in others when national averages are examined. In some areas, forest loss was quite drastic between 2000 and 2005. For example, three provinces saw more than 50% of the forest cover they had in 2000 lost by 2005: An Giang saw its cover decline from 18.48% to 7.68% (a 58% loss), Tra Vinh from 15.16% to 7.04% (54% loss) Dong Thap from 18.17% to 8.74% (52% loss). Looking at districts, as would be expected from the low national deforestation rate, most have a relatively low net rate of forest change (around 0 on the plots below). However, some have quite pronounced rates of forest cover loss.

Vietnam plantation forest continued to increase in recent years, with an average of around 150,000-200,000 ha/year. It is expected that with such an increase in plantation forest in Vietnam the timber supply for the wood processing industry and the wood chip industry will also continue to grow.

TABLE 2: THE DISTRIBUTION OF PLANTATION FOREST AREAS IN REGIONS (HA) (VNFOREST, 2011)

Regions	2007	2008	2009	2010	2011
Northeast	116,544	123,863	150,055	152,328	155,394
Northwest	943,899	1,015,266	1,089,600	1.120.793	1,184,844
Red River Delta	47,618	48,547	48,915	48,675	48,701
North Central	576,556	615,443	654,793	679,872	701,160
South Central	342,349	391,892	417,323	491,500	526,117
Highland	157,575	197,324	209,450	220,495	237,366
Southeast	124,448	139,518	133,514	161,840	176,977
Southwest	244,380	238,329	215,886	207,756	199,123
Total	**2,553,369**	**2,770,182**	**2,919,538**	**3,083,259**	**3,229,682***

* numbers are slightly different than in table 1 due to the use of different sources.

Vietnam has established 128 special use forest areas covering 2,228,149 ha and accounting for 11.7% of the total forestry area or 6.7% of the total land area. There are 30 national parks, 60 nature reserves and 38 landscape protection areas in the special use forest system.

FIGURE 3: VIETNAM WOOD PRODUCTION OUTPUT FROM PLANTATION FOREST AND NATURE FOREST (HAWA)

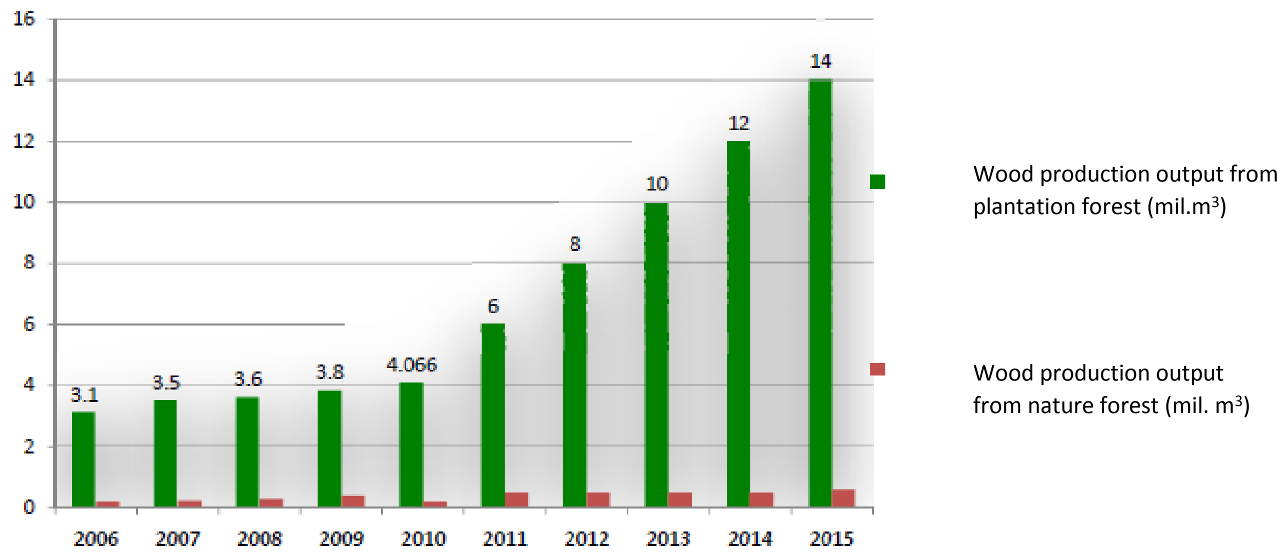
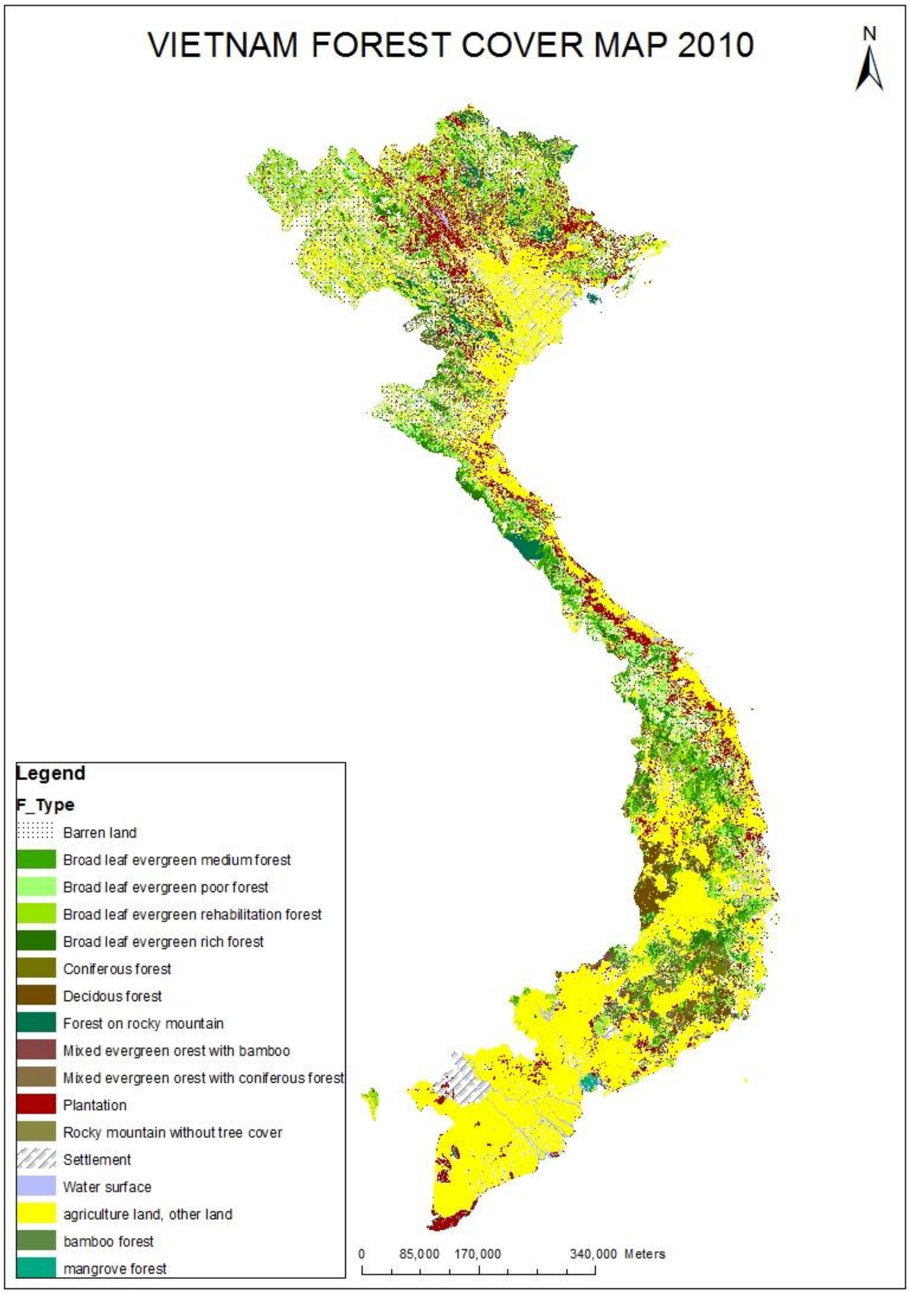


FIGURE 4: THE FOREST COVERAGE IN VIETNAM IN 2010 (SNV)



2.2 Forest harvesting and utilization

Forest utilization is in line with forest management regulations under the Decision No. 86/TTg of the Government and following series of timber and forest products harvesting management regulations. In 20 May 2011, MARD has issued the Circular No. 35/2011/TT-BNNPTNT on guiding the implementation of timber and non-timber forest product harvesting and salvaging.

Recently VNFOREST issued the Document No.98/TCLNSDR dated 10/2/2012 to direct provinces to strengthen their management of timber and timber product harvesting, especially the harvesting of natural forest timber. The harvesting of plantation forest, processing, importing, and exporting of timber and timber products have been monitored and examined thought out country.

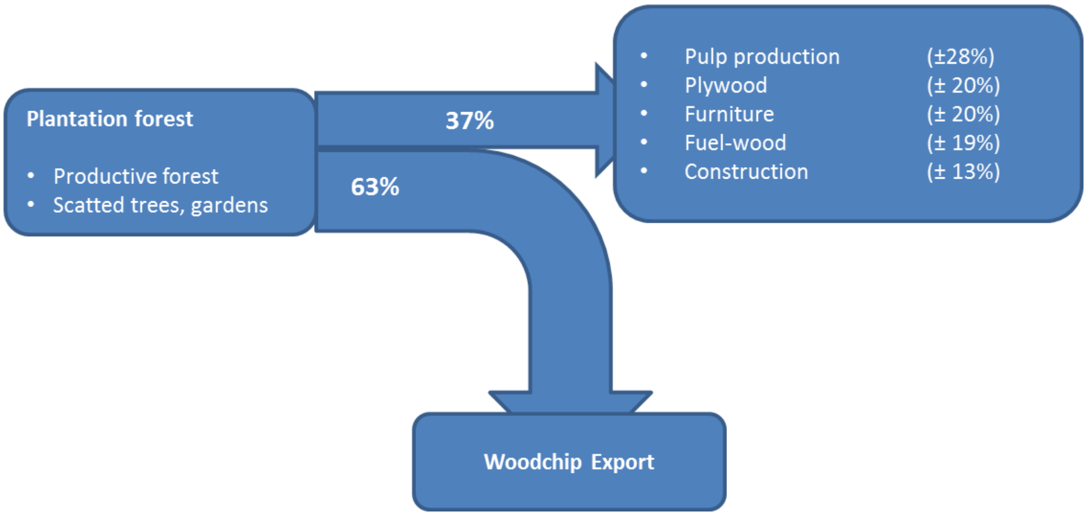
Given consumption trends in recent years, timberharvest from natural forest, scattered trees and plantation should reach 20-24 million m^3/year by 2020 (of which 10 million m^3 should be "big" timber).To achieve adequate supply to the high demand of the wood processing industry, it will be necessary to improve forest plantation productivity to average more than 15 m^3/ha/year. Natural forest growth will be 2-5 m^3/ha/year depending on forest status (FAO 2009).

Harvesting from plantation forests

Vietnam has almost 3.5 million ha of plantation forest (MARD, 2011), of which about 75% is productive forest. This can provide approximately 14.8 million m^3 of timber. In addition, scattered timber and garden trees is also very large, estimated about 2.5 million m3 per year. Total production of timber from plantations and gardens households estimated 17.3 million m^3 in 2011, that is not including about 2 million m^3 of wood from the rubber tree disposal (VNFOREST 2013).

According to estimates, about 63 % of the total amount of timber harvested from plantation forests are being processed woodchips that are entirely exported to China, Korea, Japan,…to be used for paper production. The remaining 37 % of total timber harvested go directly to the pulp and paper, artificial boards, furniture production and construction or fuel-wood as domestic uses (VNFOREST 2012). The structure of plantation forest timber distribution in the have been given in the figure below.

FIGURE 5: THE FLOW OF WOOD FROM PLANTATION FOREST AND SCATTED TREES IN 2011 (FOREST TRENDS 2013)



Natural forest

The State Forest Enterprises (SFE) manages about 26% of the natural forest for timber production. Conventional loggings are carried out by SFE or logging contractors. Intensive logging happened in the period from 1976 to 1980 with 1.62 million m^3 /year, many forest areas have been degraded and the non-commercial crops trees are left in the forest influencing the biodiversity. However, the amount of timber being harvested from the natural forest has considerably reduced over the last few years, for example, from 1.2 million m^3 in 1992, to 450,000 m^3 in 1996-1997 and 300,000 m^3 in 2001-2002. From 2005 up to date, the natural forest logging are set down to 200,000 m^3/year. The changes in the natural forest harvesting are given in the table below.

TABLE 3: THE NATURAL FOREST TIMBER HARVESTING (VIETNAM FORESTRY HANDBOOK, MARD 2012, 2013)

Time	Nature Forest exploited volume (m^3)	Annual exploited volume (m^3/yr)
1955 - 1960	3,168,160	530,000
1961 - 1965	4,957,000	991,400
1966 - 1975	8,100,000	810,000
1976 -1980	8,100,000	1,620,000
1981- 1985	7, 000,000	1,400,000
1986- 1989	5,289,000	1,300.000
1990- 1998	5,701,000	630,000
1999- 2002	1,200,000	300,000
2003-2004	250,000	250,000
2005	200,000	200,000
2011[3]	359,600	350,600
2012	160,000	160,000

Illegal logging also continues to be a problem in Vietnam, and this is not only due to to the presence of poor villagers, corrupt local officers, illegal traders or a lack of law enforcement. It is also because there is a the lack of (or uncertainty of) tenure rights given to local people living near forests containing valuable timber, thus legally excluding them from forest benefits including those from timber.

Wood from natural forest is large (diameter of imported wood is from 25 cm to 60cm) which is usually used for making handicraft, furniture and outdoor furniture. Wood from natural forests is the major raw materials for these products, taking a high proportion of structural material of wood processing industry. Vietnam is the second-largest furniture exporter in Asia, after China, mainly exporting to the US and the EU. The trade is one of the country's top five export products in monetary value (worth $2.4 billion a year). Currently, wood demand from natural forests is very high, while domestic materials only meet 20% of demand, the remaining of 80% must be imported. In 2009, Vietnam had to import 4 million m^3 for the wood processing industry.

Bamboo

Bamboo is a local forest product used mainly for handcrafts production at village level for local markets and for floor production at an industrial scale for export markets. According to MARD, the harvesting of bamboo reached 55,000 trees in 2011 and 58,000 trees by 2012. The estimated cultivation area of bamboo in Vietnam is 800,000 hectares of plantations with an average annual yield of 10 to 13 tones per hectares and 600,000 hectares of mixed forest, comprised of up to 70% bamboo.

[3] numbers are slightly different than in the text above due to the use of different sources, and there are a lot of different numbers, in the different sources.

Bamboo utilization is focused on three major subsectors in the south; value added processing (20% for pressed flooring), bulk processing (80% homeware, chopsticks and handicrafts), construction material (wattles) and emerging bamboo shoots sector at local level. Presently the demand for bamboo in Vietnam is larger than supply. Bamboo production faces land pressure issues due to the diverse demand for other forest species and forest protection enforcements. (SNV, 2012)

2.3 Wood Processing Sector Demands and Status

Timber and forest products have experienced rapid growth in terms of value in Vietnam, the sector's has great contribution to the national economy, and Vietnam is the fourth largest exporter of wood products and its timber industry (CIFOR, 2012), more recent newspaper articles indicate even the second largest after China (Vietnam.vn, 2013). The General Department of Forestry says the wood processing industry grew at an annual rate of 41–42% in the 2005–2010 period, and 20–30% in the last three years. The main wood products include rough products (sawn wood, plywood panel, composite panel), refined products (wooden board, wooden beds, etc), and handicraft or artisan products – nevertheless the competitive woodchip market is competing directly with the demand for wood.

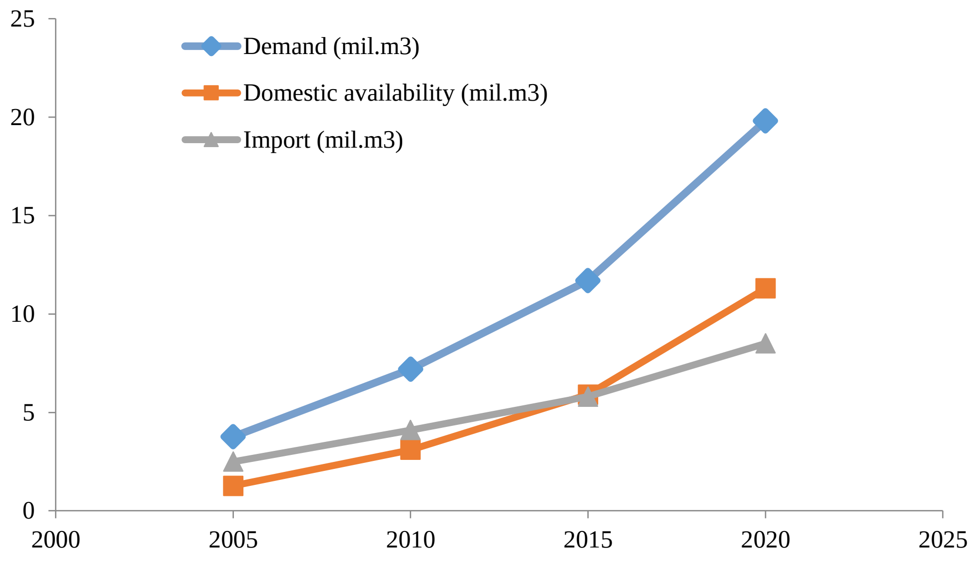
In 2011, the total volume of timber wood processing industry serves some 16 million m^3 of logs, of which 7 million $m^3$was used for chips and paper production, 3 million m^3 was used for the domestic market (processing facilities and furniture) and 6 million m^3 for export markets (Forest trend 2013). The wood materials for the wood processing industry tend to increase every year.

Wood from plantation forest in Vietnam is is medium and small sized and therefore not suitable (in general) for the furniture industry and typically used as material for processing paper, manufacturing artificial wood board (planks, boards chips, fiber plywood). It is estimated that about 63% is being processed to chips and the remaining 37% goes directly to the pulp and paper sector, artificial boards, (small amounts to) furniture production and construction (VNFOREST 2012).

The raw timber from plantations and natural forests in the country for the wood processing industry is limited, reaching 12,3 million m^3 round wood/yr. Each year Vietnam has to import about 4 million m^3 of logs to serve furniture manufacturers, accounting for approximately 70-80% of wood materials in the furniture industry (Forest trend, 2013)(CIFOR, 2012). Raw materials are mainly imported from other countries such as Laos, the U.S., China, Malaysia, Thai Land, Cambodia. The amount of wood materials imported into Vietnam increased from 1 million m^3 in 2003 to about 4 million m^3 of logs in 2008-2009. The imported wood material is mainly sawn timber which account for 55%; 15% is round wood and remaining 30% is MDF and different type of plywood.

According to MARD's forecast, the sawn wood demand for wood processing industry in Vietnam in 2020 will increase to 7 million m^3, equivalent to 15 million m^3 of round wood, and Vietnam still has to import raw materials timber till 2020.

FIGURE 6: THE SAWN WOOD DEMAND FOR FURNITURE PRODUCTION IN VIETNAM (SOURCE MARD)



The domestic wood production during 2001–2009 increased by only 5.9%, whereas imports increased by 18% in the same period. Vietnam Forestry Development Strategy 2006 – 2020 aims to reduce dependence on international imported timbers (from 80% to 20%) by 2020 by expanding the area of plantations, developing domestic forest reserves to replace imports, certifying 30% of national production forests and developing and upgrading the export processing industry (CIFOR, 2013).

TABLE 4: FORECAST FOR VIETNAM'S TIMBER DEMAND (MARD, 2006)

Wood timber type (1000m^3)	2003	2010	2015	2020
Domestic consumption and export timber	7,420	14,004	18,620	22,160
Large timber used for industry	4,561	8,030	10,266	11,993
Small wood used for producing particle board and wood-based paneling	1,649	2,464	2,992	1,682
Pulpwood	1,150	3,388	5,272	8,283
Pit wood	60	120	160	200

2.4 Woody biomass development plans

The forest and forestry objectives for 2020 given in the Vietnam Forestry Development Strategy to 2020 are focusing on the following:

To establish, manage, protect, develop and use 16.24 million ha of land planned for forestry and to increase forest cover to 47% by 2020. Growth in the value of forest production (including forest product processing and environment services) is targeted at between 3.5% and 4% per year, this goes hand in hand with a GDP from forestry growth, with a goal of 2-3% of GDP.

To manage, protect, develop and sustainably use 8.4 million ha of production forest — including 4.15 million ha of plantation forest, 3.63 million ha of natural production forest and 0.62 million ha of rehabilitating natural forest for agro-forestry — 5.68 million ha of protection forest and 2.16 million ha of special use forest.

Conduct reforestation after harvest of 0.3 million ha per year, plant 200 million scattered tree per year. While afforesting 1.5 million ha in the period of 2010-2020 and harvesting around 20-

24 million m^3/year (of which 10 million m^3 are big timber), to meet the material demands from the forest product processing and pulp industry, and for export.This export of forest products is expected to reach US$7.8 billion (US$7 billion of timber products and US$0.8 billion of NWFPs). With the current growth rate of export of forest product at around 20%/year.

Fuel-wood harvest for the rural area to amount to 25÷26 million m^3/year. However, forecasts fuel-wood demand to reach 10.24 million tones by 2020 (FAO, 2009).

Increase in income from forest environmental values through the Clean Development Mechanism (CDM), eco-tourism and water resource protection will reach US$2 billion by 2020.

3. ENERGY POTENTIAL AND USAGE OF WOOD RESIDUES

The woody biomass residues can be divided groups of products, as show below:

1) Forest residues, often left in the forest – as currently it is often not economically feasible to transport them out of the forest. This includes stumps, branches, leaves and bark.
2) Saw mill residues & 3) wood processing industry - this could include bark, woodchips, sawdust and wood shavings and/or odd-sized chunks.

Besides the above more obvious residues there are also the bamboo residues produced during processing ranging from 50% to 70% of the total bamboo processed (SNV 2012). The waste material from bamboo processing is used for making briquette charcoal, such as bamboo shavings, bamboo particle, bamboo ends, and bamboo sticks in different length.

The heating value of woody biomass has relatively little variation, it depends on the composition of the wood. Energy content is proportional to the dry-weight of wood; so higher density woods have higher calorific values. In general, softwoods have higher heating values than hardwoods and branches have a higher heating value than bark. Moisture content also affects the potential heating value, the drier the fuel, the higher the heating value. Some indicators of the compositions are given in the table below, this are just for indication.

TABLE 5: HEATING VALUES FOR SEVERAL TYPES OF WOODY BIOMASS (RESIDUES)

(ENERGY BASIC, FACT SHEET 5.8)

Fuel type	Moisture content (%)	Net heating value (MJ/kg)	Net heating value (Kcal/kg)	Ash content (%) (ECN, 2014)	Volatile (%)	Fixed carbon (%)
Green Wood	50%	9.5	2,27	3.56	35.98	10.46
Seasoned Wood	20%	15.5	3,71	-		
Dry Sawdust	13%	16.2	3,87	1.29	72.93	12.78
Wood Pellets	10%	16.8	4,02	0.2	73.98	15.82
Dry Wood (Non-resinous)	0%	19.0	4,54	2.15	81.02	16.83
Dry Wood (Resinous)	0%	22.5	5,38	-		
Dry Stem wood	0%	19.1	4,57	1.7	79.8	18.5
Dry Bark	0%	19.6	4,69	6.8	59,32	13.48
Dry Branches	0%	20.1	4,80			
Dry Needles	0%	20.4	4,88	1,5	72.4	26.1

The moisture content plays a crucial role in determining the calorific value. The moisture content of wood is around 50 % (of total weight) when first harvested, whereas air-dried wood contains between 12% to 20% of moisture yielding a calorific value between 14 MJ/kg and 16 MJ/kg. The depicts the influence that wood moisture has on calorific value is given in table below.

TABLE 6: INFLUENCE OF WOOD MOISTURE ON CALORIFIC VALUE (ENERGYPEDIA, 2014)

Moisture content (%)	Heat value (MJ/kg)	Heat value (Kcal/kg)
0	19.0	4,538
10	16.9	4,036
20	14.7	3,511
30	12.6	3,009
40	10.4	2,484
50	8.2	1,958
60	6.1	1,456

The wood residues in Vietnam has slightly lower quality compared with above data, the property of wood waste in Vietnam is provided in the table below.

TABLE 7: HEAT VALUE OF DIFFERENT WOODY BIOMASS MATERIAL (QUYNH, 2009)

	Woody biomass /fuels	Moistures content (%)	Heat value	
			MJ/Kg	Kcal/Kg
1	Wet-Wood	40	10.9	2,604
2	Dried wood (not in good storage condition)	20	15.5	3,703
3	Dried wood	15	16.6	3,965
4	Dried up wood	0	20.0	4,778
5	Sawn dust	12 - 20	18.5 -19.0	4,420 - 4,778

Wood residues can be used as energy or input materials for other energy products type such as wood pellet, charcoal. In which, sawdust is mostly used as feedstock for pellet production because of its small size (it doesn't required additional preprocessing like crushing). Meanwhile the branches and other big wood waste collected from forest are used for charcoal production or firewood. The bark waste is not widely used as fuel in industry because of its low volatile content. Moreover, bark is bulky waste that is not effective in transportation. Bark waste normally collected by local people and used for cooking purposes.

The sources of wood residues include both forests and non-forest lands. Forests include natural forests, plantation forests, other woodlands including shrub lands. Non-forest lands can include village woodlots and small tree farms, agro-forestry systems, home gardens, crop lands, and scattered and line trees on roads, rivers, canals and areas considered as wastelands.

Vietnam has enormous potential for fuel-wood development and scientists have estimated that natural forests are likely to provide about 41 million tones of fuel-wood/year, plantation forest 1-2 million tones/year and scattered trees 8-10 million tones/year with a total of 70 ÷ 80 million tones per year (26 ÷ 28 million TOE).

3.1 Forest management – residues and potentials

Forest residues consist of everything that is not taken from the forest when the logs are taken out, the rate of materials taken out of the forest depends on the diameter and quality of the log. Of the log input, the main forms of waste are log ends and trims (7%), bark (5%), log cores (10%), green veneer waste (12%), dry veneer waste (8%), trimmings (4%) and rejected plywood (1%) (FAO, 1990).

Recovery rates vary considerable depending on local conditions and on the type of forest it can be anywhere between 40% and 60%. The ratio 50/50 is often found in the literature e.g. for every cubic meter of log removed, a cubic meter of waste remains in the forest. In case logging is carried out for export purposes, values can go up to 2 cubic meter of residues for every cubic meter of log extracted.

In Vietnam, most of the wood residues are left in the forest to rot, in particular in sparsely populated areas where demand for wood fuels is low. In some cases the residues are converted into charcoal or the local people living nearby the forest come and collect the fuel-wood for their cooking purposes. For Vietnam the assumption based on literature has been made that about 60% of the materials taken from the forest is utilized and about 40% stays behind.

Estimated amount of residues from logging is 2.2 million tones (2009), based on a wood yield of 40% from logging (FAO, 1997). In 2010, 4.7 million tones of logged wood processed (0.7 tone/ m^3). There is a considerable recovery of logging residues through collection or production of wood chips for industrial use, or by collection by households for domestic purposes. Bigger residues are converted into charcoal, which is then sold to the industrial sector.

It is estimated in the same report that the distances in which fuel-wood transport is still economically viable is around 100 km (this is estimated at around 50km in Europe), this implies that fuel-wood may be available in interior and mountain regions and mainly serve the needs of local communities as residential fuel-wood. The difficulty in using residues from logging is that the transportation cost is relative high compared with the selling price due to the fact that you are transporting a lot of water and air instead of heating value.

Based on the wood yield of 40% from logging, as the timber demand forecast given in Table 8 (section 2.3), the volume of wood waste drived from logging is calculated in the same table. The residues from logging is mainly wet wood that applying the heat value of wet wood of 10.9 MJ/kg, wood residues from logging in the year of 2003 – 2020 would generate a potential energy source as in table below. This is the potential before the actual conversion of the residue into energy, for example when converting it in standard boilers another 10-20% loss of energy value will take place, when further converted into electricity more losses will occur. All potentials shown in the next few paragraphs are the theoretical potentials. Also the potential is based on the heating values with 40-50% moisture content through natural (sun) drying and the density of wood applied 0.7 tone/m^3.

TABLE 8: FORECASTED ENERGY POTENTIAL GENERATED FROM WOOD LOGGING RESIDUES[4]

Wood type	Unit	2003	2010	2015	2020
Timber demand (60%)	$1000m^3$	7,420	14,004	18,620	22,160
The logging wood waste (40% of timber demand))	$1000\ m^3$	4,947	9.336	12,413	14,773
	1000 tones	*3,463*	*6,535*	*8,689*	*10,341*
Wet wood heat value	MJ/kg			*10.9*	
Energy potential	**TJ**	**37.743**	**71.234**	**94.714**	**112.720**

There are no economic figures on the costs it would take to transport such forest residues from the forest (or after chipping) to a nearby village for economic or energy use. Currently such residues, if collected, are used on household level only. All literature review available in Vietnam indicates that it is not economically interesting to collect such residues from the forest for energy use – nevertheless no financial figures have been given to support these assumptions. It is recommended that a in-field survey is executed to make clear estimations of such costs.

One source (Yoshida, Suzuki, 2010) giving figures on the collection of forest residues from rubber plantations after cutting (tops or branches) in Cambodia (about 30% of the cut volume) can be done relatively affordable, the cost price is around US $5–7/ m^3, including the transportation cost to the customer. The residues in this case are used as fuel for kilns at neighboring brick factories. Another example from the same article but for Malaysia gives examples of cost prices for collection between 16 and 20 USD per m^3, where the selling price is as low as 3 to 5 USD/ m^3.

Scattered trees are the small uneconomical trees left behind with the logging residues. It is estimated there is more than 200 million scattered trees per year in Vietnam, equivalent to 100,000 hectare of plantations (VNFOREST, 2011). A fuel wood yield of 0.4-0.5 tone/ha/year is expected, therefore, the fuel wood potential is about 50,000 tones per year (FSIV, 2009). Collection of these scattered trees and other forest residues can only be done based on sustainable forest management planning (to make sure sufficient material stays behind, for nutritious and biodiversity reasons). In 2005, some 3.45 billion scattered trees were planted, which is equivalent to 3.45 million ha planted at the density of 1,000 per ha. Scattered trees produced 6.04 million tones of fuel wood in 2005. In the period 2006-2020, about 200 million trees are planned to be planted every year. As a result, the amount of fuel wood to be harvested by 2010 was expected to reach 7.79 million tones.

3.2 Estimations of the available residues from the industrial sector

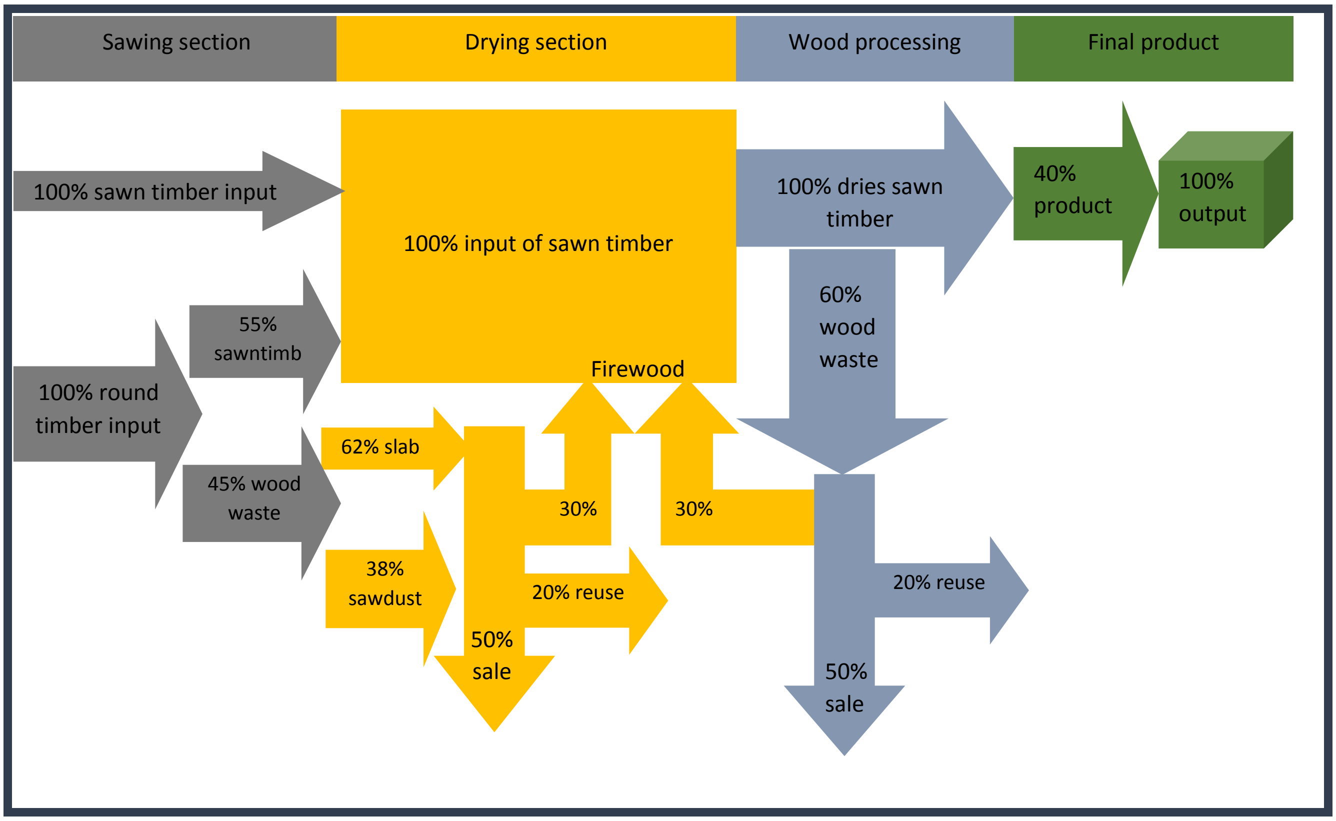
The Green Growth Forestry Strategy of Vietnam stimulates the (1) the use of sustainable raw material, (2) the use of wood waste for energy production and (3) the development of sustainable product. The use of wood waste (or residues) of the processing and forestry sector could be for the products as written in Chapter 2.4.

Currently in Vietnam the industry is not using the full potential of wood residues. It is reported that 20% of the wood remaining (branches etc.) after harvest is collected and

[4] To simplify the calculation, the same heating value is used for all residues (the 40%), therefore it is slightly over estimated.

traded/used by local people and/or the processors. An estimated 30% of biomass by-products or waste is used for energy production, which means that the utilization of waste materials for energy purposes is really small (Worner, 2012). An overview given by the same source give a clear indication of the opportunities (a mass balance for wood processing industry).

FIGURE 7: THE BALANCE MATERIAL AND ENERGY USED IN WOOD PROCESSING INDUSTRY IN VIETNAM (WORNER, 2012)



It is given the figure that 100% of round wood will generate 45% of wood waste in sawing section, that include about 62% of slap shapes and 38% of sawdust at high moisture content. The 55% of sawn timber goes into drying section and ready for the processing section. The wood waste from sawing section will be reused about 20% for particle boards, fiber board production and others; 30% will be utilized as fuel-wood for drying section and the remaining 50% will be sold to the market for multi-use purposes (for fuel for other industries, paper production, packing material etc.).

The energy potential from wood waste in this chapter will be calculated based on the forecasts for demand of Vietnam's timber and forest product that has been issued by MARD (2006), based on the emerging growth in demand for timber (see also more in Chapter 2.3).

Saw mills – residues and potentials

Wood sawmills play an important intermediary role in wood processing industry that connecting the raw material harvesting from forestry to the furniture manufacturing. In the ongoing developments in the wood processing industry, many sawmill have appeared country wide like for example in Ha Tinh (300 workshops), Quang Nam (717 workshops), Quang Binh (384 workshops), Yen Bai (230 workshops) and Phu Tho (400 workshops). In addition, many sawmills are not registered in the official statistics of Vietnam like additional ones in Quang Binh, Kon Tum, Dak Lak, Nghe An etc. The capacity of these sawmills ranging from 300 m^3 to

2000 m^3 round wood/year, provide sawn timber mainly for the domestic use (Forest trend 2011). Saw mills can either be directly connected to the processing plant, or can operate independently and feed into the processing plants.

The wood residues from sawmill include on average 12% bark, while slabs, edgings and trimmings come up to a total 34% while sawdust is another 12% of the log input. After kiln-drying the wood, further processing may take place resulting in another 8% waste (of log input) in the form of sawdust and trim end (2%) and planer shavings (6%). For calculation purposes a yield factor of 50% has been used of wood entering the sawmilling process (38% solid wood waste and 12% sawdust).In 2010, the amount of wood residues from saw milling was estimated about 2.35 million tones and the price of sawdust was about 250 – 400 VND/kg (Forest Trend 2013).

In large sawmills these wood residues are typically used for providing process heat for timber drying purposes, whereas the waste from small mills is typically used locally for domestic cooking or collected for other purposes like energy for brick or lime factories, small industrial application and/or as a source for parquet making (see also the chapter on pellets, Chapter4.2). Some facilities additionally utilize sawdust by mixing with binding material to produce particleboard (Quyen, 2006). In some cases sawdust is used for insect repellent making. Sawdust sometimes is briquetted and carbonised and sold as a high-grade charcoal, which commands a higher price than normal charcoal. Considerable quantities are also used to cover charcoal mound kilns.

The energy potential of residues from saw mills is large. The wood residues as indicated above are woodchip (shavings), slap wood (62%) and sawdust (32%) which totally account for 45% of input material (Figure 7). Stationary mill chippers are often used to screen and re-chip some of the residues to make the product more uniform in size and quality. A good quality mill chip is considered a high-grade product, both for combustion systems and as a feedstock for paper mills, particle boards, fiber board manufacture.

The energy potential from wood waste generated during sawing section will be calculated based on the annual timber demand and assuming waste generation ratios of slap wood and sawdust and its heat value given above. As the sawing section is before the drying section, the wood residues from sawmills still contain a high moisture content.

TABLE 9: FORECASTED RESIDUE TO ENERGY POTENTIAL IN SAWING SECTION

Wood type	Unit	2003	2010	2015	2020
Timber demand (100%)	1000 m^3	7,420	14,004	18,620	22,160
Sawing wood waste (45% of timber demand)	1000 m^3	3,339	6,301	8,379	9,972
Slap wood waste (62% of sawing wood waste)	1000 m^3	2,070	3,907	5,195	6,183
	1000 tones	*1,449*	*2,735*	*3,636*	*4,327*
Sawdust (32% of sawing wood waste)	1000 m^3	1,269	2,395	3,184	3,789
	1000 tones	*888*	*1,676*	*2,229*	*2,653*
Wet wood heat value	MJ/kg	*10.9*			
Wet sawdust heat value	MJ/kg	*10.9*			
Moisture content	%	*40-50%*			
Energy potential of slap wood waste	TJ	15,795	29,811	39,637	47,173
Energy potential of sawdust	TJ	9,681	18,271	24,294	28,912
Total	**TJ**	**25,476**	**48,082**	**63,931**	**76,086**

The residues in the sawing section will be utilized for timber drying section and therefore 50% will already be used within the process, the other 50% can be sold or utilized otherwise (current destinations for this are unknown). Sawmills in remote areas have difficulties with transporting the wood residues and are therefore the wood residues are normally (when not fully collected by local people).

Wood processing industry – residues and potentials

In the wood processing sector, the rate of wood residue depends very much on the processing technology, the type of input material and the type of products that are made. However, due to the old fashion techniques used in Vietnam it is known that only a small volume of wood material is utilized as final product by the wood manufactures, about 40% of the timber (Figure 7). Therefore, wood waste volume is large (about 60% of input material). Woodchips after wood processing is various in sizes and types. Therefore, it requires separation for treatment and processing, something that not all factories are willing to do. Nevertheless homogeneous waste products have higher market prices. When the woodchips are sorted they can be used to make particle boards, fiber boards (MDF) and wood-wool – it could also be used to fuel to processes if heat is required in the wood processing industry itself (drying - mainly in the large industries).

The usage of the residues from this sector are very similar to the usage of the residues from the sawmill sector. Large amounts of residues are also sold to (nearby) households for cooking purposes, with the rising living standard the demand reduces over the years. Instead of using these wood chips, people use long wood pieces for burning because of its convenience in transportation and combustion, and because it requires less attention during cooking tasks. Wood chips from large scale factories, are often being recycled and used for producing particle boards, fiber boards, or used for energy purposes for wood drying (ENERTEAM, 2012).

TABLE 10: RESIDUES FROM WOOD PROCESSING (IE, 2011)

Sources of wood waste	Wood waste useful for energy production (million tones in 2010)
Butt ends and tree bark	5.58
Sawdust and shavings	1.12
Building (timber formwork and house repairs)	0.80
Total	**7.50**

The wood residues from wood processing industry have been calculated based on the volume of timber consumed and the ratios of residues generated during processing with sawdust (10% wood material) and woodchip (50% wood material) as totally of 60% and its heat values (GiZ, 2011)

In 2010, about 16 million m^3 was processed to produce 6.5 million m^3 of sawn wood, the wood residues was calculated to be 9.5 million m^3, equivalent to 6.7 million tones (including 5.58 million tones of wood waste and 1.12 million tones of sawdust).

TABLE 11: ENERGY POTENTIAL FROM WOOD WASTE IN THE WOOD PROCESSING INDUSTRY

Wood type	Unit	2003	2010	2015	2020
Large timber demand (100%)	1000m^3	4,561	8,030	10,266	11,993
Dried wood chip (50% of timber demand)	1000 m^3	2,280	4,015	5,133	5,996
	1000 tones	*1,596*	*2,810*	*3,593*	*4,196*
Dried sawdust (10% of timber demand)	1000 m^3	456	803	1,027	1,199
	1000 tones	*319*	*565*	*719*	*839*
Dried woodchip heat value	*MJ/kg*	*20.0*			
Dried sawdust heat value	*MJ/kg*	*18.5*			
Energy potential of woodchip	TJ	31,927	56,210	71,862	83,951
Energy potential of sawdust	TJ	5,906	10,398	13,294	15,530
Total	**TJ**	**37,833**	**66,608**	**85,156**	**99,481**

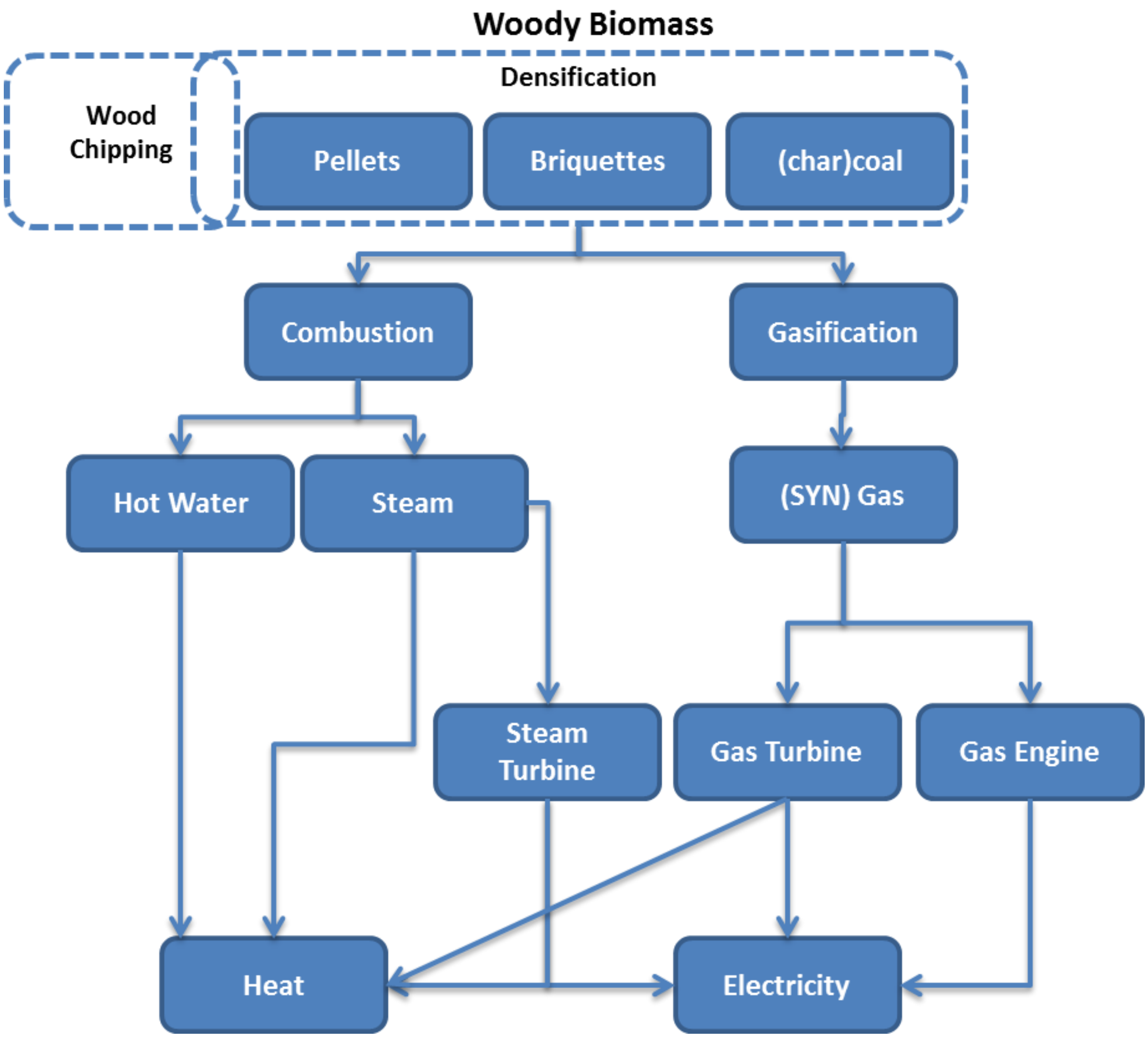
The residues from forestry sector are huge potential for fuel-wood and energy production. The estimation for year of 2015 shows that, there will be available approximately 9 million tones of wood waste from forest harvesting activities and 10 ÷ 12 million tones of wood residues from wood processing industry, carried 244,000 TJ energy in total. The production of bio-energy in Vietnam will become more realistic and woody biomass sources are likely to be competitive with fossil energy in power sector in future.

4. FROM WOODY BIOMASS TO ENERGY CARRIERS

In this chapter three aspects of energy carriers will be discussed, (1) the technology on how to make it including potential suppliers in Vietnam and the costs, (2) the characteristics of the product and the input materials needed and (3) the current use of the product in Vietnam. The focus is on woodchip, pellets, briquettes, and charcoal. And in a lighter form some other topics will be discussed.

Chapter 4 and 5 are based on the overview below. Where the first chapter as said will focus on energy carriers including densification technologies, and Chapter 5 will focus on the conversion technologies available in Vietnam (Figure 8).

FIGURE 8: POTENTIAL CONVERSION STEPS FROM BIOMASS TO ENERGY (CARRIER)

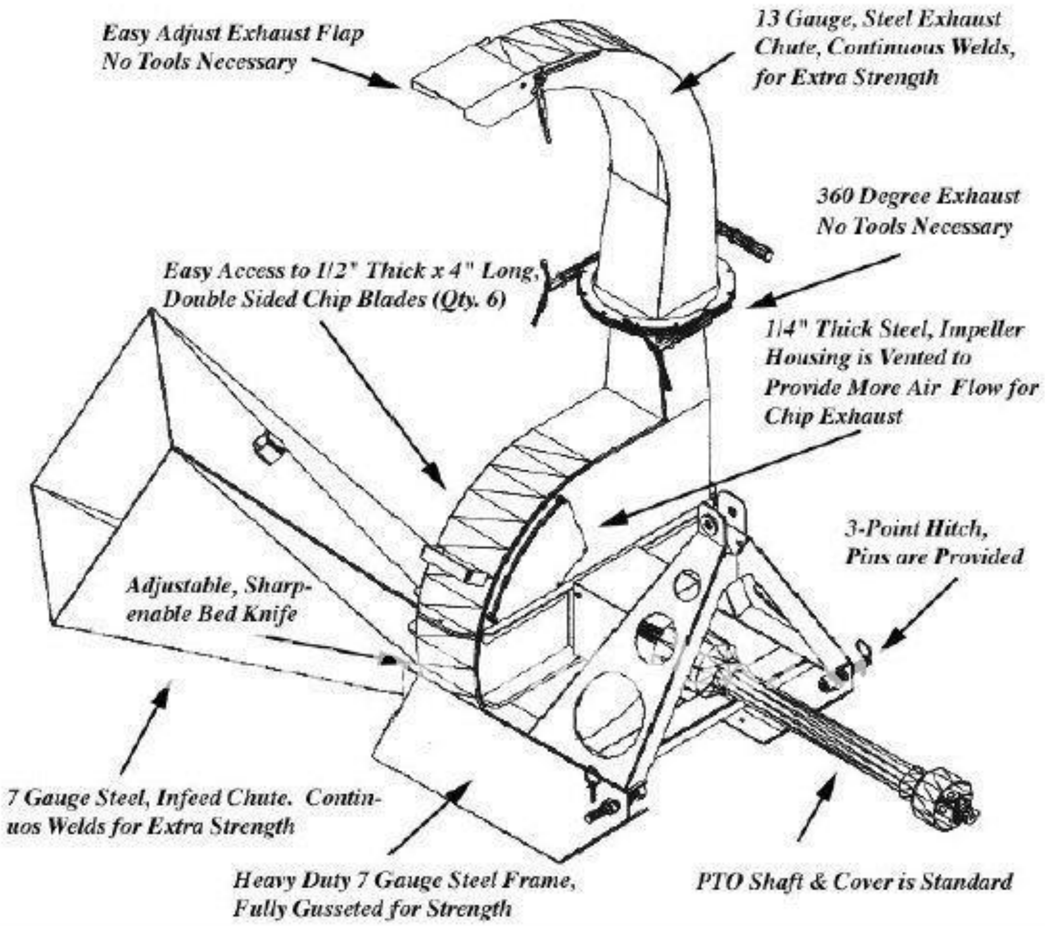


4.1 Woodchips

Technology, suppliers and costs

One of the main challenging characteristics of biomass is the moisture content and the size. When transporting biomass you are also transporting large amounts of water and air. Another problem is the transport of logs and/or branches from the forest to the desired location. Through chipping transport issues can be overcome, this will not solve the moisture challenges – even though chips can be additionally dried before transported. This can take place either on a small scale –often in the forest with portable machines as shown in Figure 9 (for smaller trees and branches) or on a larger scale where whole logs can be processed.

FIGURE 9: DESIGN OF A WOOD CHIPPER FROM QINGDAO HAYLITE MACHINERY CO. LTD.CHINA[5]



Even though Vietnam is a leading woodchip production and exporting country, Vietnam is still importing the technologies mainly from Taiwan and China for the large scale production.

National manufacturers developed and produce small chipping machines. Domestic woodchipper capacity is observed to be from 30-35tones/h, and investment costs are between 2,500 and 3,000 USD depending on its capacity (Table 12).

TABLE 12: NATIONAL WOOD CHIP TECHNOLOGY MANUFACTURERS IN VIETNAM

Name of supplier	Capacity	Type of biomass	Remark
Vietnam Pellet Machine (VPM) Ltd.	2-27 m^3/h	Woodchip	www.vietnampelletmill.com.vn
Van Phu Equipment Ltd	-	Woodchip	www.thietbicongnghiepvanphu.com
Phuong Tam Group	30-35 tones/h	Woodchip	www.maybam.vn
Phuong Quan U& I	25tones/h	Woodchip	www.mayepcuivien.com
COSACO Engineering & Machinery	10-30 m^3/h	Woodchip	www.cosacovietnam.com

[5]Design just used for information purposes, it is not a local design nor used in Vietnam yet.

Woodchip export from Vietnam has been mainly to China, Japan and Korea, with price ranges between 85USD and 138USD/ton. According to Vietnam Customs (Son Duong, 2013) Vietnam has exported 1.6million tones of woodchip in the first quarter of 2013. This high demand and better prices from abroad has created a situation where the domestic pulp and paper producers face difficulties in sourcing their materials. The Vietnam pulp-paper association has proposed to increase export tariff to 5% in order to limit the exploitation of the young forest for woodchip production for export and for keeping the woodchip sources for domestic paper production (see also chapter 0).

Wood chips properties

Woodchips are a medium-sized solid material made by cutting, or chipping, larger pieces of wood. Woodchips may be used as a biomass solid fuel and are raw material for producing wood pulp.

Moisture contents can differ a lot depending on the freshness of the wood and the processing steps taken. Moisture contents can be from 10 to 50% (ECN, 2014). All other characteristics are equal to that provided in Chapter 3, as it is a forest product. Wood chips may have a bulk energy density of about 50%. Wood chips for energy applications should meet an appropriate quality standard if they are to be used reliably in combustion equipment, especially small scale and domestic equipment – they should be homogeneous of size, especially when fed into furnaces for energy generation (for optimal combustion). Physical parameters, such as maximum size and absence of slivers or fines (sawdust), and maximum moisture content are important to allow reliable operation and prevent feed blockages.

Woodchip production and use in Vietnam

Woodchip production industry has grown explosively in the recent years. In 2009, there were 47 plants in Vietnam with woodchips export figures around 2.3 million tones. By 2012, this increased to 112 plants with a total design capacity of approximately 8 million tones/year, and with woodchip export figures that increased to 6.2 million tones (Table 14) (equivalent to 12.4 million m^3 of round woof from plantation forest), 20% of global trading amount. Currently, Vietnamese woodchip are mainly exported to China, Japan, Korea and Taiwan for the pulp-paper production industry.

Most plants are under operation located in North Central and coastal provinces. The explosion of woodchip industry could be explained by quick profits derived from woodchip export; low investment cost, and especially in the increased available input material from plantation forest.The wood chips in Vietnam is mainly from Acacia and Eucalyptus with small amount of Cu mainly plated in the South.

TABLE 13: THE STRUCTURE OF INPUT MATERIAL FOR WOOD CHIP PRODUCTION INDUSTRY IN 2011 (FOREST TREND, 2013)

Tree	Volume (m^3)	Percentage (%)
Acacia	7,684,600	70
Eucalyptus	2,964,060	27
Cajuput	329,340	3
Total (m^3)	**10,978,000**	

Another 18 woodchip plants with a capacity of approximately 0.8 million dry tones/year were expected to be put into operation in 2013. The woodchip plants normally operating with approximately 60-70% of design capacity. Once fully in operations, the woodchip industry will require about 18 million m^3 of round wood as input material from the plantation forest of eucalyptus and acacia. Given the current status of plantation forest, Vietnam will not have enough inputs to provide those woodchip plants in the future. In 2012 the material was provided by individual households (50%), state-owned enterprises and cooperatives (15%) and private enterprises (35%).

TABLE 14: THE DISTRIBUTION OF WOODCHIP PRODUCTION IN VIETNAM (FOREST TREND, 2013)

No	Location	Plant	Design Capacity *(max tones/yr)*	Export output *(Tones/yr)*
1	Red River Delta	3	270.000	226.000
2	North East	-	-	-
3	North West	16	1.048.000	900.000
4	North Central	21	1.750.000	1.500.000
5	South Central	55	4.011.000	3.000.000
6	Highlands	-	-	-
7	Southeast	6	590.000	400.000
8	Mekong River Delta	7	400.000	200.000
	Total	**112**	**8.069.000**	**6.226.000**

TABLE 15: WOODCHIP SUPPLIERS AND ITS CAPACITY PER ORGANISATION TYPE (FOREST TRENDS, 2013)[6]

Form of business	Quantity	Installed capacity (tones dry mass/year)
Limited companies	60	4.536.000
Joint stock companies	20	1.338.000
Private companies	12	385.000
Joint venture companies	18	1.650.000
Foreign companies	2	160.000
TOTAL	**112**	**8.069.000**

4.2 Wood Pellets

Technology, suppliers and costs

The pelletizing of biomass such as sawdust, shavings from wood processing industry or from forest residues, helps solving the relativelow -density problem of wood wastes. Wood pelletis a type of biofuel made by compressing woody sawdust (from saw mills / wood processing factories) as small pellets with diameter of about 4mm and moisture of lower 10%, which makes it a very efficient for combustion.

Vietnam has limited experienced with pelletizing technology and imports wood pelleting technology (i.e from Japan, German or Taiwan). Some domestic companies and research centres have started studying and developing woody pelleting machines to adopt to

[6] This survey is missing data from the Northwest and the Highlands

Vietnamese condition such as Vietnam Institute of Agriculture Engineering and Postharvest Technology (VIAEP) and Vietnam Energy of Institute. An overview is given in Table 16 on local technologies available.In most cases the raw materials are collected from surrounding households, sawmills and processers as input materials for the production processes.

TABLE 16: SMALL SCALE WOODY RESIDUES PELLET MACHINE SUPPLIERS IN VIETNAM

Name of supplier	Compressing capacity	Type of pelletized biomass	Remark
Vietnam Research Institute Agriculture Machinery (RIAM)	1-3 tones/h	Biomass residues (rice husk, coffee shell, corncob, sawdust…)	www.riam.com.vn
Vietnam Institute of Agriculture Engineering and Post-harvest Technology (VIAEP)	-	Biomass residues (rice husk, coffee shell, corncob, sawdust…)	www.viaep.org.vn
Vietnam Pellet Machine (VPM) Limited	0.5-4 tones/h	Woody wastes	www.vietnampelletmill.com.vn
Hatech Energy Corp	1,000 tones/h	Woody wastes	www.escohatech.com
Phuong Quan U&I Ltd	500-800kg/h	Woody wastes	www.mayepcuivien.com
Hoang Phi Limited	250-500kg/h	Rice husk	www.mayepcuitrau.com
Phuong Tam Group	500kg/h	Woody wastes	www.mayepcui.net
VPM Equipment & Technology	0.8-1.2 tones/h	Woody wastes	www.thietbivpm.com
Thanh Danh D.N Ltd	350kg/h	Woody wastes	www.thanhdanhdn.com
Nhat Phu Thai Ltd	1-1.8 tones/h	Woody wastes	www.nhatphuthai.vn
Che Tao Viet JSC	-	Woody wastes	www.chetaoviet.vn
Van Phu Equipment Ltd	-	Woody wastes	www.thietbicongnghiepvanphu.com

The Institute of Energy (Cuong, 2013) has estimated productioncosts of pelletizing in Vietnam as the table below.

TABLE 17: PRODUCTION COST OF BIOMASS PELLET (CUONG, 2013)

Type of applied technology	Type of biomass	Production cost (VND/kg)
Pelleting	Rice husk	1.968
	Bagasse	1.467
	Mixed bagasse and rice husk	1.532

Wood pellet properties

The feedstock necessary to make this biomass fuel has anoptimal moisture content of less than 10% (a drying step is a standard stage of the pellet making process). Wood pellet production has rapidly developed in Vietnam recently, following the ongoing trend of Renewable Energy in general. Pellets are easier to store and can be handled automatically. Pellet production systems are usually simpler and less expensive to install. The application of fuel pellets are quite diverse, including: livestock, industry, in power, in domestic as for cooking. Some specific specifications of wood pellets in Vietnam are given in Table 18. Official reporting by IE has indicated nevertheless that the average heatingvalueof pellets from Vietnam is between 14.5 and 15 GJ/tone (Table 19, compared to –for example- 16.9GJ/tone for Canadian wood pellets.

TABLE 18: THE TECHNICAL SPECIFICATION OF A WOOD PELLET PRODUCER IN VIETNAM

Technical specification	Pellet from sawdust*	Wood pellet from woodchip*	Wool pellet from rubber[7]
Diameter	8 mm x 10 - 15 mm	6 – 8mm x 10 – 50 mm	6mm
Density	-	650 – 700 kg/m^3	-
Heat value	4600 Kcal/kg	> 4500 Kcal/kg	17.84 MJ/kg / 4260 kcal/kg
Moisture content	6 - 8%	< 6%	8.08%
Ash content	1,5 - 2%	< 1.2%	1.17%
Sulfate content	< 0,03%	0.023%	-
Carbon content	< 15%	-	-

TABLE 19: LOW HEAT VALUE (LHV) OF BIOMASS PELLETS (CUONG, 2013)

Type of pelletized biomass	Low heat value-LHV (MJ/kg)	Low heat value-LHV (Kcal/kg)
Woody residues	14.5-15	3,463 – 3,582
Bagasse	7.8-8	1,862 – 1,910
Rice husk	12.5-13	2,985 – 3,104
Rice straw	11.5-12	2,746 – 2,866
		** examples from TTK Wood Pellets Company*

The European market has quite strict norms for the production of pellets, the most commonly used norms are the DIN 51731 or Ö-Norm M-7135, with less than 10% water content and a uniform density level (higher than 1 tone per cubic meter[8]). When produced by hammer mills there is almost no difference in finished product even if different wood types are used – this is heavily dependent though on the equipment used for production. The European market also has a special sustainability label for wood pellets called the "EN-plus" label. This makes that no pellets are currently transported to Europe. Nevertheless the Korean market is desperately looking to import pellets from the Asia region their domestic supply is only 30% or less than their demand[9]. The Korean market has no strict rules or standards on quality of the pellets, even though prices for higher qualities are slightly higher.

BOX 2: POTENTIAL BUSINESS CASE FOR PELLETS - MANH THONG J.S.C. (SNV, 2012)

Manh Thong J.S.C. is a wood processing company; with 2500 Ha own concessionaries, making products from the Hybrid Acacia tree, one of the most common trees in Vietnam.

During this process large amounts of residues are produced, as shave-wood, bark, sawdust (estimated in 10% humidity, around 125MT / working day). They are planning on constructing three Completed Wood Pellet Plants with 2 - 4 MT/Hr each plant on their plantation in Daknong Province and their Sawmill in Binh Duong Province. After obtaining quotations, and visiting providers, in several countries among them, US, Italia, Germany and China, Manh Thong is still looking for support in technology and financing, even though they are ready to invest themselves. Feasibility studies show acceptable payback times as potential prices are below the current market value of wood pellets. Furthermore the (co)ownership of Manh Thong of the concessionaries, wood processing

[7] The rubber wood pellet qualify test control sample, product of Tan Phat company, certified by SGC
[8] This means it sinks in water. Bulk density about 0.6-0.7 ton per cubic meter.
[9] Interview with VinaWoodPellets

and pellet production plant will give multiple benefits, secured feedstock supply is the most important one.

Wood pellet production and use in Vietnam

Vietnam could potentially become an important wood pellet producer with a large and rapidly expanding timber industry; the total technical potential of sawdust was estimated to be 5.8 million tones, but other small wood residues are also milled to sawdust for pellet production. In 2010, Vietnam exported to Korea and Japan 4399 and 1019 tones wood pellet respectively at the price of 91 EUR/tone (IEA BioEnergy , 2011). Total production capacity of the large wood pellet plants in Vietnam was reported to be between 120 - 140 Ktones.

Beside the companies below, there are some notifications of wood fed pellet plants in Vietnam, mainly small scale supplying pellets for local demand – no public information on this is available.

TABLE 20: SEVERAL LARGE WOODY PELLET PRODUCERS IN VIETNAM

Name of producer	Type of pellet	Capacity	Location	Remark
Vinaconex	Wood pellet	49,000 tones/year	Yen Bai province	Under construction
Ha Thanh Group	Wood pellet	50,000 tones/year	Phu Tho province	Equipment imported from German
Duy Dai Cooperation	Wood pellet	24,000-36,000 tones/year	Da Nang province	
Silocorp	Wood pellet	60,000-80,000 tones/year	Tan Thanh district, Ba Ria Vung Tau province and Nghi Son-Thanh Hoa province	Under construction (to be put in operation in 2014)
Phu Tai Bioenergy	Wood pellet	54,000 tones/year	Quy Nhon-Binh Dinh province	Operating
Thao Nguyen Xanh company	Wood pellet	3,000 tones/month	Nghi Loc-Nghe An province	Looking for capital
Trasesco company	Wood pellet	120,000 tones/year	Vinh Cuu-Dong Nai province	Looking for capital
Thanh Thanh Khang company	Wood pellet	5,000 tones/month	Binh Duong province	Operating
Seon Environment Technology (Korea) & DHT company (Vietnam)	Wood pellet	2,000 tones/month	Van Canh-Binh Dinh province	Under construction
MEGA CAPITAL	Wood pellet	1,000 tones/year	Thang Binh-Quang Nam province	Under construction
Hoa Thien Wood pellet company		3,000 tones/month	Thai Nguyen province	Operating since 2011

Sources: (IEA BioEnergy , 2011), http://silopcorp.vn/, http://woodpellet.com.vn/, Can Tho stnews, Quang Nam Province, Vinawoodpellets

There is also a domestic market under development, for example for the use of pellets in gasification stoves like Minh Quang Group and their Bio-Cooker and GreenCom with their Trexanh stove. Demands for this local use is still small though.

BOX 3: PELLET PRODUCTION AT HOA THIEN FACTORY IN THAI NGUYEN (HTTP://VINAWOODPELLET.WORDPRESS.COM/)

Hoa Thien is a pellet production company with installed capacity of 2,000 – 3,000 tones/month, using Chinese Technology. The factory stated operating since 2011 with 10 pellet production lines. The investment cost was around 2 million US$, party financed with commercial bank loans.

The sawdust is the main input material for pellet production that collected from sawmills and wood manufactures around, the sawdust input with the moisture content of 40 – 50% buy at the price 15 - 60 US$/tone depend very much on the season. To ensure the sufficient input sawdust material for production, Hoa Thien has sent the crushing machines to the local wood processing factories to crush the larger wood material in to smaller powder to use for the wood pellet production. The moist sawdust need to be dried up to 8 - 10% and then pelletized. The dryer system utilizes 100% the firewood as material that purchased locally from processing factories or collecting from forest to produce steam for input material drying. .

Hoa Thien exports their pellet product mostly to Korea market at the FOB price of up to 125 $/ton. The payback period is expected to be 3- 5 years.

4.3 Wood briquettes

Technology, suppliers and costs

Wood briquettes are made from wood chips, shavings or dust and are pressed together under high pressure (no binder necessary), this has multiple advantages as already mentioned in the above chapter on pellets, this is especially related to the transportation of biomass (higher density, higher caloric value, less moisture).

The wood briquetting machine making is even less developed than the pellet sector in Vietnam. In of 2011, the Vietnam Energy of Institute (GiZ, 2011) has imported from Thailand a fuel briquetter to try on the domestic feedstock of woody sawdust, rice husk, coffee shell and bagasse. Based on the experiment results, IE has identified the need to improve this screw-model briquetter and offered some improvements for this equipment. Research also went into lengthen the longevity of the screw. The improved version was then substantiated at different places nationwide for widespread promotion to people and training was provided to the business and technicians.

The Institute of Energy has estimated productioncosts briquetting in Vietnam.

TABLE 21: PRODUCTION COST OF BIOMASS PELLET/BRIQUETTE (CUONG, 2012)

Type of applied technology	Type of biomass	Production cost (VND/kg)
Briquetting	Rice husk	761
	Coffee husk	797
	Sawdust	820
	Bagasse	1.093

Wood briquettes properties

Wood Sawdust can be directly used for briquetting. Sawdust briquettes is produced with two distinct types: briquette with holes through the centre, and solid briquettes. A solid briquette is manufactured using a piston press and ones with a hole are produced using a screw press.It is a very similar process to forming a wood pellet but on a larger scale. Under heating at high temperature, the natural lignin in the wood binds the particles of wood together to form a solid. Burning a wood briquette is far more efficient than burning firewood. Sawdust briquettes is used as fuel for boiler, replacing for other type of fuel as coal.

TABLE 22: THE TECHNICAL SPECIFICATION OF A WOOD BRIQUETTE IN VIETNAM

Technical specification	Wood briquette from sawdust*
Diameter	70 mm, 80mm, 90mm
Density	1.2 – 1.4 kg/dm3
Heat value	4,400 – 4,600 Kcal/kg
Moisture content	5.8%
Ash content	1.2%

According to testing results done by SGS Certification Company for the woody briquettes produced Viet Phat Bio Corp key properties of woody briquettes are as flows

TABLE 23: KEY PROPERTIES OF WOODY BRIQUETTES (VIETBIOENERGY WEBSITE)

Key properties	Unit	Briquette size (L* W * H = 150 * 60 * 92 mm)	Briquette size (L* W * H = 185 * 75 * 115 mm)
Total moisture	%, wet basic	7.5	7.57
Volatile mater	%, dry basic	83.55	81.80
Ash content	%, dry basic	0.83%	1.45
Fixed carbon	%, dry basic	15.62	16.75
Gross calorific value	Kcal/kg, dry basic	4,683	4,625
Sulfur	%, dry basic	0.0176	0.0257
Bulk density	Kg/m^3	978.2	944.6

Wood briquettes production and use in Vietnam

In Vietnam, woody briquettes are mainly produced by using sawdust, pine wood, rubber wood and acacia or a mixture of these. It has a wide range of application and can be used for all kilns, furnaces, stoves and especially in industrial boiler systems. Currently, there are many companies producing woody briquettes such as Viet Phat Bio Cooperation, Gia Gia Nguyen Ltd, Nhat Hanh Ltd, Cuu Long Company and Wood Pellets Vietnam. Most these companies are based in the South of Vietnam. The producers of the wood briquette making machines are the same as the companies that make the wood pellet machines (as it is very similar) – see also Table 16.

FIGURE 10: A SAWDUST BRIQUETTE PRODUCING LINE IN VIET PHAT BIO CORP

As observed the briquette supply capacity of domestic companies can be up to 7,000 tons/month and the free-on-board (FOB) price being traded on the market is around 100-140USD/ton.

4.4 Charcoal

Technology, suppliers and costs

In Vietnam, charcoal is produced mainly from wood, coconutshells and bamboo residues. Charcoal is produced through a carbonization process. Types of charcoal kilns used in Vietnam are simple (inefficient) earth mound kilnsthat are polluting the environment due to heavy smoke development. The conversion efficiency of this type of kiln is typically about 10-15% (BTG, 2013). Recently, some domestic companies such as Biffa have adopted charcoal production technology from Japan (similar to brick kiln, often with higher efficiencies up to 30%) to make charcoal production more clean, they are using branches and top of acacia, and the production is aimed at export to Japan at 1-1.4 USD/kg (DoST Binh Dinh, 2013). It is reported that there are about 100 of these new kilns built in Binh Dinh province to provide about 300 tones charcoal per year.

Bamboo residues cause environmental problems due to dumping and due to unsustainable use (SNV, 2012) this can be prevented by using this for charcoal making as well. This is getting more attention by scientists in Vietnam recently. In Thanh Hoa province -where there are about 49 bamboo processing workshops that annually generate about 76,000 tons of bamboo wastes- a pilot project which utilises bamboo residues for charcoal making was implemented and the results showed that 1kg bamboo residue can be converted into 76gram charcoal (MONRE, 2008). Besides, charcoal sourced from coconut shell is popular in Southeast of Vietnam. It is made by using closed brick kilns to carbonise coconut shell in anaerobic condition. However, these kilns are not equipped with heat recovery system for utilization and smoke is being emitted into the atmosphere which makes it environmentally polluting.

FIGURE 11: CHARCOAL MAKING KILN FROM COCONUT SHELL

The highest and most consistent carbonisation efficiencies can be achieved using (semi-) industrial retorts not yet available in Vietnam, and also have a higher investment costs (BTG, 2013). Also to achieve higher conversion efficiencies and improved environmental performance the implementation of chimneys and of tar and methane recovery facilities is worth investigating.

The market price of charcoal is changing time to time and depending on the nature and quality of charcoal and is normally ranged from 500-800 USD/tone. To evaporate one kilogram of water takes about 2.5 MJ. In the case of charcoal, the calorific value is around 30 MJ/kg. In its statistics, the FAO uses a conversion factor of 165 kg of produced charcoal from one cubic meter of fuelwood (see more in 4.4.2).

Charcoal properties

There are many type of charcoal that made from different input material. Charcoal could be made from wood collected from forest such as the whole tree wood or branches. Charcoal also can be made from peanut shell, coconut shell or rice husk/sawdust briquette. The current status information of charcoal production in Vietnam is only limited available, however, it is reported that charcoal is mainly produced at households scale. The specification of a charcoals producer in Vietnam has been given in Table 24 and Table 25.

TABLE 24: AN EXAMPLE OF TECHNICAL SPECIFICATION OF CHARCOAL IN VIETNAM FROM ARTEX THANGLONG JSC

Specification	Wood charcoal	Mangrove charcoal	Coconut sheel
Moisture content	1.75%	2.39%	3.57%
Ash content	2.72%	2.04%	2.67%
Volatile matter content	28.17%	21.95%	15.02%
Fixed carbon content	69.11%	76.01%	82.31%
Calorific value	7216 Kcal/kg	7905 Kcal/kg	7930 Kcal/kg

TABLE 25: KEY PARAMETERS OF CHARCOALS

Parameter	Coconut shell based charcoal (http://www.vietcoconut.com.vn/)	Acacia based charcoal	Charcoal sourced from bamboo(www.gret.vn.com)
Ash content	5-15%	3.5%	< 6%
Volatile content	25%	-	-
Calorific value	5,000-7,000kcal/kg	7,000kcal/kg	7,500kcal/kg
Moisture content	5-7%	9%	-

Charcoal production and use in Vietnam

The charcoal production and utilization are concentrated in North-East-South zone, Mekong River Delta and several provinces of South-Central Coast zone. However, charcoal making is still executed in traditional ways with extreme low efficiencies, causing many environmental and social impacts. The capacity of kilns is about 25-50 tones of charcoal with an average wood conversion efficiency of 22-25% and fuel end use efficiency about 45-46%. In more efficient systems this could be as high as 40% (BTG, 2013).The yields are dependent on many variables, such as geographic location, moisture content of wood input; size of material and the experience of the operators. The charcoal is mostly used for domestic cooking, food vending, tea drying, or can be used for non-energy purposes such as water purification, for soil texture improvement, and in chemical and steel industries.

Charcoal in Vietnam comes mainly especially from Mangrove wood. Wood material is collected from forest with an optimal diameter of above 15cm and below 30cm, since this size will produce less ash during incineration, (the wood with size more than 30cm is too heavy for cutting and transportation). Charcoal is also produced from coconut shell; sawdust briquette or bamboo residues that the input materials are more available.

4.5 Other uses of woody biomass in Vietnam

Plywood production

Like the total wood processing industry, the sector for Medium-density fibreboard (MDF)has also grown rapidly recently. The wood products made from artificial board has play important role in the market. In 2010, the artificial board processing industry produced 650,000 m^3 of finished products, equivalent to about 1.3 million m^3 of wood raw material, mainly from plantation forest, in 2012, the plywood production capacity increased to reach about 2 million m^3/yr, a significant growth of the sector. Statistical Table 10 factories producing artificial board the current operating in Vietnam and the current raw material demand for these plants.

TABLE 26: MDF PRODUCTION IN VIETNAM 2012

Factories	Design capacity (m3)
Fiber MDF (10 companies)	1,318,000
Particle board (okal) (6 companies)	716,500
Total	**2,034,500**

When all MFD factories operate at their full capacities they will require about 4 million m^3round timber/yr. The input materials are mobilized mostly from plantation forest. In case they will run at full capacity this will put more pressure on the sector.

Firewood

According to Vietnam's Forestry Development Strategy (2007), demand for fuel-wood will rise from 25 million m^3 per year in 2003-2005 to a level off at 26 million m^3 to 2020 (FAO 2009).Firewood is used to fuel brick and ceramic kilns, noodle, cake and tofu manufacture, sweet processing and domestic cooking. Annually, about 24.5 million tones of firewood are consumed (equivalent to 8,805 million TOE) (FAO 2009) and about 75% of Vietnam's population lives in rural areas and is reliant on traditional fuels including wood and other biomass (SNV, 2011).

Firewood is only sustainable when it comes from forests that are managed in a sustainable way, firewood is both collected manually (and potentially illegally) by households in Vietnam as well as collected in an official way and sold to (domestic) users. Currently, the firewood is sold in the market at the price of 200,000 – 500,000 VND/m^3 depend on the quality.

The proportion of biomass used in total national energy consumption fell from 73% in 1990 to 50% in 2002; however, the quantity of biomass used has increased from 12.39 million TOE (1990) to 14 million TOE (2002)

In the recent development in Vietnam, more modern energy sources are used; firewood is being replaced by other energy sources such as electricity and gas. By 2020, total firewood consumption is expected to fall and more efficient modes of firewood utilization will become widespread; however, firewood will still be an important energy source in rural and mountainous areas (as indicated above) rural population will still rely on biomass for cooking needs and as an important energy source for local industries.

The LEAP (Long-term Energy Alternative Planning) 2002 had developed a number of scenarios based on economic development forecast and found that the timber consumption for commercial energy demand will be decrease in the economic development. The timber consumption as fuel-wood for different levels use of household, industries, agriculture and service has been forecasted as table below.

TABLE 27: FUEL-WOOD DEMAND, UNDER DIFFERENT SCENARIOS (MILLION TONES) (FAO 2009)

Scenario	1995	2000	2010	2020
Baseline Scenario: Sectors using wood energy included in future calculations are households, industry, agriculture and services.	23.77	24.50	25.28	23.93
Scenario 1: Baseline + replacing fuel-wood with other alternative fuel at different levels of households, industry, agriculture and services	23.77	22.87	19.19	12.83
Scenario 2: Scenario 1 + 5% of urban households, 15% of rural households are using advanced kitchens for cooking, by 2020	23.77	22.79	18.10	10.76
Scenario 3: Scenario 2 + industrial tree planting and a scattered tree planting program	23.77	22.79	17.82	10.24

Paper / Pulp production and needs

In 2011, the pulp and paper industry in Vietnam has reached 353,500 tones of final product, this is equivalent to 1.76 million m^3 of input timber consuming. The actual demand for pulp and paper products is greater than domestic production, therefore Vietnam imports about 30% of the total input pulp material for the paper industry. The table below shows actual production and consumption of pulp paper in Vietnam.

TABLE 28: PULP CONSUMPTION, PRODUCTION AND IMPORT OF VIETNAM DURING 2007-2011

Pulp paper	2007	2008	2009	2010	2011
Domestic production	353.698	316.914	311.246	345.875	353.500
Import	131.590	134.454	99.800	106.477	132.000
Actual consumption	**485.288**	**451.368**	**411.046**	**452.352**	**485.500**

The shortages caused by the explosive development of woodchip industry as described above. The pulp sector cannot compete with woodchip industry on the input material which has led to import pulp and paper material from abroad, causing high production cost. It is interesting to observe that large amounts of woodchips are now exported, while input materials for the pulp industry are imported. As local producers identified this, and would like to reduce the production cost, the pulp and paper sector has requested the Government to introduce an export tax for woodchip export (Forest trend 2013).To avoid exploiting young timber and reserve wood material for domestic production, this request has been officially be hand in by MOIT to the Ministry of Finance requesting a woodchip export tax of 5%. This tentative scheme is now under negotiation process (Vietnam News. 2013).

5. UTILIZATION OF WOODY BIOMASS

Energy is one of the main applications of woody biomass and forest residues. While there are figures on the domestic demand for fuel wood (as indicated above) the amount of fuel-wood used for energy production has not been assessed by any study or research, when studying the individual technologies and opportunities it can nevertheless be assumed that the usages for energy purposes –besides domestic cooking- is limited. According to Cuong (2012), the potential of wood energy is about 43million tones, mostly waste from the forest (53%). The wood energy potential has been indicated as table below.

TABLE 29: THE WOOD ENERGY AND WOOD WASTE AVAILABLE IN VIETNAM (CUONG, 2012)

Woody biomass resource	Amount for energy usage (million tones)
Natural forest	14.07
Plantation forest	9.07
Bare land	2.47
Industrial perennial	2.0
Fruit tree	0,41
Scattered tree	7,79
Woodchip	5.58
Sawdust and shaving	1,12
Reused from construction	0,8
Total	**43.31**

The Government has implemented programs to plant forest not only for industries and environmental purposes but also to meet the huge demand for fuel-wood. Besides formal programs, there are about 200 million scattered trees planted in the country each year. These trees could provide about 5 million m^3 of small wood and fuel-wood and 15 million m^3 of firewood for construction and energy needs in rural areas and reduce pressure on natural forest (MARD, 2006). More on the use of woody biomass for energy purposes can be found in the Chapters 4.4 to 4.6.

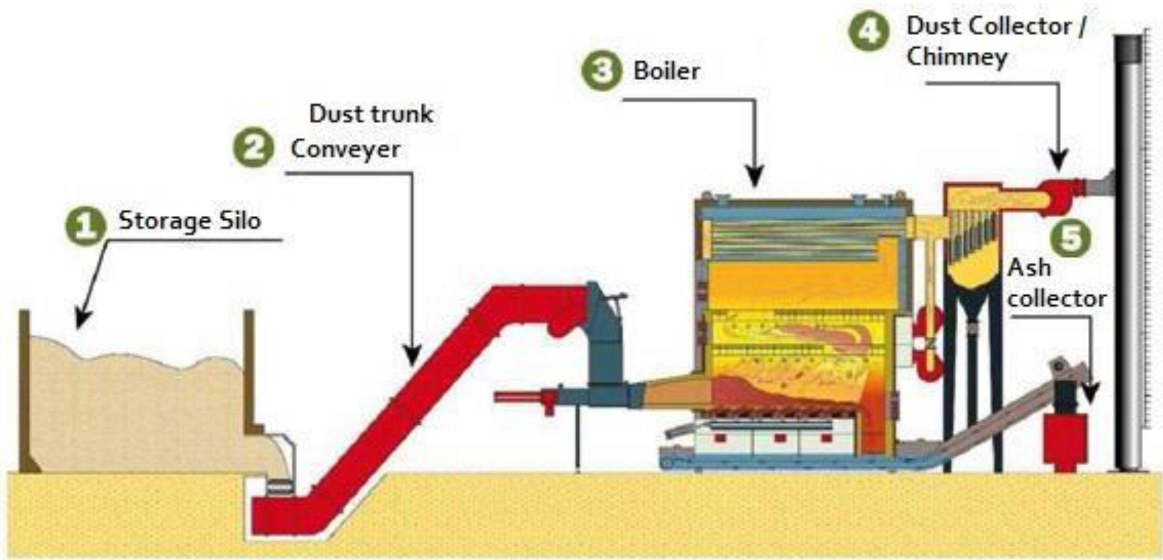
5.1 Heat generation through combustion

Vietnam has a large scale demand of heat for drying purposes, this can be in the wood processing industry but also in many other sectors like the agricultural sector, brick making, cement industry, beer breweries, pottery etc. Traditionally often inefficient furnaces are being used, resulting in steam and/or hot air used to dry the agricultural or other products such as firewood fired furnaces or co-firing coal and firewood are used to provide the hot air for drying green tea. In new installations constructed over the last 5 years, it is observed that the popular boiler technology applied for steam generation using biomass wastes are Fluidized Bed Combustion (FBC) and produced locally by Vietnamese mechanical companies.

Since 2009 an increasing number of Vietnamese industries are switching to renewable energy for the generation of their process heat. Those companies have traditionally generated heat using boilers fired with diesel, natural gas or fuel oil but now switch to biomass through energy service providers. The energy service providers are specialized companies that finance, build, own and operate the biomass boiler plant and sell the energy to the adjacent manufacturing facilities. The energy is typically sold at a discount of 20% or more compared to energy generated using fossil fuels. The biomass fuel is normally wood residues, such as sawdust, wood shavings and other waste from wood processing enterprises.

In Vietnam there are about 5 enterprises that act as energy service providers. Tin Thanh Industrial Steam and Electricity Company and Green Energy Joint Stock Company (both based in Ho Chi Minh City) are market leaders in this field. Both companies have more than 20 biomass boilers operating. All projects involve biomass boilers (chain grate and circulating fluidized bed) that generate steam. No electricity is (co)generated. Their projects are located adjacent to food and beverage, rubber and paper mills. The investment cost is about 1.5 million USD per project, or 100,000 USD per MWth. Both companies develop between 5 and 10 new biomass boiler projects per year.

FIGURE 12: ILLUSTRATION OF A BIOMASS BASED STEAM GENERATION SYSTEM [TIN THANH, 2010]



Each biomass boiler project requires between 1,000 and 5,000 m2 of land. Therefore, most biomass boiler projects supply energy to plants that are located in industrial zones. However, Tin Thanh Industrial Steam and Electricity Company is now also piloting technologies that require less space, including gasifies and boilers equipped with biomass burners.

It has recently signed a contract to supply steam to Southeast Asia Breweries in the center of Hanoi. The contract involves the installation of a boiler with sawdust burner. The entire facility occupies approximately 100 m2 and will be integrated into the existing brewery. The investment cost of this plant is approximate 80,000 USD per MWth.

TABLE 30: SEVERAL EXAMPLES OF TYPICAL WOODY BIOMASS BASED HEAT GENERATION PROJECTS IN VIETNAM

Name of project	Type of biomass	Boiler capacity	Applied boiler technology	Location	Energy customer	Developer
Masan Biomass Boiler Project	Sawdust wastes	20 TPH	Fluidized Bed Combustor (FBC)	Di An-Binh Duong province	Masan Industrial Corp	Tin Thanh Industrial Ltd
Tin Thanh Biomass Boiler Project No. 1	Sawdust briquette	25TPH	Fluidized Bed Combustor (FBC)	Hue city	Hue Brewery Company Limited	Tin Thanh Industrial Ltd
Tin Thanh Biomass Boiler Project No. 2	Wood waste residues	30TPH	Fluidized Bed Combustor (FBC)	Da Nang city	Da Nang Rubber Joint Stock Company	Tin Thanh Industrial Ltd
Tin Thanh Biomass Boiler Project No. 3	Sawdust wastes	10TPH & 15 TPH	Fluidized Bed Combustor (FBC)	Binh Duong province & Binh Dinh province	Sai Gon Mien Trung Beer Joint Stock Company&Sai Gon Binh Tay Beer Joint Stock Company	Tin Thanh Industrial Ltd
Tin Thanh Biomass Boiler Project No. 4	Woody biomass	30TPH	Fluidized Bed Combustor (FBC)	Dong Nai & Ba Ria-Vung Tau provinces	Vinacafe Bien Hoa Joint Stock Company	Tin Thanh Industrial Ltd
Biomass based steam supply projects for Vinamilk	Biomass	-	Adopted from Japanese technologies	Da Nang	Vinamilk group	Green Energy JSC part of SSG Group

TABLE 31: WOOD WASTE BASED BOILER SUPPLIERS IN VIETNAM

Name of manufacturer	Type of boiler technology	Type of fuels
Nhiet Nang Joint Stock Company	Fluidized Bed Combustion (FBC)	Biomass wastes
Vietnam Boiler JSC	Dump-grate or fixed grate	Bagasse
Truong Quang II Company Limited	Fluidized Bed Combustion (FBC)	Biomass wastes
Mien Trung Energy andBoiler Joint StockCompany	Fluidized Bed Combustion (FBC)	Biomass briquette
Hoa Phu Refrigeration Electrical Engineering Joint Stock Company	Fluidized Bed Combustion (FBC)	Biomass briquette
Dong Anh Boiler JSC	Fluidized Bed Combustion (FBC)	Biomass briquettes & rice husk
Dai Phat Mechanical Engineering and Energy Company Limited	Fluidized Bed Combustion (FBC)	Biomass briquettes
Vietnam Institute of Agriculture Engineering and Post-harvest Technology (VIAEP)	Fluidized Bed Combustion (FBC)	Biomass wastes (rice husk, coffee husk, corncob, cassava trash…)

5.2 Power generation and/or co-generation through combustion

Generating electricity based on woody biomass sources is not common in Vietnam and does not draw attention from investors in this regard due to a lack of feed-in-tariff mechanism. In fact, the wood processing industry has demand of both heat for drying wood and electricity for its process. Operating a co-generation plant is more economic than sole electricity generation due to higher overall efficiency of up to 90% (Educogen, 2001).

Moreover, Vietnam has no incentive policies for utilization for energy generation to attract potential investors. Currently, a draft version of feed-in-tariff incentives for biomass based power generation projects have been under development and discussion, but has not been concluded yet. However, the proposed tariff of 5.6$cent/kWh is quite low and potential project developers indicate that it is unattractive to develop woody biomass fired power plants.

Sumitomo Forestry Ltd (funded by the Japanese Government under a REDD plus program) has just completed two feasibility studies on utilization of wood wastes for power generation in Vietnam. It studied a 5MW power generation plant in Son La province and another one with a forecasted capacity of 4MW in Dien Bien province. Both will utilise wood wastes and logging residues generated during timber processing to provide the electricity for timber processing mills and neighbouring houses and facilities, instead of connecting to the gird (Sumitomo Forestry, 2011). This study also indicates that there are no activities on larger scale woody biomass electricity generation in Vietnam.

Below an overview of a number of woody biomass based power plants is given for Vietnam. The status is continuously changing, and over the last few years the construction of many plants was announced without any real construction following.

TABLE 32: WOODY BIOMASS BASED POWER PLANTS IN VIETNAM

Project title	Capacity	Employed technology	Project owner	Location	Project status
Woody Biomass-based Power Generation (Sumitomo, 2011)	5MW	Forecasted to be imported from Japan	Vietnam	Son La province	Technical assistance for completion of FSR in 2011 (MOEJ, 2013)
Woody Biomass-based Power Generation(Sumitomo, 2012)	4MW	Forecasted to be imported from Japan	Vietnam	Dien Bien province	Technical assistance for completion of FSR in 2012 (MOEJ, 2013)

Cogeneration technology was early introduced in Vietnam since 1960s, but has been developed slowly, technology is outdated, there is a reportedlack of financing available and a lack of skilled manpower for installation and operation. In 2002 year the Cogen program (www.cogen3.net, funded by the European Commission) was executed in Asia and included Vietnam to enhance awareness of policy makers and to actively promote private sector involvement in the potential industries with cogeneration technology such as sugar mills, paper mills, rice mills, sawing mills, cement, fertilizer etc. However, so far most cogeneration systems in Vietnam are in the sugar and paper industries which generate a large amount of biomass wastes onsite suitable for cogeneration system installation (often state owned). The wood processing sector also has biomass available and a demand for heat and electricity, and is therefore a potential sector for cogeneration. Nevertheless many processors are small, and wood residue collection (from the frest) is not well managed to provide sufficient input materials, furthermore as the systems are not locally available, the upfront investment to import the systems from (often) Europe are high.

5.3 Gasification

Biomass gasification in Vietnam came into the spotlight in the early 1980s when there was a shortage of petroleum and power. However over the years it became less popular again due to many reasons. Recently biomass gasification is back on the table, due to the increasing prices for fossil fuels, and have drawn attention of many domestic companies and research centers. Gasification can be divided into two segments and/or markets. Small scale gasification, more focused on household cooking and/or SME use or Large Scale gasification for Industrial purposes. Especially the small scale gasifiers have more and more attention in Vietnam but they are mainly rice husk fed and not with woody biomass due to the fact that direct combustion in case of wood makes more sense technology wise. Nevertheless there are developments ongoing focusing on gasifier stoves which utilise biomass wastes including rice husk, coffee husk, biomass pellets, and woodchip as fuel. These stoves are clean and high efficient and widely delivered to rural areas in Vietnam.

TABLE 33: GASIFICATION STOVE PRODUCERS AND DEVELOPERS IN VIETNAM

Name of supplier	Type of technology	Type of biomass
Thao Nguyen Company	Gasification	Rice husk
Duc Nhan Company	Continuous gasification	Rice husk
SolarService Company	Gasification	Woodchip
Thuan Phat Company	Continuous gasification	Rice husk
VINASILIC JSC	Gasification	Biomass pellets
GreenCom	Gasification	Biomass pellets
Quang Minh group	Gasification	Biomass pellets
Center for Research and Development of Industrial Technology	Continuous gasification	Rice husk
VINA FAT JSC	Continuous gasification	Rice husk

Larger scale applications for electricity generation also received increased attention. In neigbouring countries, like for example Cambodia, this is already extremely popular (mainly fed with rice residues though, not with woody biomass) but electricity tariffs are almost 4 to 5 times higher in Cambodia than in Vietnam. Interests in Vietnam comes mainly from research centers and institutes such as the Vietnam Institute of Agriculture Engineering and Post-harvest Technology(VIAEP); Advanced Institute for Science and Technology-AIST (under HaNoi University of Science and Technology) and Center of Research and Development for Industrial Technology - Machinery-R&D Tech(under Ho Chi Minh Industrial University). But also commercial companies, (as mentioned above) like Tin Thanh Industrial Steam and Electricity Company are looking into the application of gasification, especially to safe space in urban areas and at existing locations.

Also, the AIST showed its study results on Potential for biomass gasification based electricity generation in Vietnam using Geospatial Software. The study was focused on agricultural biomass such as rice crop, corn crop, peanut crop, and sugar cane crop and cassava crop residues and applied with small scale syngas and diesel fuel dual engine for off-grid communities. The outcomes showed that the levied cost for the electricity generation using biomass is about 0.217$USD/kwh, while this using diesel is about 0.343$USD/kwh. If the technology functions with a difficult feedstock like rice residues it will be no problem at all to run on woody biomass, like woodchips. Nevertheless production costs will be much higher due to the prices of the input materials (there is not sufficient information available to provide an example calculation for the Vietnamese context).

Generally, biomass gasification remains new to Vietnam and Vietnam has little experience in this respect. All biomass gasification based electricity generation projects are at lab or piloting scale, there have been not any biomass gasification based electricity generation plants at commercial scale appeared in Vietnam. One of the reasons for this, is that with the current electricity prices and the lack of feed in tariffs or other incentives, there is no strong driving factor to move into woody biomas gasification (vs direct combustion).

6. CONCLUSION AND RECOMMENDATION

Vietnam has a large number of forest program's all aiming for sustainable forest management, and to reduce forest degradation and deforestation. Even though some successes have been booked, there is still a lot of work to do to reach Vietnam's goals as set out in their strategy documents. With almost 14 million hectares of forest in Vietnam, both natural and plantation forest, and at the same time a blooming wood processing sector as well as a big demand for wood pellets and chips, it is a dynamic sector. Unfortunately woody biomass to electricity is not one of the thriving sectors. The use of woody materials is mainly limited to the domestic cooking sector and the use for small industries for heat – often produced inefficiently.

Woody biomass has been grouped in 3 groups, forest residues (often left in the forest, not economically feasible often to collect, includes stumps, branches, leaves and bark), saw mill residues and wood processing industry. In this report forest growing for energy use is not taken into account. A focus is on the residues and / or the waste materials, also assuming that when collecting from the forest this is done as part of a wider, sustainable forest management plan to secure sufficient materials stay behind.

With a rapidly growing saw and wood processing sector, the amount of residues available is also rapidly growing. This is either locally used for drying purposes, but this is also great input materials for the production of wood pellets, wood chips and/or charcoal. There is already an existing woodchip market in Vietnam, even though the local demand from the pulp and paper sector for woodchips is large, and prices are higher, the majority of the chips is exported for foreign markets for either energy use or for paper production. Woodchip production can be on a small scale, with portable chippers or on a larger scale for more homogeneous and larger amount of products. There are in Vietnam 120 woodchip plants with a total capacity of 8 million tones/yr, they produce and export annually 6.2 million tones woodchips. Currently a new law for a tax on the export of woodchips is under negotiation to protect the local market.

The production of wood pellets is also becoming more well-known in Vietnam, although the amounts produced are still small. Pellets are mainly used for exports, with reported prices between 91 and 125 USD per tone. There are several pellet machine suppliers in Vietnam. Pellet's don't reach the European market due to the strict standards, most of the pellets are exported to Korea and Japan. The wood briquette market is relatively small compared to chips and pellets, while the charcoal making is also mainly for domestic and SME use.

Woody biomass use for power, heat or cogeneration on a large scale is very rare in Vietnam – beyond the use as heat for small businesses through furnaces. There are no supporting policies in Vietnam like Feed-In-Tariffs or other incentives, while upfront investments are high. Several biomass projects are developed on paper but are waiting for such support mechanisms. There is a large potential, but it is not utilized due to these policy reasons, lack of knowledge and limited access to financing.

It is recommended to increase the (local) knowledge levels on biomass conversion technologies. Creating more local awareness for potential smaller scale, more efficient solutions for biomass conversion to energy. Many local processes, furnace application, charcoal making are still using low efficient technologies. This would also involve improved (biomass to) energy planning by the local government. Furthermore it is important that the initiative to introduce financial incentives for Renewable Energy continue, and that the current FIT proposal (5,6 cUSD/kWh) is reconsidered as it might not be able to cover the costs for bioenergy production.

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THE MAKING OF A NEW TRADITION: MARKET-MAKING ACTIVITIES FOR THE INTRODUCTION OF ADVANCED BIOMASS COOKING SOLUTIONS

Author: Jason Steele

Country: Cambodia

Sector: Renewable Energy

CHALLENGE

The cookstove market in Cambodia is relatively large in comparison to the number of households in the country, with an estimated 2.9 million households (~90% of total households) relying on traditional biomass fuels (firewood and charcoal) as their main cooking fuel, and households on average own and use 2.5 cookstoves. There are an estimated 7.5 million cookstoves in use nationwide with a total market value of approximately USD 45 million.

Almost 90% of Cambodian households cook with biomass as their primary cooking fuel on traditional stoves and cooking is primarily the responsibility of women (96%). (Photo: Thomas Cristofoletti (RUOM) / SNV)

Although the use of LPG is slightly increasing among higher income households in urban areas, the prospect for the many peri-urban dwellers and rural households in moving to modern cooking fuels is still a long way off because of the limited access to and higher prices of LPG and electricity and the abundance of fuelwood. The use of solid biomass fuels places a heavy burden on the country's natural resources. According to FAO data, Cambodia is experiencing on average a loss of 1.3 million hectares of forest per year, which is the largest deforestation rate in the region. Unsustainable fuelwood production is one key driver of deforestation in Cambodia.

Costs for traditional biomass fuels are also on the rise. Charcoal prices have increased fivefold over the last 8 years. The rural poor spend about 10% of their consumption expenditure on energy needs with cooking energy needs representing 70% of the total energy spending. This high energy expenditure among Cambodian households poses a significant obstacle for socio-economic development of the country.

Addressing the above described situation, cookstove interventions were initiated a decade ago. Today, Cambodia is recognised as one of the most developed improved cookstove (ICS) markets in the world and sales of ICS continue to increase exponentially every year. However, currently all improved cookstove technologies available in Cambodia are based on traditional designs with incrementally improved durability and fuel savings but do not address health issues related to smoke and safety.

Solid fuels is the second leading risk factor contributing to disease and premature death in Cambodia, with women and children being the most vulnerable to the effects. (Photo: Thomas Cristofoletti (RUOM) / SNV)

Cooking with solid fuels with traditional stoves has particular effects on the health of end-users as the smoke from cooking contributes to high levels of household air pollution. The Global Burden of Disease 2010 report estimated that household air pollution from cooking with solid fuels is the second leading risk factor contributing to disease and premature death in Cambodia. The WHO estimates that this results in 6,600 premature deaths per year, equal to 18 deaths per day. Even when cooking outdoors, smoke finds its ways indoors, harming health, especially of women and children.

Cookstove production in Cambodia is a traditional industry, with the supply side of ICS currently consisting exclusively of artisanal manufacturers producing the New Lao Stove (NLS) and the Neang Kongrey stove (NKS), both clay bucket stove models (NLS with metal cladding) introduced by French NGO GERES. Artisanal producers use traditional sales channels, such as mobile ox-carts and district markets to distribute stoves to end-users.

The industry suffers from a lack of national standards that could provide policymakers, donors, investors and stove experts with a credible basis to further advance stove performance beyond what is currently available. As a consequence, innovation has been notably absent from the Cambodian cookstove market since introduction of the NLS model 10 years ago.

To date, clean biomass cookstove options are not available to Cambodian consumers. While these new generation stoves are relatively expensive compared to current offerings in the market in Cambodia, they significantly cut cooking costs and time use compared to traditional stoves and have been found to be more convenient to use, cleaner and healthier.

SNV Cambodia and partners believed that the time has come for the large-scale introduction of clean biomass stoves that improve peoples' health and that are safe to use and fuel efficient. Therefore the SNV team designed the Advanced Clean Cooking Solutions (ACCS) project with the main objective to broaden the existing stove supply to the Cambodian market, giving consumers an opportunity to purchase a range of high quality, high performance and cleaner biomass cookstove appliances at different price points. If this is done, the benefits that these cookstoves provide to the households and to the local and global environment are numerous.

METHOD/SNV INTERVENTION

In order to broaden the supply chain the ACCS project would need to stimulate the interest of stove manufactuers of advanced biomass stoves and local distributors and retailers to engage in this market. Therefore, the SNV team setout to design and implement a comprehensive suite of market-making activities that would reduce market entry risk for the private sector. This set of activites includes:

1. Market Intelligence
2. Inclusive Business / MSME Capacity Development
3. Distribution Model Development and Piloting
4. Consumer Awareness and Marketing Approaches
5. Stove Testing and Research
6. Knowledge Sharing

1. Market intelligence

In the beginning of the project we set out to understand the market opportunities for advanced biomass stoves and cleaner and renewable fuels. We commissioned Emerging Markets Consulting (EMC) to conduct a large household survey and a number of focus groups to gather data and feedback including willingness to pay for these appliances to determine the scope of the market.

The research indicated the following market potential within the selected market segments in the table below:

- Economic Potential: 1,066,635 households (ability to pay)
- About 568,000 households have the desire to adopt an advanced biomass stoves
- Achievable Potential: 143,000 households (ability to pay, willingness to pay USD 100) valued at USD 14.3 million or 32% of the overall market value.

Market potential is expected to increase once advanced biomass stoves move from early adopters to a mass market product.

Fuel used by customer segment	Area	Income bracket	Avg hh income per month	No. of hhs (Economic potential)	% of hh interested to buy ABS	No. of hhs	% of hhs interested to buy ABS at US$100	No. of hhs (Achievable potential)	% of medium monthly income	Actual primary stove
Target Markets										
Charcoal	Peri-urban	Top 2/3 >$194/m	US$456	18,538	83%	15,386	29%	4,462	29%	New Lao
Firewood	Peri-urban	Top 2/3 >$194/m	US$490	22,125	75%	16,594	21%	3,485	30%	Traditional
LPG	Peri-urban	100%	US$322	127,657	67%	85,530	42%	35,923	29%	LPG 200ml
Charcoal	Urban	Top 2/3 >$251/m	US$677	6,392	80%	5,114	39%	1,994	22%	Traditional
Firewood	Rural	Top 1/3 >$178/m	US$459	544,097	48%	261,166	35%	91,409	33%	Traditional
Subtotal				*718,809*		*383,791*		*137,272*		
Untargeted Markets										
Firewood / Charcoal	Peri-urban	Bottom 1/3 <$194/m	US$149	185,362	69%	127,900	0%	0	67%	Traditional
Charcoal	Urban	Bottom 1/3 <$251/m	US$218	4,236	71%	3,008	16%	481	40%	Traditional
LPG	Urban	100%	US$300	7,671	46%	3,529	5%	176	33%	LPG >200ml
Charcoal	Rural	Bottom 1/3 <$178/m	US$722	150,557	33%	49,684	11%	5,465	31%	Traditional
Subtotal				*347,826*		*184,120*		*6,123*		
Total				**1,066,635**		**567,911**		**143,395**		

These findings are also supported by market research studies conducted by the Global Alliance for Clean Cookstoves, which clearly show market potential but lack of clean cookstove options beyond those stoves with incrementally improved efficiency. This research also indicates consumer willingness to utilise financing schemes to lower the investment barrier.

SNV demonstrating the Philips HD4012 to two women that participated in the Consumer Acceptability Study for the Philips stove. (Photo: Jason Steele, SNV)

Moreover, Consumer Acceptability and Willingness-to-Pay Studies conducted by the ACCS project on several stove models indicate there is considerable appetite among households for cooking equipment upgrades beyond what is currently available to them, and a general readiness to embrace new, more modern technologies. The team used a number of data collection techniques during these studies including Stove Use Monitors (SUMs) to quantitatively collect data on the frequency of stove use.

SNV commissioned Fast-Track Carbon to undertake a study on baseline consumption of cooking charcoal and wood in Cambodia. Charcoal measurements were performed in 33 cities and wood consumption in 63 villages. The study implemented surveys in 2,072 Cambodian households. The surveys were implemented between June and August 2014 by the local firm Angkor Research Consulting. The study provided valuable baseline data on household cooking behaviour. Some key data points are:

- The average cooking firewood consumption among firewood users: 4.87 Kg/household/day.
- The average charcoal consumption throughout the study: 2.023 Kg/household/day
- Percentage of wood users that purchase firewood: 29%
- Percentage of firewood users that collect firewood: 85.6%
- Charcoal and wood users spend 105-108 minutes cooking per day
- Traditional Lao Stove (TLS) remains the most prominent stove for both wood users (58.2%) and charcoal users (60.2%).

2. Inclusive Business / MSME Capacity Development

SNV training sales agents from LES on the use of the Envirofit stove. (Photo: Dennis Barbian, SNV)

For local distributors that wanted to engage, the SNV team supported them to pilot the distribution of stoves including providing them sales agent training and support to create consumer awareness.

In collaboration with the ADB funded project "Harnessing Climate Change Initiatives to Benefit Women" that SNV is also implementing, we supported distributors in the identification, training, and coaching of female sales agents in order to mainstream gender into their supply chain of advanced biomass stoves. This coaching included how to conduct effective village level stove demonstrations.

3. Distribution Model Development and Piloting

"The proof is in the pudding". Survey and focus group data only has so much value. Conducting a pilot to confirm all assumptions made about the market is a key milestone in reducing the risk for the private sector to engage. SNV conducted a couple different pilot activies. One was in collaboration with stove manufacturer, African Clean Energy (ACE), and local distribution company, Lighting Engineering Solutions (LES). The distribution pilot was implemented on a limited geographical scale, a few districts (rural) in Kampong Chhnang province, in the latter part of 2015 to test fundamentals of a sustainable business model for an advanced biomass stove supply chain, including distribution chain arrangements, consumer financing models, and marketing messages. LES and their commissioned sales agents sold over 100 ACE-1s for USD 100 each. LES provided in-house financing, allowing consumers to pay instalments over a one year period. The majority of households took this payment option. Purchases were made based on a combination of the following drivers:

Drivers	Reason
Fuel savings	More efficient than traditional biomass stoves
Convenience	Easy to light, easy to use and control, and faster cooking
Less agitation caused by smoke	Less smoke generated from gasifier stoves compared to traditional biomass stoves
Modern (primarily from a male buyer perspective)	Aspirational: looks modern, associated with high social status

The barriers to not buying the stove were the following:

Barriers	Solution
Lack of Disposable Income and High Price	Different models with different price points will be available. Local production/assembly to bring costs down Distributors should arrange a payment plan for the consumer through MFIs, in-house financing, or community savings models.
Lack of spare parts and repairing services / Fear of being deceived on quality and service	Addressed through a one year warranty and after-sales services provided by the manufacturer's representative located in Cambodia (local phone number to call) Stove distributors should get the buy-in and endorsement from local authorities prior to conducting village demonstrations, small-group meetings, and door-to-door marketing
Not enough knowledge about the product / nervous about new technology	This will increase with more promotion of the products at the village level, and more demonstrations. First adopters will spread knowledge about the products to their neighbors, friends and family, which is the most effective promotional tool.

The consumer profile of ACE1 buyers is:

- Firewood / Charcoal / and LPG 200ml users (small cannisters)
- Female
- Age range (30 to 50 years old)
- Multiple income sources (i.e. different incomes coming from different family members living in

the same household and/or different types of jobs (e.g. farming, small shop, factory)

- Type of house (as Socio-economic identifier)
  - Wood with corrugated iron roof
  - Wood with tiles
  - Half concrete half wood with tiles
  - Concrete with open kitchen (in peri-urban areas)

In one farming village in Kampong Chhnang province, 15% of households purchased the ACE1 stove. The number of households in the village are 199 and 30 stoves were purchased for USD 100 each. The village is relatively poor with 50% of the village households officially classified by the government poor. The households in the village collect firewood for free, for which it is available in abundance, so there was no direct economic savings to drive their purchase decision. Their reasons for purchasing are consistent with the purchase drivers listed in the above table. The households who purchased the stoves were a mix of poor and nonpoor households. The village sales agent, Ms. Un Lim, was a driving force behind the large sales numbers. She purchased two stoves herself and conducted several demonstrations, either for groups or for individual households at their homes, showing them how to use the stove. She also let households borrow her stove for a couple days to test it out. Her efforts combined with a good product and the one year payment plan provided by LES, made her the top seller compared to LES's other commissioned sales agents.

Another pilot was in collaboration with Differ Group (Norway) and Prime Cookstoves (Indonesia) with local company Sustainable Green Fuel Enterprise (SGFE). The pilot tested out SGFE as the wholesaler in the supply chain, with one container of Prime stoves (~1,000 units) nearly selling out within 4 months to local distribution companies and organisations.

4. Consumer Awareness and Marketing Approaches

What are the messages that hit home and make someone want to buy an advanced biomass stove? SNV and partners tested out a number of messages, and with support from 17Triggers and TNS Cambodia, conducted an action research to understand whether health messaging was effective in driving sales. The results were that health messaging combined with other product benefits is effective, versus focusing messaging solely on the health impacts. The action research resulted in several lessons learned in how to market products in villages, building trust with local authorities, and the essential need to recruit confident and proactive sales agents that believe in the product.

5. Stove Testing and Research

Cooking stations constructed for the CCTs to isolate cooks from one another to limit their ability to take on other cooks behaviours throughout the testing and increase the cooks focus on the task at hand. (Photo: Carlo Talamanca, SGFE)

For all new advanced biomass stoves that we investigated, it was important to understand how they perform compared to traditional Cambodian stoves. This data is important to share with market players and consumers, so expections and value added benefits are accurately portrayed in the local context. In order to understand fuel savings over the most prominent baseline stove, the SNV team with help from stove testing experts conducted a number of controlled cooking tests with Cambodian cooks and common Cambodian cuisine. All tests were conducted with firewood. Results, as compared to the most prominent baseline stove (Traditional Lao Stove) are the following:

Stove Model	Stove Type	Fuel Savings
Mimi Moto	Forced Air TLUD Gasifier	31%
ACE1	Forced Air TLUD Gasifier	20%
Philips HD4012	Forced Air TLUD Gasifier	22%
Prime Fuelwood	Natural Draft TLUD Gasifier	12%
BioLite Homestove	Forced Air Rocket Gasifier	7%
RocketWorks ZaMa Zama	Natural Draft Rocket Gasifier	21%
Traditional Lao Stove (Baseline)	Ceramic with thin metal cladding	0%

It was also important for SNV to build the evidence base on household air pollution in Cambodian households related to cooking smoke and the positive health impacts of advanced biomass stoves and household biodigesters. This would support claims that advanced biomass stoves are indeed a healthier option than cooking on traditional biomass stoves. To do this, SNV commissioned Berkeley Air Monitoring Group and a local field team to conduct kitchen air pollution and personal exposure monitoring on a number of households from July to September 2015. The ACE-1 sub-study was conducted in 24 peri-urban and 24 rural, wood-burning households and involved measurements of personal exposure (PE), kitchen air pollution (KAP), and stove use before and after the introduction of the ACE-1 stove (before-after study design). The biogas sub-study was conducted in 24 rural biogas households and 24 rural control households (cross-sectional study design) and also involved measurements of personal exposure, kitchen air pollution, and stove use.

ACE-1 and biogas use resulted in statistically significant decreases in kitchen air pollution (KAP) and personal exposure (PE) resulting in positive health outcomes (measured in averted disability adjusted life years, ADALYs) for the populations using these cleaner technologies, as modelled in the Household Air Pollution Intervention Tool (HAPIT) version 3, a web-based application developed by University of California, Berkeley. A summary of the results is shown below:

Technology	Kitchen Air Pollution (PM2.5 µg/m3)			Personal Exposure (PM2.5 µg/m3)			ADALYs
	Before	After	Reductions	Before	After	Reductions	
ACE-1	183	111	72	66	47	19	1,295
Biogas	172 (control)	35	137	73 (control)	28	45	2,770

SNV also commissioned Sustainable Green Fuel Enterprise (SGFE) to determine the optimal fuel source for fan powered gasifier stoves, more specifically in this case for the Philips stove (model HD4012) ("Philips stove"), for cooks in Cambodia, and compare performances against baseline stove models. The stove was tested with over 13 types of fuel, first qualitatively and then quantitatively through water boiling tests and controlled cooking tests. Fuels that came out on top were rice husk pellets, wood, corn cobs, and coconut shells. A follow up assignment, also conducted by SGFE, was a feasibility study and preliminary business plan for rice husk pellet production and distribution in Cambodia, resulting in a financially viable decentralized business model for rice millers to produce rice husk pellets and for enterprises to distribute them. To test some business plan assumptions and the marketability of rice husk pellets, SNV procured a mini-pellet mill, for which SGFE operates to produce rice husk pellets and sell them in combination with gasifier stoves. This work is still ongoing.

6. Knowledge Sharing
We shared all the market intelligence and testing and research reports with interested private sector actors to spur their interest in entering the market – this spans from international stove producers to local distributors. All knowledge products are posted on www.advancedcleancooking.org and www.thestoveauction.org.

IMPACT

Through the ACCS project intervention we have successfully engaged international stove producers and local distributors to get them interested in the Cambodia market. Our high quality knowledge products, such as our market intelligence and consumer acceptability reports, our research on health impacts, our action research on most effective marketing messages, etc, all provided highly valuable information to the private sector about the market. This resulted in their investment in Cambodia, through sending in containers of stoves at their own costs, making several visits to learn more about the landscape and meet potential distributors, and hiring local representation (Differ and Prime) or starting up offices in Cambodia and making steps toward local production (ACE).

We also built enough evidence to demonstrate market potential and opportunity for scaling-up, and secured funding for a four year results-based financing program funded by Energising Development to further stimulate the private sector to accelerate the market for advanced biomass stoves.

Through this intervention, SNV prides itself in having catalysed the growth of an emerging market, bringing proven advanced biomass cookstove technologies to Cambodia for the first time ever.

TESTIMONIALS

"When I was firstly contacted by Mr. Chanty-LES's staff in July 2015, I was hesitatant to engage in distributing the stove as I never had any experience and I do not trust the product's quality. When I attended the first meeting, followed by the training, I became confident. Unexpectedly, I sold 24 stoves in two months, generating around 192 USD. My husband appreciates my work and sometime helps me to do household chores when I am not around to promote the stove". Ms. Un Lim, Top Sales Agent, Kampong Chhnang province

"In my village, we do not have option besides using traditional cookstove. I feel proud that I can provide better options to my villagers. Through distributing the ACE1, I feel I contribute to development of my villagers through helping them to have better health, save money and time". Mr. Koy Vannak, Sales Agent, Kampong Chhnang province

STANDARD DATA

Start and end date of contract: January 2014 to December 2015

Team: 2 SNV Staff and 2 LCBs

Financial resources invested: EUR 750,000

Funded by: Ministry of Foreign Affairs of the Netherlands