ENERGY AND CARBON BALANCE IN WOOD PELLET MANUFACTURING

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INTRODUCTION

In recent years, the world has witnessed a dramatic increase in the production of wood pellets for fuel. As a home-heating fuel, wood pellets can sometimes stand on their own as an economically viable alternate to more expensive heat sources such as electricity, propane or fuel oil. These markets are most often served by smaller manufacturing facilities with bagging equipment at the end of the production line. However, the bulk of the new and proposed facilities are manufacturing pellets for use as boiler fuel for electrical power generation. Pellets must rely on government incentives for viability. They cannot compete economically with alternate boiler fuels such as coal and natural gas. These incentives are in place in Europe as a result of the Renewable Energy Directive. This directive aims to set the total European renewable energy content at 20 percent by 2020 [7] in an effort to reduce greenhouse gas production. Biomass fuel, and in particular, wood pellets are often seen as the least-cost alternative for meeting these standards. Pellet plants are being built in many distant locations to supply this market. Biomass energy is normally considered to be “carbon neutral” if the resource is re-grown, since the new growth absorbs carbon dioxide from the atmosphere equal to the amount released in burning.

When government incentives are used to force a new technology into a market, often factors that can normally prevent the technology from entering a free market remain hidden. For example, estimates of the energy required to produce ethanol range from 50 percent to 150 percent of the produced energy [6]. In the case of wood pellets, a large quantity of high quality energy, i.e., electricity as required for manufacturing, which has its own associated carbon dioxide emissions. The purpose of this paper is to evaluate the energy gain and net carbon dioxide emissions from wood pellet manufacturing to provide a clear understanding of the net environmental benefits.

DESCRIPTION OF THE PELLETING PROCESS

The energy requirements of a typical wood pellet plant will be considered for this analysis. The plant produces 250,000 tons (1 ton =2,000 pounds) for shipment to European markets. Pellet specifications are as follows:

Diameter:	8 mm
Length:	3.15 to 40 mm

Species:	Southern Yellow Pine
Moisture Content:	Less than 10 percent, wet basis
Ash Content:	Less than 1 percent
Fines Content:	Less than 1 percent

A few energy-related comments are in order regarding the above specification. Some pellets are manufactured to 6 mm diameter. This requires about 5-10% more energy at the presses. Southern yellow pine requires about 10% less energy at the presses than mixed southern hardwoods. The ash content of less than 1 percent is not difficult to obtain as both wood and bark of southern yellow pine have less than this. Some harvest practices involve dragging or skidding felled stems to a central location. This can result in large quantities of dirt entrained in the bark, which can show up as ash in the pellets. These logs must be either washed or debarked. Bark contains a high silica content which shortens the life of press. Debarking provides the dual advantages of prolonging press life and provides a supply of bask as energy for the dryers.

Traditionally, pellet plants are divided into three parts and referred to as islands: a green wood preparation island, a drying island and a pellet island.

<u>Green Wood Preparation Island</u>

The plant under consideration receives tree-length southern yellow pine logs on pole trucks. The trucks are unloaded by a rotary crane and stacked in a partial circle below the crane. A crane places the logs on an infeed deck which feeds a rotary drum debarker. Bark is hogged and stacked in a pile for use as dryer fuel. Since there will not be enough bark to fully fuel the dryer, facilities are provided to receive extra purchased fuel which may be residual bark from a nearby wood processing plant or logging residues chipped in the field.

Debarked logs are fed to a chipper that produces ⅜ inch chips or "mini-chips". These are smaller than standard paper mill chips which are ¾ inch long. The smaller chips are produced by special chippers made especially for the pellet industry. If ¾ inch chips are produced, they must be further reduced in size by green hogs for optimal drying. Chips are stored outdoors and reclaimed by mobile equipment to feed to the dryers. Chips must be screened for overs before drying. The oversized chips go to a green hog for further size reduction.

<u>Dryer Island</u>

The dryer is a single-pass 18' diameter x 70' long rotary drum with partial recycling exhaust gas. Non-recycled gas goes into a wet electrostatic precipitator (WESP), then to a regenerative thermal oxidizer (RTO). The RTO functions to raise the temperature of the exhaust gas to promote destruction of volatile organic compounds (VOC's) before discharging to the atmosphere. Natural gas is used as the heat source for this and the regenerative feature reduces the amount of gas required by capturing waste heat in a heat storage medium. Providing the dryer with partial gas recycling reduces the size requirements of the WESP and RTO and reduces the amount of natural gas required for the RTO.

The dryer fuel is bark and other biomass residues. Since the fuel source is biomass that will ultimately be re-grown, it will not be counted as an energy input or as a source of CO_2 emissions.

Wood chips enter the dryer at 50 percent moisture, wet basis, and leave at 10 percent. Bark fuel is also assumed to be 50 percent moisture.

Dry wood chips are stored in a silo with auto-reclaim sized for 8 hours of storage.

<u>Pellet Island</u>

Before the wood can be made into pellets, it must first be further reduced in size. This is best done after the dryers. Dry wood is more friable than green wood and requires less energy for size reduction. Particle size must meet not only the requirements of efficient pelleting, but also the requirements of the end user, since the pellets must be pulverized before feeding to the boiler furnaces. For European power plants this is typically:

100% less than 4 mm
95% less than 2 mm
65% less than 1 mm
Less than 3% under 1 mm

The power requirements for this size reduction are quite large. This plant requires four hammer-mills at 500 horsepower each. The hammer-mills are usually air-assisted in that air is pulled through them with induced-draft fans to help move the light, fluffy fiber through the hammer-mill grates. The air must be passed through bag filters before discharging to atmosphere. Fines collected in the filters are returned to the process.

The fiber is stored in a silo with automatic reclaim capabilities sized for 8 hours retention. Fiber reclaimed from the fiber silo passes through a Pre-Conditioner where a small amount of water is added for optimum pelletizing characteristics. From here, the fiber is transported by a conveyor to a series of seven pellet presses. The presses are preceded by ripening bins, allowing time for the water added at the pre-conditioner to be absorbed by the fiber. Conditioners provide an opportunity to add water, steam or additives just prior to pelletizing. Pelletizers in the U.S. usually only add water at this stage. This helps lubricate the fiber as an aid in pelletizing.

The pellet presses are major power users. A single press can produce 5 ton/hour of pellets and this plant requires seven presses at 500 HP each.

The pellets are heated by friction in the presses and discharge at around 200 degrees F. They are fragile at this temperature and must be cooled quickly to below 110 degrees. This increases strength and reduces breakage. This is done with pellet coolers which draw ambient air around the pellets with induced-draft fans. The air must be passed through bag filters or high-efficiency cyclones before discharging to the atmosphere. Fines from the collectors are recovered to the process.

Pellets discharged from the cooler are screened and fine particles from the screen are recycled to the hammer-mills. Acceptable pellets are stored in a silo and loaded into trucks for transport to a port facility.

ENERGY INPUTS AND CO_2 DISCHARGES

Planting and Harvesting

Planting includes site preparation, application of herbicide and mechanical planting. In the southern United States, most existing and planned large pellet facilities are purchasing tree-length logs for on-site chipping. Harvest may be plantation thinning or final. Based on information provided by Georgia Forestry Commission [4], a reasonable estimate for planting and harvesting would be 1.7 gallons of diesel per ton of harvested logs. Unit fuel consumption is 246.6 Btu/pound of pellets. Unit CO_2 emissions is due to combustion of diesel is about .039 pounds/pound of pellets.

Transportation of Logs to the Plant Site

For this plant, an annual delivery of 528,000 tons of green logs is required to produce 250,000 tons of dry pellets. In addition, 16,200 tons of purchased fuel is required. For this study, we assumed 100 miles round trip for both fuel and logs. Fuel consumed was 14.6 gallons per round trip. Energy consumption was 45.5 Btu/pound of material delivered or 99.67 Btu per pound of pellets.

Assuming complete combustion of diesel fuel, CO_2 emissions were calculated to be 21.47 pounds/gallon of fuel burned and 0.0155 pounds/pound of pellets.

Pelleting Process

The pelleting process is very energy-intensive, requiring large amounts of electricity plus some natural gas and diesel fuel. Electricity is not a primary energy form and must be produced from combustion of a primary fuel such as coal, wood pellets or natural gas. Therefore, the electrical energy requirements must be converted to primary energy requirements to determine the net gain.

Also, the CO_2 emissions from the primary source must be accounted for. For this paper, we will assume a thermal efficiency of 35 percent in converting primary fuel to electricity. Electrical power consumption will be based on 65 percent of connected horsepower. EPA suggests a factor of 0.000689 metric tons of CO_2 emitted per kWh of electrical consumption, or 1.55 pounds CO_2 /kWh [1].

Green Wood Preparation Island

Total connected horsepower: 2,562 HP
Estimated primary fuel consumption: 185.5 Btu/pound of pellets
Estimated CO_2 emissions: .029 pounds/pound of pellets

Fuel usage of a single front-end loader or dozer working to feed chips and bark to the dryer is estimated to be 8.8 gallons/hour.
Estimated fuel consumption: 17.3 Btu/pound of pellets
Estimated CO_2 emissions: 0.0029 pounds/pound of pellets

Dryer Island

Total connected horsepower: 2,478 HP
Estimated primary fuel consumption: 179.5 Btu/pound of pellets
Estimated CO_2 emissions: 0.028 pounds/pound of pellets

Natural Gas to RTO
Natural gas consumption: 4,037 SCF/hour
Estimated Unit Energy Consumption: 54.6 Btu/pound of pellets
Estimated Unit CO_2 emissions: 0.007 pounds/pound of pellets

Pellet Island

Total connected horsepower: 7,172 HP
Estimated primary fuel consumption: 519.4 Btu/pound of pellets
Estimated CO_2 emissions: 0.081 pounds/pound of pellets

Transportation to Port Facility

For this facility, a round-trip distance of 200 miles is assumed. This requires an estimated fuel consumption of 29.2 gallons of diesel or 85.2 Btu/pound of pellets. For longer trips, it is probable that rail transportation would be considered to decrease the fuel consumption. CO_2 emissions were estimated at 0.0142 pounds/pound of pellets.

Port Facility

Pellets may be unloaded from rail or truck and stored in large domes at the port. From the domes, the pellets are loaded onto ships with specialized ship-loading equipment. Much of the equipment operates intermittently, but the dome ventilation equipment operates virtually continuously. For one facility currently under construction, total connected horsepower is 3,400. Accounting for intermittent loading, estimated primary energy consumption is 25.2 Btu/pound of pellets. Unit CO_2 emissions due to electrical power generation is 0.0040 pounds/pound of pellets.

Ocean Transportation

The cost of ocean transportation varies greatly, depending on distance, size of ship, back-haul opportunities, and distance to port of loading. One study on cost of shipping grains found the following cost for various ship sizes, assuming no backhaul [8]:

Ship Size (dry weight tons)	Fuel Consumption (ton-mile/gallon)
30,000	574.8
50,000	701.9
70,000	835.1
100,000	1,043.4

Since many grains have bulk densities similar to wood pellets (about 42 pounds/cubic foot), similar fuel consumptions might be expected for wood pellets. For a voyage from Florida to Rotterdam, Netherlands, the estimated shipping distance is 4,600 miles. For a Panamax-sized ship, a ship-size of 70,000 dwt could be assumed. Using these conditions, the estimated fuel usage is 414.3 Btu/pound of pellets. The CO_2 emissions from this fuel consumption are 0.0711 pounds/pound pellets.

This represents a very significant, yet highly variable portion of the total energy requirement and CO_2 emissions. Fuel can be reduced with larger loads and short ballast voyage (ballast voyage is the trip from last unloading port to the loading port). Efficient back-hauls can reduce the ballast voyage. In some cases it might be necessary to attribute the entire return voyage to the pellets.

This is one area where eastern U.S. suppliers should have a competitive advantage over more distant pellet supply locations such as British Columbia or South America.

DATA SUMMARY

	Energy Consumption	CO_2
Emissions		
	Btu/Pound of Pellets	Pounds CO_2
/		

		Pound Pellets
Planting and Harvesting	246.2	0.039
Transportation of Logs	99.1	0.016
Green Wood Preparation	202.8	0.032
Dryer Island	234.5	0.035
Pellet Island	519.4	0.081
Transportation to Port	85.2	0.014
Port Facility	25.2	0.004
Ocean Transport	414.3	0.071
Totals	1,828	0.292
Pellet Fuel Combustion	7,740	0

DISCUSSION OF RESULTS

The higher heating value of oven-dry wood is about 8,600 Btu/pound [3]. Corrected for 10 percent moisture, the HHV is reduced to 7,740 Btu/pound. Total energy consumption in production and transportation of wood fuel pellets is estimated to be 1,828 Btu/pound of pellets, or about 24 percent of the pellet fuel energy. About a 22 percent this is in ocean transport, indicating that a significant energy savings would accrue from domestic utilization of the pellets.

The CO_2 emissions assume that no net CO_2 results from combustion of pellets. Using a conversion efficiency of 35 percent in yields CO_2 emissions of 0.37 pounds per kwh of produced electricity, compared to 1.55 pounds CO_2 per kWh using the EPA factor described above.

CONCLUSION

Clearly, in the scenario considered here, use of wood pellets to generate electricity results in a net energy gain of 4:1. There is also a clear reduction in CO_2 emissions by about 4:1. Some other environmental advantages to using wood pellets as a fuel include low sulfur and mercury content when compared to coal. There appears to be a need to quantify and publish effects of ocean-transport variables on energy consumption and CO_2 emissions. Ocean transport represents a significant percentage of the total energy consumption and CO_2 emissions, and the factors contributing to these quantities are highly variable.

The Author

Allen Wiley is a registered professional engineer with over 32 years of mechanical design and engineering experience. He has served as a Senior Mechanical Engineer at Hunt, Guillot & Associates (HGA) for over 7 years and is an expert on wood product manufacturing.

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