Case Study Evaluations for Three Wood Energy-Dry Kiln Facilities
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*Millcraft Products, D.J. Molding and MET, Inc.*

# CASE STUDY EVALUATIONS FOR THREE WOOD ENERGY-DRY KILN FACILITIES

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**MECP Wood Energy Demonstration Project**

The Michigan Energy Conservation Program (MECP) was established to help farmers and wood energy users reduce their energy costs by several different conservation methods. The program was funded by Michigan's legislature and is the result of two federal court decisions stemming from oil overcharges during the 1970s. The Wood Energy Demonstration Project was one of six areas within the MECP and was designed to help wood fuel users establish energy systems by providing model demonstration sites for other organizations. All Michigan businesses, governmental units, and not-for-profit organizations were eligible for the grant program. A total of $300,000 in funding was provided to 8 demonstration sites to upgrade an existing system or to install a new wood energy system. The project was administered through the State of Michigan Department of Agriculture and also through Michigan State University's Department of Forestry.

As grant recipients for the MECP Wood Energy Demonstration Project, Millcraft, MET, and D.J. Molding hosted several facility tours, which were free and open to the public. Technology transfer activities also included case study work and wood energy system evaluations.

## Wood Energy Background

**Millcraft Products, Allegan**

Millcraft Products is a manufacturer of wood products for industry, including furniture and cabinet components, dimension stock, and moldings. As part of a plant expansion Millcraft recently built lumber dry kilns and a wood energy system at a newly acquired industrial site. The firm dries primarily hardwood lumber, including 1-inch thick maple and red oak, used in manufacturing operations.

**MET, Inc., Ludington**

MET, Inc. is a wood dimension products manufacturer facility in Ludington, Michigan, that converted from natural gas fuel to wood energy for drying lumber. Green sawdust and other manufacturing residues from an adjacent sawmill are used for fuel, allowing energy savings as well as a reduction in waste material.

**D.J. Molding, Coleman**

D.J. Molding is a producer of trim and moldings for the construction industry. Principal operations include planing, sanding, and finishing. The wood energy system started operation in late 1989 and currently provides heat to the shop facility. Sawdust from an adjacent sawmill is used to fuel the wood energy system. The sawmill produces about 15-16 MBF of lumber daily, primarily red oak.

## MECP Project Plan

**Millcraft**

Millcraft Products utilized a $75,000 MECP grant towards the cost of a wood energy system which was constructed at a recently acquired site near Allegan. About 4 acres of the 20-acre complex is used to house the firm's manufacturing and wood

MECP is a cooperative effort of the:
Michigan Department of Agriculture - Michigan Soil Conservation Districts - USDA Soil Conservation Service
Michigan State University's Agricultural Experiment Station and Cooperative Extension Service

energy facilities. The wood-fired boiler currently burns dry mill residues to provide heat for 114 thousand board ft. (MBF) capacity of lumber dry kilns.

**MET, Inc.**

MET, Inc. received a $75,000 MECP grant towards construction and installation of an automated wood energy system, replacing a natural gas boiler. Green sawdust from an on-site sawmill operation is used as an energy source to heat lumber dry kilns. MET dries primarily 4 x 4 red oak lumber and currently has dry kiln capacity of 60 MBF. Edge-glued hardwood panels and dimension stock are also produced on-site from the dried lumber.

**D.J. Molding**

D.J. Molding used a $10,000 MECP grant toward two separate projects designed to increase the boiler efficiency and heating capacity of a wood energy system. One project involved installing a stack booster onto the exhaust stack. This unit is designed to increase air flow through the wood energy system, resulting in greater heat transfer and boiler efficiency. The second project involved installing a hot water conversion unit as part of the heating system. The conversion unit is resulting in greater heating efficiency of shop and factory buildings.

## System Operations

**Millcraft**

Dry manufacturing residues are transported about 3 miles from Millcraft's furniture mill to the wood energy facility. Fuel is stored in an outside cement storage bunker with a capacity of about 600 cubic yards. A front end loader is used to transport fuel to a secondary bin which meters fuel directly into the burner in response to current fuel demands. Fuel is loaded into the burner by an auger. Since the particle size is very uniform, no additional screening or reduction is needed.

A 250 HP fire-tube boiler utilizes dry fuel, with a 6 to 8 percent average moisture content. Low pressure process steam is used to heat 3 dry kiln compartments. A multicyclone emission control unit separates ash and uncombustible particles from the primary airstream.

During the start-up period of the summer of 1991, wood fuel requirements averaged about 2 to 3 tons per day, based on 114 MBF of dry kiln capacity. During winter months, fuel use is expected to double or triple after construction of three additional dry kilns is complete. The three dry kilns will have a combined capacity of 114 MBF.

Millcraft Products currently maintains 3 dry kilns (114 MBF total capacity) to dry primarily 1-inch thick maple and red oak. About 2 million board ft. of lumber will be dried annually. Kiln cycles average 30 days for green lumber and 15 days for previously air-dried lumber. During summer months, much of the lumber is first air-dried, resulting in shorter kiln-drying times.

**MET, Inc.**

MET started drying lumber in April 1990 with two 30 MBF capacity dry kilns. A 50 horsepower (HP) natural gas system was used initially as the energy source. A 225 HP wood-fired boiler fueled primarily with green sawdust from an on-site sawmill has replaced this natural gas boiler. The system currently provides low pressure steam (about 10 psi) for the dry kilns with plans to heat additional dry kilns, a lumber predrier, and shop facilities. Fuel requirements for the wood system average 5 tons per day. Green sawdust is obtained from an adjacent sawmill which cuts primarily 1 inch thick red oak (about 1.5 million board ft. per year). Lumber from this sawmill is then dried in the kilns at MET before processing. Wood fuel is transported directly from the sawmill to a 220 cubic yard capacity bin by front end loader.

Airflow through the system is facilitated by under-fire and over-fire air fans on the burner as well as an induced draft fan which is part of the exhaust stack. A multicyclone emission control unit separates flyash and uncombustible particles from the primary airstream; ash is then landfilled.

Operating conditions for the burner are regulated by a programmable logic controller. This electronic control system is capable of adjusting fuel feed rates and combustion temperatures to maximize the efficiency of the wood energy system. Alarms are activated to indicate any problems with steam pressure, fuel feed rate, induced draft fans, combustion temperatures, boiler water levels, or inlet fuel temperatures.

Lumber is dried in 2 dry kilns with a combined capacity of 60 MBF. Two additional dry kilns with a capacity of 60 MBF are planned. MET dries primarily 4 x 4 red oak lumber from the green condition to a final moisture content of about 7 percent during a 30-day kiln cycle.

*Natural gas fuel*

MET initially used natural gas to heat its dry kilns. Natural gas is often used as a backup fuel where wood is the main energy source. High BTU natural gas typically contains about 1,000 BTU per cubic ft. (at specified conditions). Natural gas energy systems are relatively inexpensive and easy to install and maintain compared to wood systems.

The advantages of wood fuel vs. natural gas were apparent for MET because of the availability of green sawdust from a neighboring sawmill. When wood fuel is available in large quantities at little or no cost, higher rates of return may be realized by investing in a wood energy system rather than a less expensive natural gas system. Using wood as a fuel source may reduce landfill requirements, resulting in additional cost savings and environmental benefits. Wood energy also has the advantage of being utilized in remote regions where natural gas may not be available.

**D.J. Molding**

D.J. Molding installed a 40 horsepower (HP) boiler system fueled by green sawdust [35 to 40 percent moisture content green basis (MCGB)] from an adjacent sawmill. Low pressure steam provides heat to the molding shop and will be used to heat 3 dry kilns totalling 76 MBF capacity. Hot water condensate from the steam will be used to heat a proposed 40 MBF predryer facility.

Wood fuel consumption is as high as 1.5 tons per day during winter months. A wood fuel metering bin with a capacity of about 500 cubic ft. is located adjacent to the boiler system. A 3 HP motor driven auger system operates intermittently to transfer fuel from the bin into the burner. The 40 HP fire tube boiler has a double pass design in which hot combustion gasses travel 2 lengths of the system for efficient heat transfer to the boiler water. Two 1/4 HP fans run intermittently to provide underfire combustion air into the burner. Boiler pressure is maintained between 8 and 16 psi.

Bottom ash is removed manually from the combustion chamber and is used locally as a soil amendment. During the most recent heating season about 500-600 lbs. of bottom ash was produced (and was removed from the burner during 2 cleanings). Much of the ash consisted of glass and clinkers from sand that was combined with the wood or bark.

As part of the MECP project, DJ Molding installed an induced draft fan onto the exhaust stack to provide increased airflow through the wood energy system. The 15 HP unit operates intermittently, in conjunction with the underfire air fans.

The primary benefit of the induced draft fan is that less time is needed to bring the wood energy system up to the desired steam pressure. It is estimated that the new fan has reduced warm-up times by 25 to 30 percent, resulting in a corresponding increase in boiler efficiency and heat output. Typical warm-up times have been reduced from about 50 minutes to 35 minutes.

## Combustion Efficiency

Combustion efficiency in wood energy systems influences not only heat production and steam generation but also the composition of stack gasses. A well designed wood energy system maximizes combustion efficiency while minimizing the emissions of carbon monoxide and other products of incomplete combustion.

System performance is affected by volume and placement of underfire and overfire air, combustion chamber size, and the area of the grate which supports fuel particles during combustion. Proper volume and placement of air through the combustion chamber is necessary to bring about the turbulent mixing needed for complete combustion to occur.

Fuel moisture content and particle size affect net heating values, completeness of combustion, and gas emission products. High fuel moisture content can result in reduced combustion temperatures, incomplete combustion, greater ash production, and reduced boiler efficiency. Low moisture content fuel and/or fuel with small particle size can result in short residence times in the burner, also leading to incomplete combustion. Residence time, combustion temperatures, and turbulence all affect the completeness of combustion.

*D.J. Molding - Wood Fuel*

The effect of high vs. low feed rate on combustion gas parameters was evaluated at D.J. Molding. Combustion parameters for green sawdust fuel were recorded at both low and high fuel feed rates (Table 1). Combustion air volume was maintained at a constant level for all tests.

For the low fuel feed rate, the fuel to air ratio was relatively low, resulting in high levels of oxygen, excess air, and combustion efficiency. Low levels of carbon monoxide, carbon dioxide, and combustibles were also recorded. All of these parameters indicate good combustion conditions.

For the high feed rate, the ratio of fuel to air was higher, and combustion conditions were therefore less favorable than for the low feed rate. The oxygen content was about 10 percent lower than for the low feed rate, carbon dioxide was about 6 percent higher, and excess air levels were considerably lower. Carbon monoxide and uncombustible particulate levels were higher for high feed rate, indicating reduced combustion efficiency.

*Millcraft Products - Wood Fuel*

At Millcraft Products, combustion parameters were evaluated for a medium fuel feed rate (Table 1). Carbon monoxide levels were relatively low, indicating favorable combustion conditions. Combustion parameters for Millcraft's system were intermediate to those from D.J. Molding's system, evaluated at both high and low fuel feed rates. Green sawdust was the fuel type for both systems.

*MET - Natural Gas*

Combustion efficiency of MET's natural gas system was evaluated for oxygen ($O_2$), carbon monoxide (CO), combustibles, carbon dioxide ($CO_2$), excess air, and combustion efficiency (Table 1). Combustion parameters were consistent over three sampling dates. The oxygen content varied from about 5.5 to 6.0 percent, carbon dioxide varied from about 8.5 to 9.0 percent, and excess air was typically between 30 and 35 percent (Table 1). By contrast, carbon monoxide (CO) levels varied considerably depending on the sampling date. Average CO values ranged from 22 to 673 parts per million (ppm). The average combustible content was closely related to the CO level.

## Economics and Energy Savings

Forest products producers often have access to wood residues such as sawdust, edgings and planer shavings at little or no cost. Millcraft, MET, and D.J. Molding are utilizing their own manufacturing wastes for fuel with only nominal transportation and labor costs. Each facility will be heating dry kilns on a year-round basis. Project payback for each system is estimated to be about 2 years.

Energy requirements for drying lumber depend on many factors, including species, lumber thickness and thickness variations, wood density, and initial and final moisture contents. Boiler and kiln efficiencies also vary from site to site. It is estimated that one thousand bd. ft. of 1-inch thick red oak lumber may require more than 6 million BTUs for drying from 80 to 7 percent moisture content. This corresponds to fuel requirements of approximately 1.6 tons of green wood.

**Table 1**

**Combustion parameters for wood energy systems at D.J. Molding and Millcraft Products, and for the natural gas system at MET.**

| fuel feed rate | sample size | oxygen (%) | carbon dioxide (%) | carbon monoxide (ppm) | combustibles (%) | excess air (%) |
|---|---|---|---|---|---|---|
| **D.J. Molding - Wood Fuel** | | | | | | |
| LOW | 8 | 17.6 | 2.2 | 392 | 0 | 480 |
| HIGH | 9 | 8.3 | 8.2 | 1/ | 1/ | 60 |
| **Millcraft - Wood Fuel** | | | | | | |
| MEDIUM | 10 | 13.9 | 6.8 | 40.4 | 2/ | 197 |
| **MET - Natural Gas Fuel** | | | | | | |
| - | 12 | 5.8 | 8.6 | 313.3 | 0.28 | 34 |

1/ exceeded detectable limit
2/ measurements not taken

**Millcraft Products**

Estimated costs for operating Millcraft's wood energy and dry kiln systems are summarized in Table 2. Projections are based on the use of 6 kilns having total capacity of 228 MBF of lumber (2,000 MBF per year). Electrical costs of $30,000 per year will be required to run all fans and motors associated with the wood energy and dry kiln systems. This includes the fuel handling and metering augers, underfire and overfire air fans, an induced draft fan, and dry kiln fans.

Labor costs are estimated at $40,000 per year and include 3 employees needed for wood energy maintenance, and loading and unloading the dry kilns. The cost of transporting lumber by truck 3 miles from the manufacturing facility to the wood energy site is estimated at $11,000 per year. Taxes, insurance, and equipment maintenance are estimated at $20,000 per year. A front end loader, used for fuel handling, will cost about $10,000 per year for leasing and maintenance.

The capital cost of the combined wood energy and dry kiln systems is estimated to be $500,000. The financial analysis indicates a capital cost of $25,000 per year amortized over a 20-year useful life for equipment. The total savings from drying lumber on-site vs. custom drying at another facility is estimated to be $103,000 per year (Table 2). Wood fuel will be obtained from the manufacturing facility at no cost other than handling and transportation.

In a separate economic analysis, the Wood Energy Financial Analysis Model (WEFAM) computer program was used to calculate project economics for the wood energy system at Millcraft (not including the dry kiln facility). Year 1 energy

**Table 2**

**Projected cost savings associated with wood energy and dry kiln facilities at Millcraft Products ***

**annual drying production: 2 million bd. ft.**

**Estimated annual cost of custom kiln drying 2 million bd. ft. of lumber (dried by outside facility)**

| | |
|---|---|
| - custom drying costs | $220,000 |
| - freight costs | 25,000 |
| - total drying costs | $245,000 |

**Estimated annual costs for Millcraft Products to dry lumber (lumber dried on-site starting from green condition)**

| | |
|---|---|
| - electricity | $30,000 |
| - labor and fringe benefits | 40,000 |
| - transportation costs | 11,000 |
| - maintenance | 8,000 |
| - taxes and insurance | 12,000 |
| - miscellaneous expenses | 6,000 |
| - lease and maintenance for front end loader | 10,000 |
| - capital costs of wood energy system and dry kilns (amortized over a 20-year period) | 25,000 |
| | $142,000 |

**Annual cost savings resulting from wood energy and dry kiln facilities** **$103,000**

* includes costs associated with dry kilns and wood energy system

savings were estimated to be $144,540, based on an alternative fuel cost for natural gas of $3.00 per million BTU. Internal rate of return was 52.5 percent, corresponding to a payback period of 2 years (Table 4). The payback period for the wood energy system was considerably shorter than the project payback for the combined wood energy/dry kiln facility.

### MET, Inc.

Natural gas expenses to heat MET's 60 MBF dry kilns show seasonal variations within the range of $1,500-2,500 per month. After the dry kiln and predrier expansions are completed, the projected energy requirements are expected to more than double the current levels. Mill residues for fuel will result in estimated energy savings of $5,000-6,000 per month, compared to the use of natural gas.

The internal rate of return for MET's wood energy system is estimated at 55.1 percent, corresponding to a project payback period of about 2 years. Year 1 energy savings are projected to be $65,700 (Table 4).

### D.J. Molding

Energy savings are realized from both of D.J. Molding's wood energy system modifications. The new induced draft fan has increased the available power from the boiler, resulting in shorter times to reach steam pressure. It is estimated that warm-up periods for the boiler have been reduced an average of 25-30 percent due to the new fan. Low pressure steam is produced and delivered to the molding shop more efficiently. Increased airflow through the wood energy system results in more complete dispersion of exhaust stack gasses.

Additional savings will result from a proposed predryer heated with wood energy. Hot water condensate from the shop facility will be routed to a 40 MBF predryer building rather than returned directly to the boiler system. This secondary heat will be in the form of hot water rather than low pressure steam. The dry kilns and predryer will enable D.J. Molding to dry lumber on-site rather than paying for drying at another facility.

After completion of the dry kilns and predrier facility, energy savings for D.J. Molding are expected to be more than $31,000 per year, based on an alternative of natural gas heat. The project payback period of 2 years corresponds to an internal rate of return of 58.3 percent (Table 4).

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## Table 3

**Assumptions for Computer-Based Comparison of Wood Fuel vs. Natural Gas Heating at Millcraft, MET, and D.J. Molding.**

| WEFAM Input[1] | Millcraft | MET | D.J. Molding |
|---|---|---|---|
| 1. Energy system size (estimated actual usage, million BTU per hour) | 5.5 | 2.5 | 1.2 |
| 2. Alternative fuel | natural gas | natural gas | natural gas |
| 3. Expected usage of alternative fuel (cubic ft./year x 1000) | 48,180 | 21,900 | 10,512 |
| 4. Cost of alternative fuel ($ per year)[2] | 144,540 | 65,700 | 31,536 |
| 5. Moisture content of wood fuel (% of total weight) | 7 | 45 | 40 |
| 6. Delivered cost of wood fuel ($ per green ton) | - | - | - |
| 7. No. of operating hours/day | 24 | 24 | 24 |
| 8. No. of operating days/year | 365 | 365 | 365 |
| 9. Avg. wage rate of boiler operator ($ per hour) | 10 | 10 | 10 |
| 10. Capital cost of wood energy system ($ x 1000) | 280 | 120 | 50 |

[1] Wood Energy Financial Analysis Model (WEFAM). [computer program]. Office of Energy Programs. 1988. Lansing, Michigan, Public Service Commission. Michigan Department of Commerce.

[2] Based on a delivered natural gas cost of $3.00 per million BTU.

## Table 4

**Internal rate of return, project payback, and energy savings for wood energy systems at Millcraft, DJ Molding, and MET[1]**

| | Internal rate of return (%) | Project payback period (years) | Projected Energy savings Year 1 ($) | Projected Energy savings Year 20 ($) |
|---|---|---|---|---|
| Millcraft | 52.5 | 2 | 144,540 | 466,528 |
| DJ Molding | 58.3 | 2 | 31,536 | 101,788 |
| MET, Inc. | 55.1 | 2 | 65,700 | 212,058 |

[1] Results based on Wood Energy Financial Analysis Model (WEFAM) [computer program]. Office of Energy Programs. 1988. Lansing, Michigan. Public Service Commission. Michigan Department of Commerce.

## The Wood Energy Demonstration Project

The Michigan Energy Conservation Program for Agriculture and Forestry's Wood Energy Demonstration Project was designed to help businesses and organizations throughout the state realize cost and energy savings through the use of wood as an energy source. A $300,000 direct grant program provided competitive awards to facilities to offset the cost of installing and maintaining wood energy systems. The maximum individual grant award was $75,000.

Under terms of the grant, recipients documented all installation and operating costs. Information on operating conditions and energy savings is available to any organization interested in the economics of wood as an energy source for heat or manufacturing.

Twenty-nine applicants submitted grant proposals, including primary and secondary forest products manufacturers, schools, agricultural related businesses, and a medical care facility. Nine proposals were received from businesses that use kilns to dry lumber, representing the largest single project type.