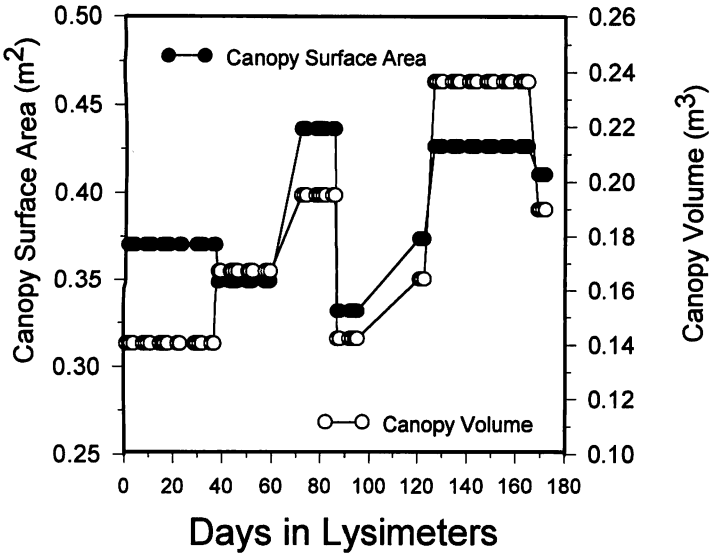

Fig. 3. Mean canopy surface areas and mean canopy volumes (width1 x width2 x height) of 'Formosa' azaleas during the period plants were within the lysimeters. Day 0 corresponds to 1 Nov. 1992 with day 172 corresponding to 22 Apr. 1993. Means are based on three replications.

lations. Higher correlations of ET_P to ET_A may have been obtained if canopy dimensions had been measured more frequently or measurements had occurred during a longer period of active growth.

Based on the bed surface area (0.209 m²) allocated to each container, a crop coefficient with a mean of 0.59 can be calculated for 'Formosa' azaleas over the 6-month period. The 95% confidence interval for this coefficient ranges from 0.50 to 0.69. Based on mean canopy surface area during the same period, the crop coefficient was 0.31 with a 95% confidence interval of 0.27 to 0.35. The canopy area basis is comparable to the 25% replacement of ET_P shown to produce acceptable growth of field-grown gardenia (Ponder, et al., 1984), while the 59% replacement is similar to the minimum requirements of field-grown Japanese holly and dogwood (Eakes et al., 1985).

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ENERGY REQUIREMENTS FOR FLORIDA ORNAMENTALS PRODUCTION[1]

RICHARD C. FLUCK, C. DIRELLE BAIRD, AND BALWINDER S. PANESAR
Agricultural Engineering Department
IFAS, University of Florida
Gainesville, FL 32611

Additional Index Words: FAECM, spreadsheet, model, direct energy, total primary energy, energy consumption, foliage

Abstract. **A spreadsheet-based microcomputer energy consumption model of Florida agricultural production has been developed. The Florida Agricultural Energy Consumption Model (FAECM) quantifies as many as 21 categories of direct and indirect energy inputs required for producing each of approximately 60 major and another 30 minor crop and livestock commodities. Eight different budgets are used to cover all Florida ornamentals production. The model is based on production budgets converted to energy budgets, and production levels.**

The model will be described. Results will be presented for Florida ornamentals production and for specific commodities. Florida ornamentals production required 7.50 trillion Btu of direct energy and 25.0 trillion Btu of total primary energy in 1990. Foliage crops are first among ornamentals and second among all agricultural commodities in both direct and total primary energy consumption. Comparisons will be drawn with other Florida agricultural commodities, with all of Florida agriculture, and with total Florida energy consumption.

Previous estimates of the energy required in the production of Florida ornamental horticultural products are almost non-existent. Smerdon et al. (1974) provided per acre and statewide estimates for diesel, gasoline and LP gas consumption for chrysanthemums and gladioli. However, no other energy consumption estimates for ornamentals production, in Florida or elsewhere, were found in the literature. Comprehensive and complete assessments are needed that include all energy-requiring inputs to enable focusing of research efforts to achieve better energy pro-

[1]Florida Agricultural Experiment Station Journal Series No. R-03439. This research was supported by the Florida Energy Office and the Florida Energy Extension Service.

ductivity and to guide actions in response to potential energy shortages.

Materials and Methods

The energy consumed in the production of Florida ornamentals was determined using the Florida Agricultural Energy Consumption Model (FAECM) developed by Fluck et al. (1992a). FAECM is a computer-based spreadsheet model that is contingent on crop acres and number of head of livestock and the quantities of energy necessary for the amounts of production inputs required per acre and per head. The objective of FAECM is to provide energy consumption data for all Florida agricultural production. FAECM determines total primary energy requirements. Total primary energy is the sum of 1) heat or direct energy in fuels, lubricants and electricity (energy commodities), and 2) indirect energy required to provide energy commodities and all other production inputs. FAECM predicts all the energy required for all of Florida's agricultural production and to provide all production inputs necessary to bring the product to the farm gate. FAECM is described further in Fluck et al. (1992b)

Sources for the ornamental horticulture production budgets were the Farm Systems Lab, Food and Resource Economics Department, University of Florida (various years), Taylor et al. (1990), Semprevio et al. (1979), Hodges (1992), Smith, et al. (1988). Crop production acreages for 1990 were taken in part from data provided by the Florida Agricultural Statistics Service (1991); data for 1990 for ornamentals crops not reported by FASS and data for earlier years were from 1974, 1978, 1982 and 1987 Agricultural Censuses (U.S. Dept. Com., 1977 and following issues).

Results and Discussion

Production of all Florida agricultural commodities (fruits, vegetables, ornamentals, agronomic crops and livestock) in 1990 required about 38.7 trillion Btu of direct energy and about 89.6 trillion Btu of indirect energy, or 128.3 trillion Btu of total primary energy. In comparison, the direct energy and the total primary energy required to produce all Florida agricultural commodities were approximately 1.2% and 3.9%, respectively, of the total energy consumption in Florida. The total Florida energy consumption includes all energy consumption for all residential, commercial, industrial and transportation purposes. Florida agricultural production requires 7.7% and 25.5%, respectively, of the direct energy and the total primary energy consumption required for all of Florida's industrial production.

In Table 1, the direct and total primary energy consumed in the production of all Florida agricultural commodities, of all ornamentals, and of specific ornamentals are shown. In 1990, energy required in Florida ornamentals production was 7.50 trillion Btu of direct energy and 25.02 trillion Btu of total primary energy. Production of ornamentals accounted for 19.4% of the direct energy and 19.5% of the total primary energy required for the production of all Florida agricultural commodities. The production of ornamentals is very energy intensive, as evidenced by the fact that ornamentals required almost one fifth of Florida agricultural energy consumption, but were grown on less than 4% of the state's acres that were in agricultural crop production. Ornamentals required more direct energy than all other four commodity groupings except fruits and more total primary energy than each of the commodity groupings of vegetables and agronomic crops.

Table 1. Total energy consumption in 1990 in all agricultural production and in the production of ornamentals as calculated from the FAECM model.

	Direct energy (Btu)	Total primary energy (Btu)
Florida Agr.	38.70×10^{12}	128.25×10^{12}
All ornamentals	7.50×10^{12}	25.02×10^{12}
Foliage plants	3.65×10^{12}	11.76×10^{12}
Bedding plants	1.03×10^{12}	3.19×10^{12}
Container nursery	0.92×10^{12}	3.01×10^{12}
Cut greens & flowers	0.56×10^{12}	2.90×10^{12}
Field nursery	0.60×10^{12}	1.77×10^{12}
Sod	0.49×10^{12}	1.41×10^{12}
Bulbs	0.18×10^{12}	0.78×10^{12}
Potted flowers	0.06×10^{12}	0.19×10^{12}

Foliage plant production required the largest portion of the energy for ornamentals, followed by bedding plants and container nursery production. Foliage plant production accounted for 49% of the direct energy for ornamentals and 47% of the total primary energy for ornamentals. In fact, foliage plants require a very large portion of the energy (9.4% of the direct energy and 9.5% of the total primary energy) required for all Florida production agriculture.

The energy budget for foliage production in central Florida under cover, as an example of the eight ornamentals energy budgets in the FAECM model and, as the ornamentals crop whose production required the largest quantity of energy, is shown in Table 2. It contains the quantities of the 18 (of potentially as many as 21) inputs used for Florida foliage production in central Florida, the direct energy requirements of those that are energy commodities and the total primary energy requirements of all 18 inputs, the sum of the direct energy and the sum of the total primary energy, and the percentages that each input is of the sums. The amount of direct energy (total heat Btu) for covered foliage production in FAECM was 1240 million Btu/acre and the total primary energy was 4090 million Btu/acre (Table 3 and Fig. 1 & 2). The major primary energy inputs for foliage production in central Florida under cover were "other costs" (35.2% of the total), diesel fuel (22.0%), labor (17.0%), electricity (13.0%), and LP gas (8.2%) (Table 2). "Other costs" for covered foliage production includes such inputs as transplants and seed, containers, shipping supplies, depreciation and supplies shrinkage, facility repair and maintenance, potting soil, insurance, other supplies and telephone. Open field foliage production requires considerably less energy per unit area in FAECM: 162 million Btu/acre direct energy and 740 million Btu/acre total primary energy.

The energy requirement data for all Florida ornamentals production in 1990 are shown in Table 4. Diesel fuel (including that used for irrigation) was 4.23 trillion Btu, or more than 56% of the 7.50 trillion Btu of direct energy requirements. LP gas was second highest at 1.58 trillion Btu or 21.1 % of the total direct energy requirements. The total primary energy requirements of 25.02 trillion Btu

Table 2. Energy consumption in the production of foliage in central Florida (per acre basis).

Energy	Units	Btu/unit	#units	Direct energy Btu	Direct energy % total	Total primary energy Btu	Total primary energy % total
Diesel	gal	139,700	5208.0	728,100,000	58.9	884,000,000	21.6
Diesel/irrig.	gal	139,700	83.6	1,170,000	0.9	1,420,000	0.4
Gasoline	gal	126,000	525.8	66,200,000	5.4	80,500,000	2.0
Lubricants	gal	153,000	108.7	16,700,000	1.4	20,300,000	0.5
LP gas	gal	96,100	2882.4	27,700,000	22.4	337,000,000	8.2
Electricity	kWh	3,412	39,794.3	136,000,000	11.0	529,000,000	12.9
Elect/irrig.	kWh	3,412	98.4	340,000	0.0	1,310,000	0.0
Nitrogen	lb[z]	32,730	1096.1			58,900,000	0.9
Phosphorus	lb[z]	7,502	548.0			4,110,000	0.1
Potash	lb[z]	5,890	548.0			3,230,000	0.1
Herbicides	lb[z]	122,377	166.0			20,300,000	0.5
Insecticides	lb[z]	99,481	140.5			14,000,000	0.3
Fungicides	lb[z]	78,211	48.2			3,770,000	0.1
Other pest.	lb[z]	100,023	24.6			2,460,000	0.1
Lime	lb[z]	445	1008.0			450,000	0.0
Other chem.	lb[z]	24,160	35.1			850,000	0.0
Labor costs	man-h	54,133	12,684.0			696,300,000	17.0
Other costs[y]	$	17,017	84,491.3			1,440,000,000	35.2
Totals				1,240,000,000		4,090,000,000	

[z]Active ingredients
[y]Other costs include plants and seeds, containers, shipping supplies, depreciation and supplies shrinkage, facility repair and maintenance, potting soil, insurance, etc.

Table 3. Energy use per unit area in the production of various crops.

	Energy (Btu/acre) Direct	Energy (Btu/acre) Total primary
All Florida crops	13.3×10^6	38.0×10^6
All ornamentals	86.1×10^6	287×10^6
Bedding plants	1270×10^6	4090×10^6
Bulbs	162×10^6	740×10^6
Cut greens & flowers	49.2×10^6	265×10^6
Foliage; covered	1240×10^6	4090×10^6
Foliage; open	162×10^6	740×10^6
Potted plants	94.8×10^6	316×10^6
Sod	9.77×10^6	29.3×10^6
Container nursery	282×10^6	957×10^6
Field nursery	37.5×10^6	114×10^6

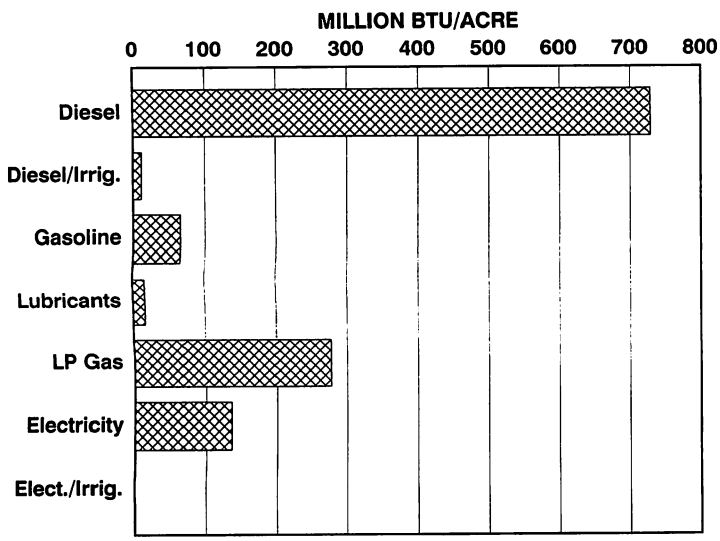

Fig. 1. Direct energy used in producing foliage plants in central Florida.

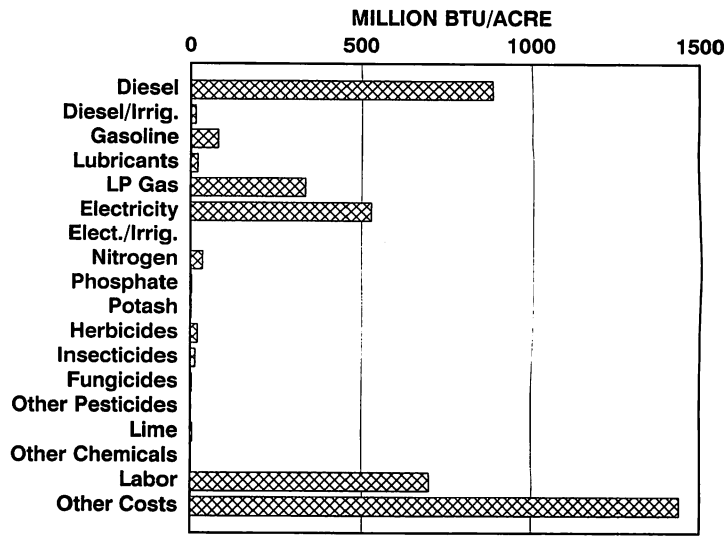

Fig. 2. Total primary energy used in producing foliage plants in central Florida.

were more widely distributed among different inputs. The largest were "other costs" at 7.84 trillion Btu (31.3%), diesel fuel (including that used for irrigation) at 5.14 trillion Btu (20.5%), labor at 4.43 trillion Btu (17.7%), electricity (including that used for irrigation) at 3.28 trillion Btu (13.1%) and LP gas at 1.92 trillion Btu (7.7%).

The requirements of direct and total primary energy per acre for the ornamentals crops grown in Florida are shown in Table 3. Ornamentals crops require considerably more direct and total primary energy per unit area than the average Florida crop (86.1 versus 13.3 million Btu/acre and 287 versus 38.0 million Btu/acre, respectively). Only sod production, among the ornamentals, has relatively low energy requirements per unit area, at 9.77 million Btu/acre direct and 29.3 million Btu/acre total primary.

In Fig. 3 and 4 the changes in direct and total primary energy consumption for all Florida ornamentals over 5

Table 4. Direct and total primary energy used in Florida ornamentals production, 1990.

(Btu)	Direct energy energy (Btu)	Total primary
Diesel	3.98×10^{12}	4.84×10^{12}
Diesel/irrigation	0.246×10^{12}	0.298×10^{12}
Gasoline	0.651×10^{12}	0.791×10^{12}
Lubricants	0.205×10^{12}	0.249×10^{12}
LP gas	1.58×10^{12}	1.92×10^{12}
Electricity	0.812×10^{12}	3.16×10^{12}
Elect./irrigation	0.030×10^{12}	0.118×10^{12}
Nitrogen		0.716×10^{12}
Phosphorus		0.099×10^{12}
Potash		0.109×10^{12}
Herbicides		0.133×10^{12}
Insecticides		0.101×10^{12}
Fungicides		0.062×10^{12}
Other pesticides		0.102×10^{12}
Lime		0.039×10^{12}
Other chemicals		0.005×10^{12}
Labor		4.43×10^{12}
Other costs		7.84×10^{12}
Totals	7.50×10^{12}	25.02×10^{12}

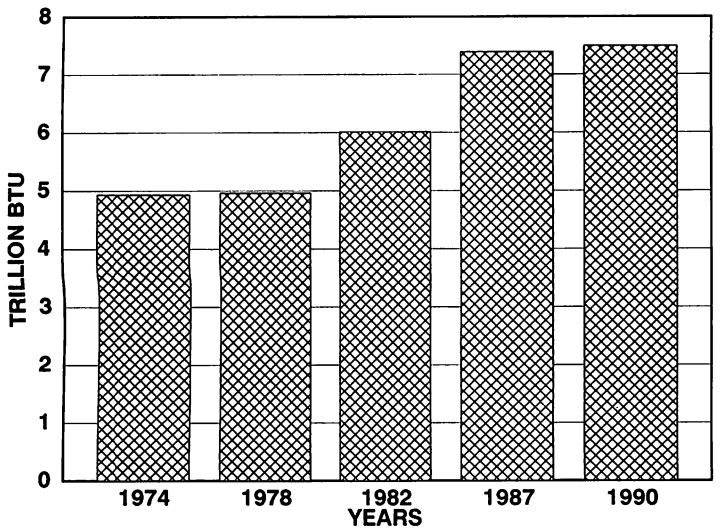

Fig. 3. Direct energy used in producing ornamentals in Florida.

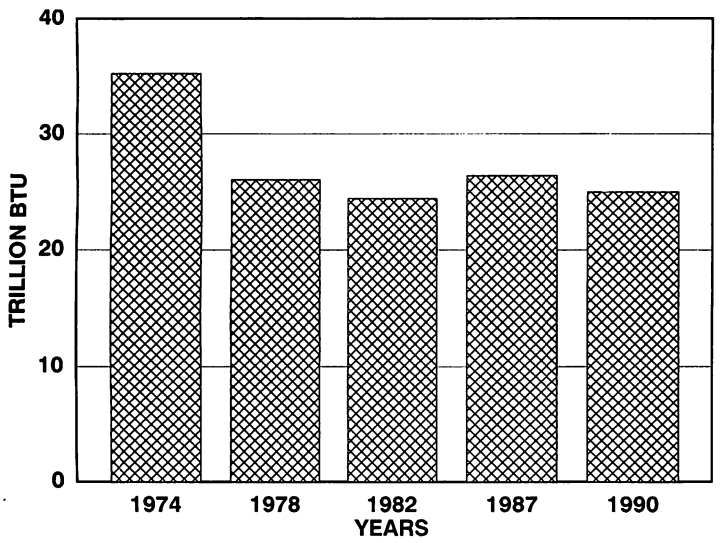

Fig. 4. Total primary energy used in producing ornamentals in Florida.

years since 1974 are shown. Direct energy requirements have increased every year for the five years calculated from 1974 to 1990. These increases were mainly the result of increasing production levels of the ornamentals commodities over time. Total primary energy requirements, on the other hand, decreased sharply from 1974 to 1978, then held fairly steady through 1990. Increasing energy efficiency in the production of inputs for ornamentals production was a major factor causing this initial reduction and allowing the following fairly steady energy requirement despite increasing acreages. Direct energy inputs have steadily become a larger portion of the total primary energy inputs, from 14% in 1974 to 30% in 1990.

Comparison of the 1990 dollar value of Florida ornamentals production with the 1990 production energy requirements showed that the dollar value per direct energy requirement of $144/million Btu was somewhat higher than the average for all Florida agriculture production of $135/million Btu. The high values of ornamentals commodities more than offset their high direct energy intensity. The average million Btu of direct energy consumed in Florida in 1990 for all purposes cost $8.66; there were, of course, other inputs required in addition to energy in agricultural production. The dollar value per total primary energy requirement of $43/million Btu was slightly less than the state's average of $44/million Btu for all Florida agriculture production. The consumer was purchasing somewhat less direct energy per dollar when purchasing ornamentals than when purchasing the average complement of Florida agricultural products but about the same amount of total primary energy.

In comparing the value of ornamentals production per million Btu of either direct or total primary energy with the other four commodity groupings, the FAECM model shows that ornamentals have higher value than livestock products or fruits, but lower value than vegetables and agronomic crops.

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