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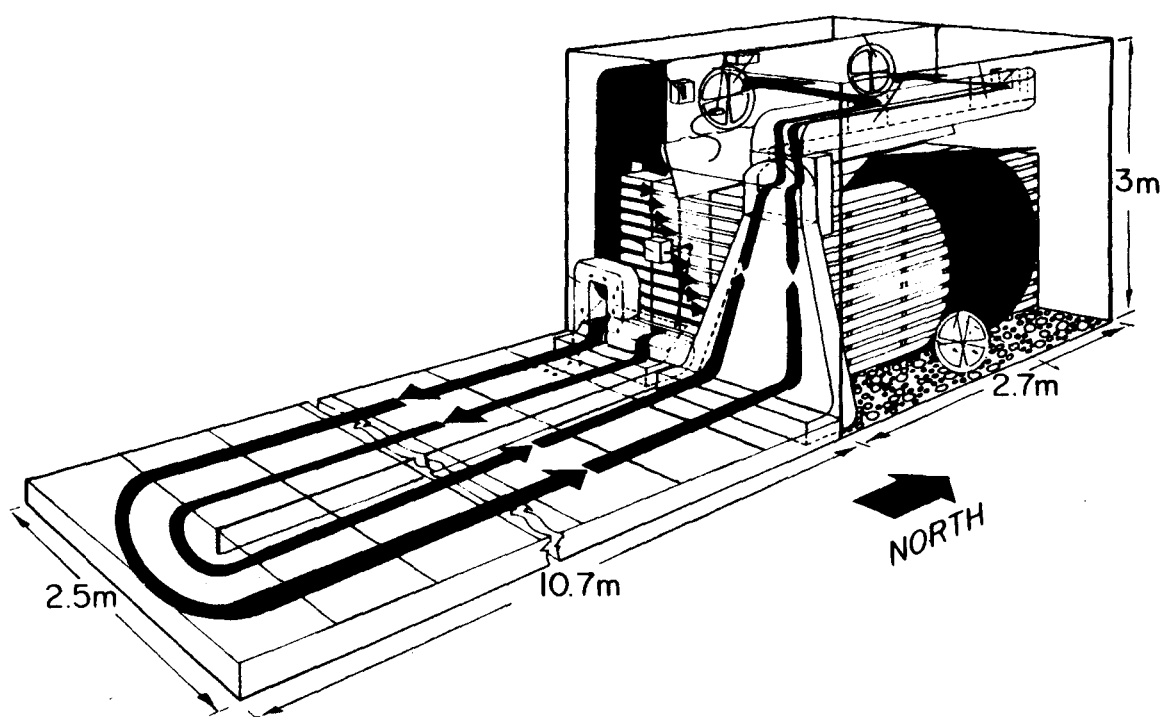
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Investment Opportunity: The FPL Low-Cost Solar Dry Kiln



Abstract

Two equations are presented that may be used to estimate a maximum investment limit and working capital requirements for the FPL low-cost solar dry kiln systems. The equations require data for drying cycle time, green lumber cost, and kiln-dried lumber costs. Results are intended to provide a preliminary estimate.

Keywords: Drying, kilns, solar, economics.

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Investment Opportunity: The FPL Low-Cost Solar Dry Kiln

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Introduction

In 1975 the Forest Products Laboratory (FPL) began designing and testing low-cost solar dry kilns for tropical locations. Several kiln designs were considered. One design was selected from which three small-capacity prototypes were built and tested for operation and durability. The design was optimized for small-scale operations, such as drying green lumber for furniture manufacturing. Development and testing were done in Madison, WI, using red oak and hard maple, and in Sri Lanka and Burma using rubberwood (*Hevea brasiliensis*). The prototype solar kiln has a 6,000-board-foot (fbm) charge capacity and can receive supplemental heat from a simple wood waste combustion system. Detailed design information for the 6,000-fbm solar dry kiln is given in Tschernitz and Simpson (1985). As an expandable design, kiln size can be increased from 6,000 fbm to 9,600 fbm with only small additions of building materials and kiln equipment. These solar kilns can then be used as modules for larger systems (Simpson and Tschernitz [In Press]). This report also analyzes the energy efficiency of the system on the basis of available drying data.

The objective of this paper is to provide guidelines for making a preliminary feasibility test for prospective use of the FPL low-cost solar drying system. For economic feasibility, the test must provide an estimated construction cost less than the amount justified by the cost savings expected from purchase of green instead of kiln-dried lumber. That is, the capitalized value of cost savings is used to set an investment limit. This paper provides two equations to estimate investment limits for the FPL low-cost solar dry kiln systems.

Estimating Investment Limits

The following two equations can be used to estimate the maximum economic investment for the solar drying facility and to estimate the amount of working capital needed to operate the facility. To make these estimates, data are needed to specify the proposed charge capacity of the kiln (thousand board feet), economic life of the facility (years), market cost for kiln drying (dollars per thousand board feet), drying cycle time (number of days), and green lumber cost (dollars per thousand board feet). When the assumptions used (see below) appear reasonable, the equations can be used to estimate a maximum economic investment (investment limit) for a solar kiln and to estimate likely requirements for working capital.

Investment Limit in Dollars (\$IL)

$$\text{\$IL} = \text{MBF} \{[(\text{EL} - 5)0.025] + 1\} [1,364(\text{KDC}/\text{CYT}) - 738] \quad (1)$$

where MBF is charge capacity of the solar kiln in thousand board feet (6,000 to 9,600 fbm), EL is the economic life of the operation (5 to 10 years), KDC is the market cost of kiln drying, or the difference between the cost of green lumber and kiln-dried lumber, and CYT is the cycle time in days (i.e., 365 divided by the number of charges per year).

Basis for Estimating Procedure

Working Capital Requirement in Dollars (\$WCR)

$$\text{\$WCR} = \text{MBF} [222 + 0.0118(\text{GLC})(\text{CYT})] \quad (2)$$

where GLC is the green lumber cost.

Results are quite sensitive to the number of days entered for cycle time. To calculate a facility investment limit, cycle time should be based on the annual average number of days between loadings to account for loading, repairs, idle time, and the influence of cloudy days. Also, if supplemental energy use is expected to be significant, estimated energy costs should be deducted from the market cost of kiln drying (KDC). That is, supplemental energy costs reduce the savings to be capitalized. The charge capacity of the FPL 6,000-fbm solar kiln can be increased to 9,600 fbm for a relatively small increase in cost. Also, they can be modularly enlarged to 19,200 fbm or larger with some additional increases in construction and operating efficiencies (Simpson and Tschernitz [In press]). For this reason, when actual construction costs exceed an estimated investment limit, a larger system may provide an investment limit that will exceed the construction cost for the larger system.

In situations indicating commercial feasibility, final feasibility analyses should include carefully considered details of solar kiln construction costs, working capital requirements, energy and other operating costs, drying cycles times, and likely degrade losses.

Discounted cash flow techniques were used to estimate investment limits and working capital investments for the FPL solar drying system. Based on the results of these discounted cash flow analyses, linear equations were developed to provide a simplified method for estimating facility investment limits and working capital requirements that could be used as a test for financial feasibility.

Using discounted cash flow methods, the maximum economic investment for the facility was estimated by capitalizing differences between green lumber and dry lumber costs, less costs for operating the solar kiln. Representative lumber and drying costs for red oak and hard maple were obtained from Hardwood Market Reports (1986-1987). As shown in the following tabulation, market prices based on dollars per thousand board feet were approximated for No. 1 Common 4/4 kiln-dried lumber (partially air-dried lumber plus drying costs) and green lumber (kiln-dried lumber price less cost for drying from green).

<u>Lumber</u>	<u>Red oak</u>	<u>Hard maple</u>
Green	\$504.00	\$259.00
Partially air dried	550.00	300.00
Commercial kiln dried	642.00	382.00

Commercial kiln-drying cost is based on \$138 per thousand board feet for green red oak, \$92 per thousand board feet for partially dry red oak, \$123 per thousand board feet for green hard maple, and \$82 per thousand board feet for partially dry hard maple.

Excluding energy, variable costs are assumed to be the same for drying any species of wood. Energy costs assume that 2,333 lb of water per thousand board feet must be removed from red oak, and 1,850 lb of water per thousand board feet must be removed from hard maple to obtain a final moisture content of 8 percent. Also, 3,400 Btu are required to remove each pound of water in the FPL solar kiln with wood-waste fuels supplementing 25 percent of the total energy requirements. Use of wood-waste fuels is assumed to be directly related to cycle times for drying. Wood-waste fuels were assumed to cost approximately \$20 per oven-dry ton or \$1.25 per million Btu of recoverable heat (table 1).

Table 1 –Variable costs for solar drying

Factors	Cost (dollars/ thousand board feet)	
	Red oak	Hard maple
Green lumber	504.00	259.00
Labor	10.00	10.00
Stickers	1.50	1.50
Equipment operation ^a	3.50	3.50
Wood-waste fuels ^b	2.50	2.00
Total cost	521.50	276.00

^a Fork lift or lumber carrier, sorting table, end trimmer.

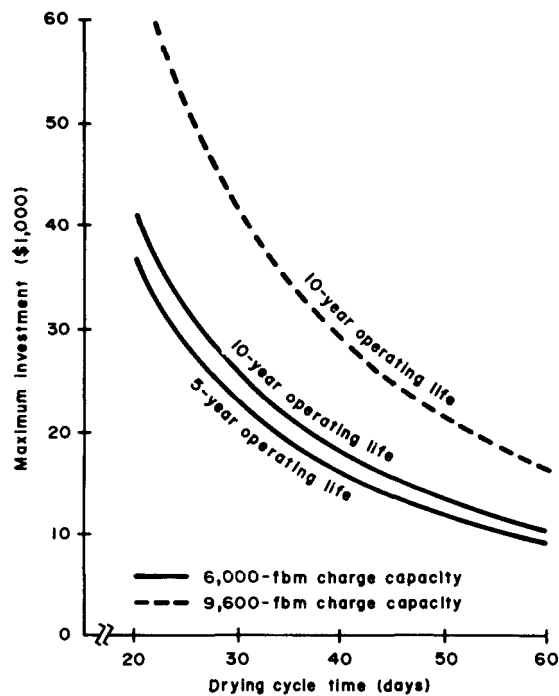
^b Assumes 8.0×10^6 Btu to dry red oak and 6.4×10^6 Btu to dry hard maple, each from green to 8 percent moisture content. Solar drying assumes 2.0×10^6 Btu and 1.6×10^6 Btu are supplied from wood residues for drying red oak and hard maple, respectively. Wood-waste fuels cost \$20 per oven-dry ton, or approximately \$1.25 per million Btu of recoverable heat.

For analysis, all costs are increased 4 percent per year. A higher rate of inflation will increase the maximum investment limit by increasing the capitalized value of the market cost for kiln drying. Other assumptions used for discounted cash flow analysis are

- land is not a component of facility investment;
- straight-line depreciation (capital recovery) of 90 percent of facility costs over facility life—assuming 10 percent salvage value;
- average annual effective tax rate of 36 percent for state and Federal taxes;
- an investment tax credit equal to 10 percent of the facility costs for solar energy property qualification; etc.
- after-tax return on investment is 12 percent (internal rate-of-return);
- working capital is provided to cover operating costs (fixed and variable costs) from the beginning to the end of the drying cycles; and
- fixed operating costs include annual property tax, insurance, maintenance, repairs, and utility costs as 6 percent of the facility investment cost.

As shown in table 2, increasing the estimated useful life of the solar kiln from 5 to 10 years increases the economic investment limit. By spreading capital recovery over a longer time, a larger investment can be recaptured at close to the same annual rate as for the shorter period. To offset increases in overhead costs, annual profit requirements can be reduced by allowing more time to obtain the required return on investment. Working capital requirements are slightly increased because of the increase in operating costs related to the increase in the facility investment, such as taxes and insurance. In turn, an increase in operating costs increases working capital requirements.

Increasing the annual throughput of lumber, which can be accomplished by using shorter drying cycles or constructing a kiln with a larger charge capacity, increases allowable facility investment (fig. 1). Length of drying cycles is primarily dependent upon species and the beginning and ending moisture content of the lumber being dried. Some air drying before solar drying and drying to moisture contents above 8 percent will shorten cycle time, but with air drying, working capital requirements increase and drying degrade losses are likely to increase.



ML88 5438

Figure 1 - Maximum facility investment limit for solar dry kiln based on two different charge capacities and different drying cycle times. (ML88 5438)

Table 2—Investment limits and operating costs (capitalized value of drying costs) for red oak and hard maple

Lumber	Investment limits (dollars)			Throughput per year ^a (thousand board feet)	Operating costs (dollars/thousand board feet)							
	Dry kiln	Working capital	Total		Variable costs	Fixed costs	Capital recovery	Taxes (36%)	Profit (10%)	Total cost	Green lumber cost	Drying costs ^b
Red oak												
Solar kiln-5 ^c	16,492	3,233	19,725	40.6	521.50	24.75	36.55	22.00	37.20	642.00	504.00	138.00
Solar kiln-10 ^d	18,550	3,252	21,802	40.6	521.50	27.81	41.12	19.23	32.34	642.00	504.00	138.00
Hard maple												
Solar kiln-5	34,293	1,785	36,078	84.2	274.00	24.54	36.65	17.95	28.86	382.00	259.00	123.00
Solar kiln-10	38,589	1,804	40,393	84.2	274.00	27.61	41.25	15.15	23.99	382.00	259.00	123.00

^a Throughput based on 6,000-fbm charge capacity with a 54-day cycle for red oak and a 26-day cycle for hard maple.

^b Drying costs = (total cost) - (green lumber cost).

^c Solar kiln with a 5-year operating life.

^d Solar kiln with a 10-year operating life.

Summary

A solar dry-kiln system, developed at the Forest Products Laboratory, has a 6,000-fbm charge capacity that can be expanded to 9,600 fbm for a small additional cost. This report provides equations for estimating investment limits for different-sized systems and cycle times based upon the capitalized value of cost savings expected from purchasing green instead of kiln-dried lumber. The methods and assumptions used to develop the equations are also provided.

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