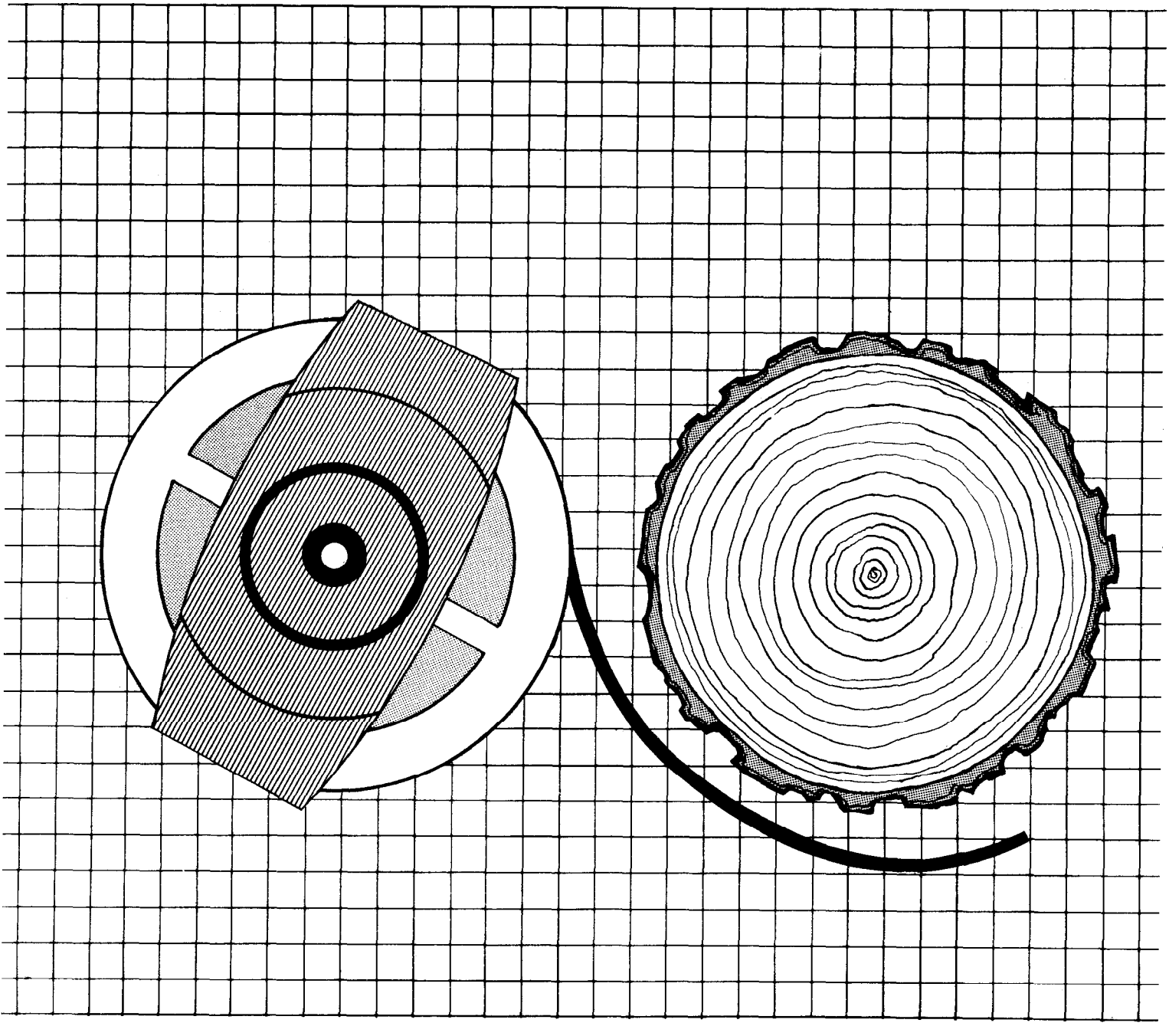
United States
Department of
Agriculture

Forest Service

Forest
Products
Laboratory

Research
Paper
FPL 415

A Wood and Bark Fuel Economics Computer Program (FEP)



Abstract

Demands for wood residue-type materials are expected to create competing alternate uses. The objectives of the wood and bark fuel economics computer program presented are to provide (1) a means to assess the relative energy values of wood and bark for use as fuel, and (2) pre-engineering assessments of the potential investment that may be justified by benefits gained through modification of wood/bark fuel systems. It is suggested that more advanced engineering and financial analytic methods be used for further evaluation whenever this program indicates favorable venture likelihoods.

United States
Department of
Agriculture

Forest Service

Forest
Products
Laboratory[1]

Research
Paper
FPL 415

September 1982

A Wood and Bark Fuel Economics Computer Program (FEP)

By

GEORGE B. HARPOLE,
PETER J. INCE,
JOHN L. TSCHERNITZ,
and
EDWARD BILEK

Introduction

Forest products harvesting and manufacturing processes are expected to provide large and continuing supplies of wood and bark residues. At the same time, the demand for wood residue-type materials for production of wood-fiber based products as well as wood and bark fuels is expected to create competing utilization alternatives. Primary objectives of the fuel economics computer program (FEP) presented here are: (I) to provide a means for assessing the relative energy values of fossil fuels and wood/bark fuels, and (2) to provide pre-engineering assessments of the potential investment that may be justified by benefits gained through modification of systems to burn wood/bark fuels.

The FEP computer program utilizes readily available fuel and economics information, standard combustion equations, and discounted cash flow analytic techniques. Because the FEP program is designed for preliminary assessments of wood/bark fuel use opportunities it is suggested that more advanced engineering and financial analytic methods be used for further evaluation whenever favorable venture likelihoods are indicated by the FEP program *(1-4)*[2]

The computer program presented is written in FORTRAN. The program listing may be found in appendix A.

Program Objectives

The computational objectives of the fuel economics program (FEP) are:

(1) To compute steam heat recovery, or theoretical wood drying capacities of exhaust gasses from different fuels (Figs. I and 2).
(2) To compute fuel costs per million Btu's of steam, or costs per thousand pounds of evaporated water (Figs. I and 2).
(3) To compute volumes of fuel types required to yield specified heat requirements, at a least cost from among alternatives (Fig. 3).
(4) To compute prospective savings in fuel costs if wood and bark residue are used as alternatives for oil, gas or other fuel (Fig. 3), and to capitalize such benefits into assignments to working capital requirements and justifiable facilities investment (Fig. 4).

[1] Maintained in Madison, Wis. in cooperation with the University of Wisconsin.

[2] Italicized numbers in parenthesis refer to literature cited at the end of this report.

********** FUEL TYPE ASSUMPTIONS AND ESTIMATES OF REQUIREMENTS, COSTS AND SAVINGS (450. DEG.F STACK TEMP.) **********

	UNIT BASIS	UNITS AVAIL. ANNUALLY	CU.FT. SOLID	SPEC. GRAV.	M.C. (WET)	$ COST PER UNIT.	- - - -HEAT-ENERGY VALUES- - - - HIGHER VALUE MBTU/UNIT	HEAT TO STEAM MBTU/UNIT	$/MMBTU
A) CURRENT SOURCE									
1) OIL	BBL	5000.	.00	.000	.0000	$ 34.00	6000.	4950.00	$ 6.87
B) PROPOSED SOURCE(S)									
2) N RED OAK	UNIT	600.	72.00	.560	.4400	$ 60.00	24237.	16739.02	$ 3.58
3) SO PINE	UNIT	400.	72.00	.470	.2400	$ 60.00	21926.	16485.05	$ 3.64
4) Y BIRCH	UNIT	800.	72.00	.550	.4300	$ 60.00	23087.	16026.88	$ 3.74
5) DOUG FIR	UNIT	100.	72.00	.450	.2700	$ 60.00	18606.	13887.79	$ 4.32
6) Y POPLAR	UNIT	900.	72.00	.400	.4500	$ 60.00	17312.	11914.09	$ 5.04
7) P PINE	UNIT	300.	72.00	.380	.2900	$ 60.00	15541.	11559.98	$ 5.19
8) w HEMLOCK	UNIT	500.	72.00	.380	.4600	$ 60.00	14516.	9915.90	$ 6.05
9) RED ALDER	UNIT	700.	72.00	.370	.4900	$ 60.00	13303.	8882.56	$ 6.75
10) E SPRUCE	UNIT	200.	72.00	.320	.3400	$ 60.00	11649.	8458.46	$ 7.09

* HIGHER OF COST OR MARKET. IE: OPPORTUNITY COST IS INCLUDED MERE.

NOTE--M IS THOUSANDS, MM IS MILLIONS.

Figure 1.—Printed output of heat-energy to steam and costs for fuel types analyzed.

(M151-269)

********** FUEL TYPE ASSUMPTIONS AD ESTIMATES OF REQUIREMENTS, COSTS\ AND SAVINGS **********

	UNIT BASIS	UNITS AVAIL. ANNUALLY	CU.FT. SOLID	SPEC. GRAV:	M.C. (WET)	$ COST PER UNIT*	- - - -HEAT-ENERGY VALUES- - - - HIGHER VALUE MBTU/UNIT	EFFECTIVE *H2O/UNIT	EVAPORATION $/M#H2O
A) CURRENT SOURCE									
1) OIL	BBL	5000.	.00	.000	.0000	$ 34.00	6000.	3529.41	$ 9.63
B) PROPOSED SOURCE(S)									
2) SO PINE	UNIT	400.	72.00	.470	.2400	$ 60.00	21926.	11148.73	$ 5.38
3) N RED OAK	UNIT	600.	72.00	.560	.4400	$ 60.00	24237.	11108.77	$ 5.40
4) Y BIRCH	UNIT	800.	72.00	.550	.4300	$ 60.00	23087.	10564.31	$ 5.68
5) DOUG FIR	UNIT	100.	72.00	.450	.2700	$ 60.00	18606.	9179.32	$ 6.54
6) Y POPLAR	UNIT	900.	72.00	.400	.4500	$ 60.00	17312.	7882.03	$ 7.61
7) P PINE	UNIT	300.	72.00	.380	.2900	$ 60.00	15541.	7592.41	$ 7.90
8) W HEMLOCK	UNIT	500.	72.00	.380	.4600	$ 60.00	14516.	6319.15	$ 9.49
9) RED ALDER	UNIT	700.	72.00	.370	.4900	$ 60.00	13303.	5512.99	$ 10.88
10) E SPRUCE	UNIT	200.	72.00	.320	.3400	$ 60.00	11649.	5418.89	$ 11.07

* HIGHER OF COST OR MARKET. IE: OPPORTUNITY COST IS INCLUDED HERE.

NOTE--M IS THOUSANDS, MM IS MILLIONS.

Figure 2.—Printed output of effective evaporative capacities and costs for fuel types analyzed.

(M151-268)

**** PROSPECTUS REQUIREMENTS (58000. MILLION STEAM-HEAT BTU'S/YEAR) AND ANNUAL SAVINGS ****

--------ANNUAL VOLUMES REQUIRED AT VARIOUS MOISTURE CONTENTS (WET BASIS)--------

PROPOSED SOURCES	UNIT BASIS	AT GIVEN M.C.	AT HIGHER MOISTURE CONTENT* + 5 PCT.	+ 10 pct.	+ 20 PCT.	AT LOWER MOISTURE CONTENT * * -5 PCT.	-10 PCT.	-20 PCT.
A) CURRENT SOURCE								
1) OIL	BBL	360.8	710.1	1079.2	4078.4	93.3	.0	.0
B) PROPOSED SOURCE(S)								
2) N RED OAK	UNIT	600.0	600.0	600.0	600.0	600.0	600.0	600.0
3) SO PINE	UNIT	400.0	400.0	400.0	400.0	400.0	400.0	400.0
4) Y BIRCH	UNIT	800.0	800.0	800.0	800.0	800.0	800.0	800.0
5) DOUG FIR	UNIT	100.0	100.0	100.0	100.0	100.0	100.0	100.0
6) Y POPLAR	UNIT	900.0	900.0	900.0	900.0	900.0	900.0	900.0
7) P PINE	UNIT	300.0	300.0	300.0	300.0	300.0	300.0	300.0
8) W HEMLOCK	UNIT	500.0	500.0	500.0	.0	500.0	500.0	500.0
9) RED ALDER	UNIT	700.0	700.0	700.0	.0	700.0	611.7	407.0
10) E SPRUCE	UNIT	.0	.0	.0	.0	.0	.0	.0
AVG. COST/MMBTU		$ 4.66	$ 4.86	$ 5.08	$ 5.60	$ 4.50	$ 4.36	$ 4.15
EST. ANNUAL SAVINGS		$ 128.1M	$ 116.2M	$ 103.7M	$ 73.7M	$ 137.2M	$ 145.7M	$ 158.0M

* WOOD FUEL CALCULATIONS ASSUME 40-PCT EXCESS AIR AND 4-PCT HEAT LOSS FROM UNBURNED FUEL, RADIATION AND UNACCOUNTED LOSSES. THE PROGRAM ALLOWS WOOD FUEL MOISTURE CONTENTS TO DROP BELOW 0-PCT BUT DISQUALIFIES A FUEL TYPE WHEN MOISTURE CONTENT EXCEEDS 65-PCT. NON-WOOD FUEL ASSUMES A BOILER EFFICIENCY OF 82.5-PCT UNLESS OTHERWISE SPECIFIED BY DATA ENTRY.

NOTE--M IS THOUSANDS, MM IS MILLIONS.

Figure 3.—Printed output of fuel requirements and costs for specified heat-energy requirement.

(M151-270)

********** CAPITALIZED VALUE OF PROSPECTIVE FUEL SAVINGS **********

ECON. LIFE OF PROSPECTUS	= 10 YRS	AD VALOREM COSTS (8.50 PCT. OF CAP. VAL.)	= $ 26.7M
AVERAGE FUEL INVENTORY SUPPLY	= 2.4 WKS	CHANGE IN OTHER OPER. COSTS (DOLLARS)	= $ 20.0M
AVERAGE ANNUAL RATE OF INFLATION	= .0800	FIRST YEAR INV. TAX CREDIT (10.00 PCT. OF CAP. VAL.)	= $ 31.4M
REQUIRED IRR TO INVESTMENT	= .2000	EFFECTIVE TAX RATE	= .4500

CAPITALIZED VALUES FOR...

	GIVEN PROSPECTUS	---CHANGE (+ OR -) IN CAPITALIZED VALUES DUE TO CHANGE IN MOISTURE CONTENT--- INCREASE OF MOISTURE CONTENT			DECREASE OF MOISTURE CONTENT		
		+5 PCT.	+10 PCT.	+20 PCT.	-5 PCT.	-10 PCT.	-20 PCT.
FACILITIES INVESTMENT	$ 313.8M	$ -36.0M	$ -74.1M	$ -162.0M	$ 27.6M	$ 53.5M	$ 91.3M
WORKING CAPITAL	$ 14.6M	$ -.1M	$ -.2M	$ -3.4M	$ .1M	$ -.1M	$ -.5M
TOTAL	$ 328.5M	$ -36.1M	$ -74.3M	$ -165.3M	$ 27.7M	$ 53.4M	$ 90.8M

NOTE--M IS THOUSANDS, MM IS MILLIONS.

**** PROGRAM ASSUMPTIONS ****

1) STRAIGHT LINE DEPRECIATION IS TAKEN ON ALL DEPRECIABLE ASSETS (IE: FACILITIES).

2) INITIAL INVESTMENTS (FACILITIES AND WORKING CAPITAL) ARE COMPUTED FROM DISCOUNTED PRESENT VALUE OF ANNUAL NET FUEL SAVINGS. SUBSEQUENT INVESTMENT REQUIREMENTS--SUCH AS INCREASES IN WORKING CAPITAL REQUIREMENTS AND REPLACEMENT OF MOBILE EQUIPMENT, ETC.--ARE NOT INCLUDED.

Figure 4.—Printed output of economically justified facilities investment costs.

(M151-271)

(5) To compute capitalized values of cost changes associated with changes in specified moisture contents of wood/bark fuels considered (Fig. 4).

There are also two important computational characteristics of the program:
(1) for simplicity, computations of sensitivities to changes in fuel moisture content will allow adjusted wood/bark fuel moisture contents to drop below zero percent moisture content (Fig. 1 and 2); (2) the program will only compute capitalized values when annual fuel savings exceed annual operating costs and working capital requirements. (See Tables 1-3 for conversion and estimating factors.)

FEP Data Input Requirements

Card Type 1

Title card-one only. May be used to enter alpha numeric title information in columns 2 through 29.

Card Type 2 Data Requirements

Only one Card Type 2 is required that provides input information independent of fuel types considered (Fig. 5). The following types of information are required for program input with Card Type 2:

Output copies.—The number of printed output copies desired must be entered in column 1, up to a maximum of 9 copies. If no entry is made the program will provide one set of printed output.

Number of alternatives.—The total number of different types of fuel to be included in analysis must be entered in columns 4 and 5, up to a total of 10. The number entered must correspond to the number of Card Type 3 cards prepared and positioned in the data card deck following Card Type 2.

Stack gas temperature.—A stack gas temperature, in Fahrenheit degrees, must be entered in columns 9 though II to provide program control and information required for computation of boiler efficiency and resulting heat-energy to steam computations. Boiler efficiency calculations assume 40 percent excess air and 4 percent heat loss from unburned fuel, radiation and unaccounted heat losses (*1* and *4*). The following equations are used for computation of boiler efficiencies for wood/bark fuels:

Range of moisture content (wet basis)		Boiler Efficiency (BE) vs. Moisture Content (MCW) and Stack Temperature (ST)
From	To	
0	0.285	BE = 0.9350 - (MCW * 0.18182) - (ST * 0.000310)
0.286	0.443	BE = 1.0019 - (MCW * 0.35454) - (ST * 0.000345)
0.444	0.545	BE = 1.0920 - (MCW * 0.51232) - (ST * 0.000385)
0.545	0.614	BE = 1.3128 - (MCW * 0.87770) - (ST * 0.000410)
0.615	greater	BE = 1.4646 - (MCW * 1.09615) - (ST * 0.000445)

Table 1.—Higher heating value, specific gravity and moisture content for some softwood and hardwood species

Timber	Higher heating value[1] (Btu/O.D. lb)	Specific gravity[2]	Green moisture content[2] (wet basis)
Softwoods			
Douglas-fir:			
Old growth	9,200	0.45	0.27
Second growth	8,800	.45	.27
Engelmann spruce	8,100	.32	.34
Ponderosa pine	9,100	.38	.29
Southern pine	10,380	.47	.24
Western hemlock	8,500	.38	.46
Hardwoods			
Northern red oak	9,360	.56	.44
Red alder	8,000	.37	.49
Yellow birch	9,340	.55	.43
Yellow poplar	9,630	.40	.43

[1] See Ref. 4.

[2] For heartwood. See Ref. 5.

Table 2.—Average volumes of solid wood/bark content for some standard units

Units	Cubic feet of solid wood/bark content
200 Cubic Foot Units:	
Sawdust	80
Sawdust and shavings	57
Hogged fuel	73
Pulp chips	72
1,000 Board Feet of Lumber	60 to 83
1,000 Board Feet of Logs (Scribner Decimal C Scale):	
15-inch diameter and larger	144 to 169
Less than 15-inch diameter	170 to 220
One Cord:	
Slabs and edgings	67 to 75
Pulpwood	90 to 110

[1] From conversion factors for Pacific Northwest forest products, Institute of Forest Products, State of Washington, 303 Anderson Hall, Seattle, Wash., 1957, 28 pages.

For non-wood/bark fuel entered via the first Card Type 3, a boiler efficiency of 0.825 will be assumed for heat-to-steam computations unless an override fraction is entered in lieu of moisture content (see moisture content data input instructions).

The FEP program may also be used to estimate the effective evaporative capacities of furnace exhaust gases used for kiln drying. If a stack gas temperature is not entered the FEP program will compute an estimated effective, or theoretical evaporative capacity (pounds of H_2O evaporated) of the furnace exhaust gases for each specified unit of fuel. The assumption has been used that 1,700 Btu's (higher heating value) of furnace exhaust gases is required for each pound of water evaporated from a dry kiln operating at about 60-percent efficiency. This assumption can be changed via program card 15.

Table 3.—Range of approximate energy requirements for drying of some species of wood products[1]

Products	Btu's required per pound of H_2O evaporated
Lumber:	
Douglas-fir	2,000 - 3,000
Southern pine	1,600 - 2,200
Red oak	3,000 +
Plywood:	
Douglas-fir	2,000 - 3,000
Southern pine	1,600 - 2,200
Particleboard:	
Dry wood residues	2,000 - 3,000
Wet wood residues	1,600 - 2,000
Green wood chips	2,000 - 2,500

[1] From G. L. Comstock, Energy requirements for drying of wood products, *In:* Wood Residue as an Energy Source, Proc. No. P-75-13, Forest Products Research Society, Madison, Wis., 1975.

The effective evaporative capacities for each standard unit of wood/bark fuels are computed using the following formulas:

$$EEC = EEA * (HHX - 0.54 * LBPU) \quad (1)$$

where,

EEC is the effective evaporative capacity of heat energy per standard unit of fuel type,

EEA is the effective evaporative coefficient of heat-energy in excess of that required to evaporate moisture contained in the fuel (see formula 2).

HHX is the higher heating value per standard unit of fuel (see formula 3).

0.54 is the approximate weight of chemically produced water per pound of dry wood/bark fuel (*4*), and

LBPU is pounds of dry wood/bark per standard unit of fuel.

$$EEA = (1.0/EVRT) - (MCW/(HHV(1.0 - MCW)) \quad (2)$$

where,

EEA is the effective evaporative coefficient,

EVRT is the effective rate of evaporation expressed as thousands of BTu's required to evaporate each pound of water from a dry kiln charge,

MCW is the moisture content fraction, wet basis, of the corresponding fuel.

HHV is the higher heating value, in thousands of Btu's per dry pound of wood/bark fuel type.

$$HHX = SG * 62.42 * CFPU * HHV \quad (3)$$

where,

HHX is the higher heating value per specified unit of fuel,

SG is the specific gravity of wood/bark fuel type, 62.42 is the weight of water per cubic foot, in pounds.

CFPU is the cubic feet of solid wood/bark material per standard unit of fuel type, and

HHV is the higher heating value per dry pound of fuel type, in thousands of Btu's.

Some caution should be used when analyzing the effective evaporative capacities of fuels in kiln drying processes because of the greater number of climatic, facilities, wood products, and kiln scheduling variables that contribute to the required number of Btu's for evaporation of water in kiln drying operations. A practical approach for using the FEP program in preparing an analysis for a specific kiln is to determine from historical operating data the average annual number of Btu's (higher heating value) required to evaporate each pound of water removed from the wood processed. The FEP program assumption of 1,700 Btu's (higher heating value) per pound of water evaporated may be changed via program card 15.

Yearly heat requirement.-The yearly heat requirement, or pounds of evaporated water requirement must be

FEP DATA CODING RECORD Date_____

Estimates prepared by_____

CARD TYPE 1 (Title Card): _____

CARD TYPE 2: Data and program control card. First card only.

Data description	Output copies (Max. 9) (I1)	No. of alternatives (I2)	Stack gas °F (F4.0)	Yearly heat requirement (MMBTU'S) (F10.0)	Years considered (I2)	Advalorem costs (F6.4)	Chg. in other op. costs (F6.0)	Inflation (F6.4)	Invest. tax credit (F6.4)	Discount rate (F6.4)	Effective tax rate (F6.4)
Cols.	1	4-5	8-11	14-23	26-27	30-35	38-43	45-51	54-59	62-67	70-76
Data Entry	1	10	450.	55000.	10	.085	20000.	.08	.10	.20	.45

CARD TYPE 3: Unit volume, cost, and heat specifications. One card for each unit, up to 21 cards.

Data description	Resource name	Unit basis	Cu. ft. per unit* (F5.0)	Cost per unit (F6.2)	Units avail. annually (F7.0)	Higher Ht'g value (1,000 BTU) (F5.1)***	Specific gravity (F5.4)	Moisture content (wet) (F5.4)	Inventory tenure (weeks) (F5.2)	CARD #
Cols.	1-18	21-26	29-33	36-41	44-50	53-57	60-64	67-71	74-78	
Data Entries	Oil	BBL	—	30.00	5000.	6000.0	—	—	0.5	1**
	Doug Fir	Unit	72.	60.00	100.	9.2	.45	.27	2.5	2
	E. Spruce	Unit	72.	60.00	200.	8.1	.32	.34	2.5	3
	P. Pine	Unit	72.	60.00	300.	9.1	.38	.29	2.5	4
	So. Pine	Unit	72.	60.00	400.	10.4	.47	.24	2.5	5
	W. Hemlock	Unit	72.	60.00	500.	8.5	.38	.46	2.5	6
	N. Red Oak	Unit	72.	60.00	600.	9.4	.56	.44	2.5	7
	Red Alder	Unit	72.	60.00	700.	8.0	.37	.49	2.5	8
	Y. Birch	Unit	72.	60.00	800.	9.3	.55	.43	2.5	9
	Y. Poplar	Unit	72.	60.00	900.	9.6	.40	.45	2.5	10

* Cubic content of solid material.

** Current source fuel type.

*** Total BTU value per unit for card #1. Card #2 through #10, enter BTU **value** per oven dry pound.

Figure 5.—FEP data coding record form sample, filled out. (M151-359)

entered in columns 14 through 23. If a stack gas temperature has been entered the program will be instructed to compute boiler efficiencies and resulting heat-to-steam values. In electing this option for computation, a yearly heat requirement must be entered in millions of Btu's. If the stack gas temperature entry is left blank the program will be instructed to compute the effective evaporative capacities for each fuel type. If this option is chosen, the number of pounds of water evaporated annually, as from a kiln, must be entered in thousands of pounds.

Years considered.—The number of years entered in columns 26 and 27 indicates the number of years over which discounted cash flow analyses will be completed for computation of the capitalized values of the net benefits that might be realized from use of wood/bark fuels as alternatives to a specified non-wood/bark fuel type.

Advalorem costs.—Economic analyses are directed to estimation of the capitalized value of fuel costs savings that might be realized from use of alternative wood/bark fuels via new facilities investment. For this reason, operating costs that may be associated with such new investment need to be considered as a reduction of a gross fuel cost savings. Advalorem operating costs are typically regular and recurring costs such as for repair, maintenance, service supplies local taxes, insurance and such that can be expressed as a fraction of facilities investment costs. The appropriate decimal fraction of facilities investment that may be expected to represent total periodic advalorem costs must be entered in columns 30 through 35.

Change in other operating costs.—All increases in annual operating costs associated with a prospective conversion of an existing furnace system need to be considered in analysis. Cost increases that cannot be accounted for as advalorem costs should be estimated and entered as fixed annual operating costs. These costs typically cover additional labor requirements, supervision, utility costs, etc. Fuel preparation costs that are independent of the unit volume of fuels used should also be included. However, fuel preparation costs that vary directly with the unit volume of fuel should be included in the fuel type cost, designated "cost per unit," for Card Type 3 program input. The estimated annual increase in operating costs described here should be entered in columns 38 and 43.

Inflation.—The amounts entered for analysis as advalorem and increased operating costs, and the annual gross benefit computed as the annual gross savings in prospective fuel savings will be equal in each year of discounted cash flow evaluation unless an inflation rate is entered. Entering an inflation rate increases annual costs and gross benefits at an annual compound rate equal to the inflation rate entered. The program does not consider unequal rates of inflation. The annual rate of inflation selected for analysis should be entered as a decimal fraction in columns 46 through 51.

Investment tax credit.—In general, an IRS investment tax credit for 10 percent of processing equipment investment cost is allowed for tax reduction-excluding land, buildings, and other non-process fixed asset costs. Investments for cogeneration of electricity and process heat-energy may qualify for an IRS investment tax credit of 20 percent. A tax specialist should be consulted for specific information. The estimate of investment costs that might be allowed as an investment tax credit should be entered as a fraction in columns 54 through 59.

The estimate of investment cost that might be allowed as an investment tax credit will typically be less than 10 or 20 percent because of the inclusion of land and building costs in the facilities costs to which the investment tax credit fraction will computationally apply. Also, the investment tax credit computed will be treated as a tax rebate in the first year of discounted cash flow analysis, whether greater or less than the computed taxes payable for the first year. Although this is not a technically correct procedure for all circumstances, the procedure may be applicable when the investment tax credit may be fully realized as a reduction of taxes payable by a corporation.

Discount rate.—The amount entered as a discount rate should be the rate of return (interest) required for financing of similar investments (alternative rate of return). The annual rate of interest earnings for financing requirements will represent a reduction of annual gross fuel cost savings. The discount rate should be entered in columns 62 through 67 in decimal fraction form.

Effective tax rate.-Because any reduction of fuel costs, less additional operating costs, will add directly to a corporation's total profits and tax costs, an effective state and Federal income tax rate needs to be considered. Annual after-tax benefits (ATNB) are computed using the following formula:

$$\text{ATNB} = ((\text{Gross benefit} - \text{Advalorem Costs} - \text{Increased Operating Costs} - \text{Depreciation}) \times (1.0 - \text{Effective Tax Rate})) + \text{Depreciation}. \quad (4)$$

The amount of investment tax credit computed is added to the first year's after-tax net benefit. Straight line depreciation, assuming no salvage, is computed by the computer program, i.e., Depreciation = Facilities Cost/Years Considered.

Card Type 3 Data Requirements

Up to 10 different types of fuel may be included for evaluation, including the "current" non-wood/bark fuel type (Fig. 5). One card must be prepared for each fuel type and included in the data card deck following the one Card Type 2. The data card carrying the one non-wood/bark fuel type information must be the first card

following Card Type 2. Card Type 3 carries the alpha-numeric description and associated statistics for each fuel type to be considered. Appendix A includes average statistics for a selected number of fuel types.

Fuel type.—The alpha-numeric description identifying each fuel type must be entered in columns 1 through 18.

Unit basis.—The unit basis, entered as alpha-numeric input, should correspond with the fuel type's standard unit upon which cost and cubic feet of solid wood/bark material may be most commonly related. Typical entries will be "BARRELS," "OD TONS," "MBF," and so-forth. This information must be entered in columns 21 through 26.

Cubic feet per unit.—The cubic feet of solid wood or bark per standard unit varies considerably and is needed for computing the amount of heat-energy available per unit of wood/bark fuel type utilized. No data entry is required for non-wood/bark fuel as entered by the 1st Card Type 3 data card. The cubic feet of solid wood or bark per standard unit must be entered in columns 29 through 33 for each wood/bark type fuel.

Cost per unit.—The cost, or value, per unit must be entered in columns 36 through 41. The amount entered should reflect purchasing and handling costs per unit for each fuel type as entering the furnace.

If an entry is made in columns 67 through 71 for the non-wood/bark fuel the program will use this input data directly as the boiler efficiency fraction for the non-wood/bark fuel as an override of the 0.825 boiler efficiency otherwise assumed by the program. Entries in the non-wood/bark fuel card columns 67 through 71 will not affect the effective evaporative capacity computations for the first fuel type. (See appendix B for a blank data coding record form.)

Inventory tenure.— Fuel inventories will be required to cover periods of time during which fuel supplies may not be resupplied, but furnace demand continues. The costs of fuels held in inventory, and some portion of advalorem and other fixed operating costs will normally be funded by working capital investment. The FEP program assumes that advalorem and other fixed operating costs will be funded by working capital for the same period of time for which fuel inventories must be funded. Consequently, any difference in the working capital requirements computed from use of a non-wood/bark fuel and wood/bark fuels will affect the computed annual net benefit of prospective fuel costs savings. That is, any change in working capital requirements will affect annual net benefits in an amount equal to the change in interest earnings accrued to working capital by the discount rate used for analysis.

Inventory tenure requirements should be expressed in number of weeks in decimal fraction form. For example, if oil deliveries are expected every two-and-one-half weeks "2.5" must be entered in columns 74 through 78.

SUMMARY

The primary objective of the fuel economics computer program (FEP) is to provide a means for assessing relative energy and economic values of fossil fuels and wood/bark fuels, and to provide a means for pre-engineering assessments of the potential investment that may be justified by benefits gained through modification of systems to burn wood/bark fuels. The FEP computer program may be used to compute either steam heat recovery or theoretical wood drying capacities of exhaust gases from different fuels using readily available fuel and economic information, standard combustion equations, and discounted cash flow techniques.

The FEP computer program also computes a variety of quantitative and economic information including: volumes of fuel types required to yield specified heat requirements; prospective savings in fuel costs if wood and bark fuels are used as alternatives for oil, gas, or other fuel; capitalized benefits of fuels savings into working capital requirements and justifiable facilities investment; and, capitalized values of cost changes associated with changes in specified moisture contents of wood and bark fuels.

LITERATURE CITED

1. Corder, S. F. Wood and bark as fuel. School of Forestry Research Bulletin 14, Oregon State Univ., Corvallis, Oreg.; 1973.

2. Ellis, Thomas H. Economic analysis of wood- or bark. fired systems. Gen. Tech. Rep. FPL 16, Forest Prod. Lab., Madison, Wis.; 1978.

3. Harpole, George B. A cash flow computer program to analyze investment opportunities in wood products manufacturing. USDA For. Serv. Res. Pap. FPL 305, Forest Prod. Lab., Madison, Wis.; 1978.

4. Ince, Peter J. How to estimate recoverable heat energy in wood or bark fuels. Gen. Tech. Rep. FPL 29, Forest Prod. Lab., Madison, Wis.; 1979.

5. U.S. Forest Products Laboratory. Wood Handbook: Wood as an Engineering material. U.S. Dept. of Agric., Agriculture Handbook No. 72 (rev.); 1974.

Appendix A: Fuel Economics Program Listing

```
C
C *** FOREST PRODUCTS LABORATORY FUEL ECONOMICS PROGRAM (FEP)
C
C *** DIMENSION STATEMENT
      DIMENSION AVMB(7),BENI(7),CFPU(10),FI(10),HHV(10),MC(7),SG(10),
     +  TVBT(8),UB(10),VAA(10),VPU(10),DPBT(7,10),EHVU(7,10),MCW(7,10),
     +  MMBTU(7,10),TYPE(4,10),VU(7,10),CHECK(10),HHX(10),
     +  BLRE(7,10),FAO(7),TINV(7),FINV(7),WRK(7),TCAP(7),WORK(7),
     +  FAC(7),MBX(7),DBX(7),UTIL(7),TITLE(14)
C
      INTEGER OPT,SMALL,START,YRS
      REAL MCW,INFL,ITC,IRR,MMBTU
C     INITIALIZE VARIARLES
      EFF = 0.825
      EVRT = 1.7
      AVMT = 1.0
C
C *** FORMAT STATEMENTS
C
C *** INPUT FORMAT
C
   10 FORMAT(13A6,A2)
   20 FORMAT(I1,2X,I2,2X,F4.0,2X,F10.0,2X,I2,2X,F6.4,2X,F6.0,4(2X,F6.4))
   40 FORMAT(3A6,A2,A6,2X,F5.0,2X,F6.2,2X,F7.0,2X,F5.0,2(2X,F5.4),2X,
     +  F5.2)
C
C *** ERROR MESSAGES
C
   53 FORMAT('0',' ERROR: YEARS OF ANALYSIS WAS ENTERED AS 0.')
   54 FORMAT('0',' ERROR: HIGHER HEATING VALUE OF ',3A6,A2,' WAS ENTERED
     + AS 0.')
C
C *** OUTPUT FORMAT
C
C *** PART 1 SECTION 1: 'FUEL TYPE ASSUMPTIONS AND ESTIMATES OF
C ***   REQUIREMENTS, COSTS AND SAVINGS'
   60 FORMAT('1',25x,13A6,A2////)
   61 FORMAT    (19X,'********** FUEL TYPE ASSUMPTIONS AND ESTIMATES OF
     +REQUIREMENTS, COSTS AND SAVINGS **********'///
     +97X,'----HEAT-ENERGY VALUES----'/
     +       27X,'UNIT',6X,'UNITS AVAIL.',4X,'CU.FT.',4X,'SPEC.',5X,
     +'M.C.',5X,'$ COST',5X,'HIGHER VALUE',4X,'EFFECTIVE EVAPORATION')
   62 FORMAT     (5X,'********** FUEL TYPE ASSUMPTIONS AND ESTIMATES OF
     +REQUIREMENTS, COSTS AND SAVINGS (',F5.0,' DEG.F STACK TEMP.) *****
     +*****'///
     +97X,'----HEAT-ENERGY VALUES----'/
     +       27X,'UNIT',6X,'UNITS AVAIL.',4X,'CU.FT.',4X,'SPEC.',5X,
     +  'M.C.',5X,'$ COST',5X,'HIGHER VALUE',8X,'HEAT TO STEAM')
   63 FORMAT(27X,'BASIS',7X,'ANNUALLY',6X,'SOLID',5X,'GRAV.',4X,
     +  '(WET)',4X,'PER UNIT*',4X,'MBTU/UNIT ',5X,'MBTU/UNIT ',4X,
     +  '$/MMBTU'/' A) CURRENT SOURCE')
   64 FORMAT(27X,'BASIS',7X,'ANNUALLY',6X,'SOLID',5X,'GRAV=',4X,
     +  '(WET)',4X,'PER UNIT*',4X,'MBTU/UNIT ',5X,'#H2O/UNIT ',4X,
     +  '$/M#H2O'/' A) CURRENT SOURCE')
   70 FORMAT(3X,I2,') ',3A6,A2,A6,4X,F10.0,6X,F6.2,5X,F4.3,3X,F6.4,
     +  4X,'$',F6.2,6X,F8.0,5X,F10.2,6X,'$',F5.2)
   80 FORMAT(/' B) PROPOSED SOURCE(S)')
  100 FORMAT  (/' * HIGHER OF COST OR MARKET.  IE: OPPORTUNITY COST IS I
     +NCLUDED HERE.')
  101 FORMAT(/' NOTE--M IS THOUSANDS, MM IS MILLIONS.'///)
C
C *** PART 1 SECTION 2: 'PROSPECTUS REQUIREMENTS'
  108 FORMAT('1',/16X,'**** PROSPECTUS REQUIREMENTS (',F11.0,1X,'  THOUS
     +AND POUNDS OF EVAPORATED WATER/YEAR) AND ANNUAL SAVING ****'/)
  109 FORMAT('1',/16X,'**** PROSPECTUS REQUIREMENTS (',F11.0,1X,54HMILLI
     +ON STEAM=HEAT BTU'S/YEAR) AND ANNUAL SAVINGS **** /)
  110 FORMAT(43X,'--------ANNUAL VOLUMES REQUIRED AT VARIOUS MOISTURE CO
     +NTENTS (WET BASIS)--------'//
     +4X,'PROPOSED SOURCES',8X,'UNIT',7X,
     +  'AT GIVEN',11X,'AT HIGHER MOISTURE CONTENT*',
     +14X,'AT LOWER MOISTURE CONTENT**'/27X,'BASIS',8X,'M.C.',11X,
     +  '+5 PCT.',4X,'+10 PCT.',4X,'+20 PCT.',10X,'-5 PCT.',4X,
     +  '-10 PCT.',4X,'-20 PCT.'/)
  111 FORMAT(' A) CURRENT SOURCE'/4X,I2,')',1X,3A6,A2,A6,4X,F8.1,
     +  8X,F8.1,2(4X,F8.1),9X,F8.1,2(4X,F8.1)/)
  159 FORMAT(' B) PROPOSED SOURCE(S)')
  160 FORMAT                    (4X,I2,')',1X,3A6,A2,A6,4X,F8.1,
     +  8X,F8.1,2(4X,F8.1),9X,F8.1,2(4X,F8.1))
  190 FORMAT( ' **** WITH MOISTURE CONTENT CHANGED ',I3,' PCT. (WET BASI
     +S), THERE IS AN ANNUAL DEFICIT OF ',F11.1,13H MMBTU'S ****)
  219 FORMAT('0',3X,'AVG. COST/M#H2O',17X,'$',F9.2,6X,'$',F9.2,2(2X,'$',
     +F9.2),7X,'$',F8.2,2(2X,'$',F9.2))
  220 FORMAT('0',3X,'AVG. COST/MMBTU',17X ,'$',F9.2,6X,'$',F9.2,2(2X,
     +  '$',F9.2),7X,'$ ',F8.2,2(2X,'$',F9.2))
  230 FORMAT(/4X,'EST. ANNUAL SAVINGS',13X,'$',F8.1,'M',6X,'$',F8.1,
     +  2('M',2X,'$',F8.1),'M',7X,'$',F8.1,2('M',2X,'$',F8.1),'M'//)
  233 FORMAT(' * WOOD FUEL CALCULATIONS ASSUME 40=PCT EXCESS AIR AND 4=P
     +CT HEAT LOSS FROM UNBURNED '/' FUEL, RADIATION AND UNACCOUNTED LOS
     +SES.  THE PROGRAM ALLOWS WOOD FUEL MOISTURE'/' CONTENTS TO DROP BE
     +LOW 0=PCT BUT DISQUALIFIES A FUEL TYPE WHEN MOISTURE CONTENT'/
     +' EXCEEDS 65=PCT.  NON=WOOD FUEL ASSUMES A BOILER EFFICIENCY OF 82
     +.5=PCT UNLESS'/' OTHERWISE SPECIFIED BY DATA ENTRY.'/)
  232 FORMAT(' ******** DUE TO A BTU DEFICIT, THIS CALCULATION IS NOT ME
     +ANINGFUL.'/)
  231 FORMAT(' * CALCULATIONS ASSUME A KILN EVAPORATIVE RATE OF  ',
     +F5.3,' M',                                                    '
     + BTUS PER POUND'/' OF EVAPORATED WATER.  EFFECTIVE EVAPORATIVE CAP
     +ACITIES FOR WOOD/BARK FUELS ARE'/' ADJUSTED FOR FUEL MOISTURE CONT
     +ENT.  THE PROGRAM ALLOWS WOOD FUEL MOISTURE'/' CONTENT TO DROP BEL
     +OW ZERO=PCT BUT DISQUALIFIES A FUEL TYPE WHEN MOISTURE'/' CONTENT
     +EXCEEDS 65=PCT.  NON=WOOD/BARK FUEL ASSUMES AN EFFECTIVE EVAPORATI
     +VE'/' CAPACITY EQUAL TO ',F5.3,' OF THE GIVEN HIGHER HEATING VALUE
     +.  THESE ASSUMPTIONS'/' MAY BE CHANGED VIA FEP PROGRAM CARDS 141 A
     +ND 142.'/)
C
C *** PART 2: 'CAPITALIZED VALUE OF PROSPECTIVE FUEL SAVINGS'
  290 FORMAT('1',27X,'********** CAPITALIZED VALUE OF PROSPECTIVE FUEL S
     +AVINGS **********'/)
  300 FORMAT(' ECON. LIFE OF PROSPECTUS',14X,'=',3X,I2,' YRS',10X,
     +  'AD VALOREM COSTS (',F5.2,' PCT. OF CAP. VAL.)',
     + 11X,'= $',F6.1,'M'/
     +  ' AVERAGE FUEL INVENTORY SUPPLY',9X,'= ',F4.1,' WKS',10X,
     +  'CHANGE IN OTHER OPER. COSTS (DOLLARS)',16X,'= $',F6.1,'M'/
     +  ' AVERAGE ANNUAL RATE OF INFLATION',6X,'= ',F8.4,10X,
     +  'FIRST YEAR INV. TAX CREDIT (',F5.2,' PCT. OF CAP. VAL.) = $',
     +F6.1,'M' /' REQUIRED IRR TO INVESTMENT',12X,'= ',F8.4,10X,
     +  'EFFECTIVE TAX RATE',35X,'=  ',F7.4//)
  310 FORMAT(' CAPITALIZED VALUES FOR...'/31X,'GIVEN',9X,
     +  '---CHANGE (+ OR -) IN CAPITALIZED VALUES DUE TO CHANGE IN MOIST
     +URE CONTENT---'/29X,
     +  'PROSPECTUS',9X,'INCREASE OF MOISTURE CONTENT',15X,
     +  'DECREASE OF MOISTURE CONTENT'/46X,'+5 PCT.',5X,'+10 PCT.',5X,
     +  '+20 PCT.',10X,'-5 PCT.',5X,'-10 PCT.',5X,'-20 PCT.'/)
  320 FORMAT('  FACILITIES INVESTMENT',4X,'$',F8.1,'M',6X,3('$',F8.1,
     +  'M',3X),4X,3('$',F8.1,'M',3X))
  330 FORMAT('  WORKING CAPITAL',10X,'$',F8.1,'M',6X,3('$',F8.1,'M',3X),
     +  4X,3('$',F8.1,'M',3X)/)
  340 FORMAT(4X,'TOTAL',18X,'$',F8.1,'M',6X,3('$',F8.1,'M',3X),4X,
     +  3('$',F8.1,'M',3X)//)
  349 FORMAT(' ******** DUE TO A BTU DEFICIT OR NEGATIVE OPERATING BENEF
     +IT, THIS CALCULATION IS NOT MEANINGFUL.'/13X,55HSEE USER'S GUIDE F
     +OR DISCUSSION OF SUBSIDY INVESTMENTS.)
  350 FORMAT(44X,'**** PROGRAM ASSUMPTIONS ****'//' 1) STRAIGHT LINE DEP
     +RECIATION IS TAKEN ON ALL DEPRECIABLE ASSETS (IE: FACILITIES).'//
     +  ' 2) INITIAL INVESTMENTS (FACILITIES AND WORKING CAPITAL) ARE CO
     +MPUTED FROM DISCOUNTED PRESENT VALUE OF ANNUAL NET FUEL SAVINGS.'/
     +  '        SUBSEQUENT INVESTMENT REQUIREMENTS--SUCH AS INCREASES IN
     + WORKING CAPITAL REQUIREMENTS AND REPLACEMENT OF MOBILE EQUIPMENT,
     +'/'        ETC.--ARE NOT INCLUDED.')
 1000 FORMAT('1')
C
C *** READ STATEMENTS
C
      READ(5,10) (TITLE(M),M=1,14)
      READ(5,20) NUM,OPT,STKT,AHR,YRS,AVC,COOC,INFL,ITC,IRR,TXRT
      IF(YRS.EQ.0) WRITE(6,53)
      IF(OPT.EQ.0) OPT = 1
      DO 30 N=1,OPT
      READ(5,40) (TYPE(M,N),M=1,4),UB(N),CFPU(N),VPU(N),VAA(N),
     +  HHV(N),SG(N),MCW(1,N),FI(N)
      SG(N) = SG(N) * 100.0
      MCW(1,N) = MCW(1,N) * 100.0
      IF(HHV(N) - 0.0) 29,,29
      WRITE(6,54) (TYPE(M,N),M=1,4)
   29 CONTINUE
      IF(MCW(1,1).GT.0.65) EFF = MCW(1,1)
      FI(N) = FI(N) / 52.14
   30 CONTINUE
      MC(1) = 0
      MC(2) = 5
      MC(3) = 10
      MC(4) = 20
      MC(5) = (-5)
      MC(6) = (-10)
```

```
      MC(7) = (-20)
      KK = 1
C
C *** COMPUTE EFFECTIVE HEATING VALUE AND MMBTU'S AVAILABLE ANNUALLY
C ***   PER STANDARD UNIT
C
      DO 51 N=1,OPT
      J = 1
   50 CONTINUE
      IF(MCW(J,N).LE.0.2860)
     +  BLRE(J,N) = 0.9350 - (MCW(J,N)*0.18182 + STKT*0.000310)
      IF(MCW(J,N).GT.0.2860.AND.MCW(J,N).LE.0.4440)
     +  BLRE(J,N) = 1.0019 - (MCW(J,N)*0.35454 + STKT*0.000345)
      IF(MCW(J,N).GT.0.4440.AND.MCW(J,N).LE.0.5460)
     +  BLRE(J,N) = 1.0920 - (MCW(J,N)*0.51232 + STKT*0.000385)
      IF(MCW(J,N).GT.0.5460.AND.MCW(J,N).LE.0.6150)
     +  BLRE(J,N) = 1.3128 - (MCW(J,N)*0.87770 + STKT*0.000410)
      IF(MCW(J,N).GT.0.6150)
     +  BLRE(J,N) = 1.4646 - (MCW(J,N)*1.09615 + STKT*0.000445)
C *** COMPUTE COEFFICIENT  FOR EVAPORATIVE CAPACITY
      IF(STKT.LT.100.0)
     +BLRE(J,N) = 1.0/EVRT - MCW(J,N)/(HHV(N)*(1.0-MCW(J,N)))
      IF(CFPU(N).LT.1.0.AND.STKT.LT.100.0) BLRE(J,N)= AVHT/EVRT
      IF(CFPU(N).LT.1.0.AND.STKT.GT.100.0) BLRE(J,N)=  EFF
      IF(CFPU(N).GT.1.0) HHX(N) = ((SG(N)*62.42)*CFPU(N)) * HHV(N)
      IF(CFPU(N).LT.1.0) HHX(N) = HHV(N)
      EHVU(J,N) = HHX(N) * BLRE(J,N)
      IF(CFPU(N).GT.1.0.AND.STKT.LT.100.0) EHVU(J,N) =
     +(HHX(N) - (SG(N)*62.42*CFPU(N)*0.54* EVRT)) * BLRE(J,N)
      DPBT(J,N) = (VPU(N)/EHVU(J,N)) * 1000.0
      MMBTU(J,N) = (EHVU(J,N)*VAA(N))/1000.0
      IF(MCW(J,N).GT.0.65) MMBTU(J,N) = 0.0
      DBX(J) = DPBT(J,KK)
      MBX(J) = MMBTU(J,KK)
      J = J + 1
      IF(J.EQ.2) MCW(2,N) = MCW(1,N) + 0.05
      IF(J.EQ.3) MCW(3,N) = MCW(1,N) + 0.10
      IF(J.EQ.4) MCW(4,N) = MCW(1,N) + 0.20
      IF(J.EQ.5) MCW(5,N) = MCW(1,N) - 0.05
      IF(J.EQ.6) MCW(6,N) = MCW(1,N) - 0.10
      IF(J.EQ.7) MCW(7,N) = MCW(1,N) - 0.20
      IF(J.LT.8) GO TO 50
   51 CONTINUE
      DBS = DPBT(1,KK)
      VAX = VAA(KK)
      EHX = EHVU(1,KK)
      BASE = AHR * DPBT(1,KK)
      DO 52 J=2,7
      MCW(J,KK) = MCW(1,KK)
   52 CONTINUE
C
C *** RANKING SEQUENCE (TO RANK OPTIONS IN TERMS OF LEAST COST PER
C ***  EFFECTIVE MMBTU'S AT GIVEN MOISTURE CONTENT)
C
      LIMIT = OPT - 1
      DO 130 INDEX=1,LIMIT
      SMALL = INDEX
      START = INDEX + 1
      DO 120 I=START,OPT
  120 IF(DPBT(1,I).LT.DPBT(1,SMALL)) SMALL = I
      SAVE = DPBT(1,SMALL)
      DPBT(1,SMALL) = DPBT(1,INDEX)
      DPBT(1,INDEX) = SAVE
      DO 121 J=1,7
      SAVE = MCW(J,SMALL)
      MCW(J,SMALL) = MCW(J,INDEX)
  121 MCW(J,INDEX) = SAVE
      DO 122 J=1,4
      SAVE = TYPE(J,SMALL)
      TYPE(J,SMALL) = TYPE(J,INDEX)
  122 TYPE(J,INDEX) = SAVE
      DO 123 J=1,7
      SAVE = MMBTU(J,SMALL)
      MMBTU(J,SMALL) = MMBTU(J,INDEX)
  123 MMBTU(J,INDEX) = SAVE
      DO 124 J=1,7
      SAVE = EHVU(J,SMALL)
      EHVU(J,SMALL) = EHVU(J,INDEX)
  124 EHVU(J,INDEX) = SAVE
      SAVE = FI(SMALL)
      FI(SMALL) = FI(INDEX)
      FI(INDEX) = SAVE
      SAVE = CFPU(SMALL)
      CFPU(SMALL) = CFPU(INDEX)
      CFPU(INDEX) = SAVE
      SAVE = SG(SMALL)
      SG(SMALL) = SG(INDEX)
      SG(INDEX) = SAVE
      SAVE = VAA(SMALL)
      VAA(SMALL) = VAA(INDEX)
      VAA(INDEX) = SAVE
      SAVE = HHV(SMALL)
      HHV(SMALL) = HHV(INDEX)
      HHV(INDEX) = SAVE
      SAVE = HHX(SMALL)
      HHX(SMALL) = HHX(INDEX)
      HHX(INDEX) = SAVE
      SAVE = UB(SMALL)
      UB(SMALL) = UB(INDEX)
      UB(INDEX) = SAVE
      SAVE = VPU(SMALL)
      VPU(SMALL) = VPU(INDEX)
      VPU(INDEX) = SAVE
  130 CONTINUE
      DO 140 N=1,OPT
      IF(DPBT(1,N) - DBS) 140, ,140
      KK = N
  140 CONTINUE
C
C *** COMPUTE VOLUMES OF RESOURCES REQUIRED
C
      N = 1
      VAR = 0.0
      DO 151 J=1,7
      CHECK(J) = AHR
      DO 150 N=1,OPT
      CHECK(J) = CHECK(J) - MMBTU(J,N)
      IF(CHECK(J).GT.0.0) VU(J,N) = VAA(N)
      IF(CHECK(J).LT.0.0) VU(J,N) = ((CHECK(J)+MMBTU(J,N))*1000.0) /
     +  EHVU(J,N)
      IF(MCW(J,N).GT.0.65) VU(J,N) = 0.0
      IF(VU(J,N).LT.0.0) VU(J,N) = 0.0
  150 CONTINUE
  151 CONTINUE
  170 CONTINUE
C
C *** COMPUTE AVERAGE VALUE/MMBTU'S (AVMB) AND ANNUAL SAVINGS (BENI)
C
      J = 1
  200 TVBT(J) = VU(J,1) * VPU(1)
      UTIL(J) = (EHVU(J,1)*VU(J,1))/1000.0
      DO 210 N=2,OPT
      TVBT(J) = (VU(J,N)*VPU(N)) + TVBT(J)
      UTIL(J) = ((EHVU(J,N)*VU(J,N))/1000.0) + UTIL(J)
  210 CONTINUE
      BENI(J) = (BASE - TVBT(J))/ 1000.0
      AVMB(J) = TVBT(J)/UTIL(J)
      J = J + 1
      IF(J.LT.8) GO TO 200
C *** COMPUTE CAPITALIZED VALUE OF PROSPECTIVE FUEL SAVINGS
C
C
      OPR = COOC
      DO 240 J=1,7
  240 TINV(J) = 0.0
      J = 1
  239 CONTINUE
      REV = BENI(J) * 1000.
      FAO(J) = REV * (1.0-TXRT)
C *** COMPUTE WEIGHTED AVERAGE FUEL INVENTORY:
      DO 250 N=1,OPT
  250 TINV(J) = TINV(J) + ((FI(N) * (VPU(N)*VU(J,N))))
      FINV(J) = TINV(J)/TVBT(J)
C *** COMPUTE FACILITIES INVESTMENT AND WORKING CAPITAL:
  260 CONTINUE
      AVAL = FAO(J) * AVC
      DEPR = FAO(J)/YRS
      CRCF = REV - AVAL - OPR
      WRK(J) = ((OPR+AVAL)*FINV(J)) +  TINV(J)
      PCB = (((CRCF   -DEPR)*(1.0-TXRT))+DEPR+(ITC*FAO(J))) / (1.0+IRR)
      DO 270 K=2,YRS
      CRCF = CRCF * (1.0+INFL)
      PCB =((((CRCF-DEPR)*(1.0-TXRT))+DEPR)/
     +  ((1.0+IRR)**K))+PCB
  270 CONTINUE
      TEST = PCB - (FAO(J)+WRK(J))
      IF(TEST.GT.(-100.0).AND.TEST.LT.(100.0)) GO TO 280
      FAO(J) = (TEST-(TEST*AVC)) + FAO(J)
      GO TO 260
  280 CONTINUE
```

```
      FAC(J) = FAO(J)/1000.0
      WORK(J) = WRK(J)/1000.0
      TCAP(J) = FAC(J) + WORK(J)
      IF(J.GT.1)  FAC(J) = FAC(J) - FAC(1)
      IF(J.GT.1) WORK(J) = WORK(J) - WORK(1)
      IF(J.GT.1) TCAP(J) = TCAP(J) - TCAP(1)
      IF(J.EQ.1) ADVL = AVAL/1000.0
      J = J + 1
      IF(J.LT.8) GO TO 239
      COC = COOC / 1000.0
      TXCR = (FAO(1)*ITC)/1000.0
      TC  = ITC * 100.0
      AV = AVC * 100.0
      FINV(1) = FINV(1) * 52.14
C
C *** WRITE STATEMENTS
C
      IF(NUM.EQ.0) NUM = 1
      DO 195 MM=1,NUM
      WRITE(6,60) (TITLE(M),M=1,14)
C
C *** PART 1 SECTION 1: 'FUEL TYPE ASSUMPTIONS AND ESTIMATES OF
C ***   REQUIREMENTS, COSTS AND SAVINGS'
C
      IF(STKT.LE.100.0) WRITE(6,61)
      IF(STKT.GT.100.0) WRITE(6,62) STKT
      IF(STKT.GT.99.9) WRITE(6,63)
      IF(STKT.LT.100.0) WRITE(6,64)
      N = 1
      WRITE(6,70) N,(TYPE(I,KK),I=1,4),UB(KK),VAA(KK),
     +  CFPU(KK),SG(KK),MCW(1,KK),VPU(KK),HHX(KK),EHVU(1,KK),DPBT(1,KK)
      WRITE(6,80)
      DO 90 M=2,OPT
      IF(N.EQ.KK) N = N + 1
      WRITE(6,70) M,(TYPE(I,N),I=1,4),UB(N),VAA(N),CFPU(N),
     +          SG(N),MCW(1,N),VPU(N),HHX(N),EHVU(1,N),DPBT(1,N)
      N = N + 1
   90 CONTINUE
      WRITE(6,100)
      WRITE (6,101)
C
C *** PART 1 SECTION 2: 'PROSPECTUS REQUIREMENTS'
C
      IF(STKT.LE.100.0) WRITE (6,108) AHR
      IF(STKT.GT.99.9) WRITE (6,109) AHR
      WRITE(6,110)
      N = 1
      WRITE(6,111) N,(TYPE(I,KK),I=1,4),UB(KK),(VU(J,KK),J=1,7)
      WRITE(6,159)
      DO 171 M=2,OPT
      IF(N.EQ.KK) N = N + 1
      WRITE(6,160) M,(TYPE(I,N),I=1,4),UB(N),(VU(J,N),J=1,7)
      N = N + 1
  171 CONTINUE
      IF(STKT.LT.100.0) WRITE(6,219) (AVMB(J), J=1,7)
      IF(STKT.GT. 99.9) WRITE (6,220)(AVMB(J), J=1,7)
      DO 172 J=1,7
      IF(CHECK(J).GT.0.0) BENI(J) = 1000000000.0
  172 CONTINUE
      WRITE(6,230) (BENI(J),J=1,7)
      IF(STKT.LT.100.0) WRITE(6,231), EVRT, AVMT
      IF(STKT.GT. 99.9) WRITE(6,233)
      JJ = 0
      DO 175 J=1,7
      IF(CHECK(J).GT.0.0) JJ = 1
  175 CONTINUE
      IF(JJ.EQ.1) WRITE(6,232)
      DO 180 J=1,7
      IF(CHECK(J).GT.0.0) WRITE(6,190) MC(J),CHECK(J)
  180 CONTINUE
      WRITE(6,101)
C
C *** PART 2: 'CAPITALIZED VALUE OF PROSPECTIVE FUEL SAVINGS'
C
      WRITE(6,290)
      IF(CHECK(1).GT.0.0) TXCR = 1000000.0
      WRITE(6,300) YRS,AV,ADVL,FINV(1),COC,INFL,TC,TXCR,IRR,TXRT
      WRITE(6,310)
      DO 181 J=1,7
      IF(FAO(J).LT.0.0) WORK(J) = 10000000000.0
      IF(FAO(J).LT.0.0) FAC(J) = 10000000000.0
      IF(FAO(J).LT.0.0) TCAP(J) = 10000000000.0
      IF(CHECK(J).GT.0.0) WORK(J) = 1000000000.0
      IF(CHECK(J).GT.0.0) FAC(J) =  1000000000.0
      IF(CHECK(J).GT.0.0) TCAP(J) = 1000000000.0
  181 CONTINUE
      WRITE(6,320) (FAC(J),J=1,7)
      WRITE(6,330) (WORK(J),J=1,7)
      WRITE(6,340) (TCAP(J),J=1,7)
      JJ = 0
      DO 182 J=1,7
      IF(CHECK(J).GT.0.0.OR.FAO(J).LT.0.0) JJ = 1
  182 CONTINUE
      IF(JJ.EQ.1) WRITE(6,349)
      WRITE(6,101)
      WRITE(6,350)
      WRITE(6,1000)
  195 CONTINUE
      STOP
      END
```

Appendix B: FEP Data Coding Record

Date _____

Estimates prepared by _____

CARD TYPE 1 (Title Card): _____

CARD TYPE 2: Data and program control card. First card only.

Data description	Output copies (Max. 9) (I1)	No. of alternatives (I2)	Stack gas °F (F4.0)	Yearly heat requirement (MMBTU'S) (F10.0)	Years considered (I2)	Advalorem costs (F6.4)	Chg. in other op. costs (F6.0)	Inflation (F6.4)	Invest. tax credit (F6.4)	Discount rate (F6.4)	Effective tax rate (F6.4)
Cols.	1	4-5	8-11	14-23	26-27	30-35	38-43	45-51	54-59	62-67	70-76
Data Entry											

CARD TYPE 3: Unit volume, cost, and heat specifications. One card for each unit, up to 21 cards.

Data description	Resource name	Unit basis	Cu. ft. per unit* (F5.0)	Cost per unit (F6.2)	Units avail. annually (F7.0)	Higher Ht'g value (1,000 BTU) (F5.1)***	Specific gravity (F5.4)	Moisture content (wet) (F5.4)	Inventory tenure (weeks) (F5.2)	CARD #
Cols.	1-18	21-26	29-33	36-41	44-50	53-57	60-64	67-71	74-78	
Data Entries										1**
										2
										3
										4
										5
										6
										7
										8
										9
										10

* Cubic content of solid material.
** Current source fuel type.
*** Total BTU value per unit for card #1. Card #2 through #10, enter BTU value per oven dry pound.

Figure 6.—FEP data coding record form sample, blank.

(M151-355)

U.S. Forest Products Laboratory

Wood and Bark Fuel Economics Computer Program (FEP), by George B. Harpole, Peter J. Ince, John L. Tschernitz, and Edward Bilek, Madison, Wis., FPL 1982.

12 p. (USDA For. Serv. Res. Pap. FPL 415).

This computer program uses readily available fuel and economics information, standard combustion equations, and discounted cash flow analytic techniques to provide (1) a means to assess relative energy values of wood and bark for fuel and (2) pre-engineering assessments of the potential investment that may be justified by benefits gained through modifying wood/bark fuel systems. The authors suggest evaluation by more advanced engineering and financial methods whenever this program indicates favorable venture likelihoods. The program listing, written in FORTRAN, is included, as are coding record forms.

☆ U.S. GOVERNMENT PRINTING OFFICE: 1982-554-030/9