Table 4. Engineering economic analyses of the low energy landscape with native plantings with first year establishment costs and reduced yearly maintenance costs for shrubs and once every five years tree maintenance versus high energy landscape.

Energy escalation and inflation rate	Life period	Annual return on investment
0%	10 Yr.	35.9%
	20	37.7
10	10	44.9
	20	47.3
20	10	53.8
	20	56.8
30	10	62.6
	20	66.4

Table 5. Engineering economic analyses of various capital investments for low energy landscape with native plants versus a high energy landscape over a 20 year life period.

Capital investment	Energy escalation and inflation rate	Annual return on investment
$1000	0%	18.4%
	10	28.2
	20	37.9
	30	47.5
2000	0	7.1
	10	16.5
	20	25.8
	30	35.1
3000	0	2.4
	10	11.5
	20	20.6
	30	29.7
4000	0	—
	10	8.5
	20	17.5
	30	26.3
5000	0	—
	10	6.4
	20	15.2
	30	24.0
6000	0	—
	10	4.8
	20	13.6
	30	22.1

conditioning buildings. The engineering economic analyses presented here provide the effective annual returns on investment of the low energy versus high energy landscapes for residential buildings. The purchase price and maintenance costs (pesticides, water, and fertilizer) are included in all the analyses.

Perhaps the most effective way to educate people of the need to conserve energy is to first convince them how they can save money by conserving energy. Therefore, the results presented in the manuscript should serve as a useful tool in promoting the use of plants for landscaping. In addition to reducing energy expenditures for comfort conditioning, a low energy residential landscape will generally enhance the aesthetic value of a residence.

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ECONOMICS OF RESIDENTIAL LANDSCAPING FOR ENERGY CONSERVATION—A STATEWIDE PROGRAM[1]

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Abstract. **Economic feasibilities of various landscaping designs are presented for a statewide program in Florida for nine locations throughout the state. The economic feasibilities of various: 1. shading levels on walls and roofs; 2. exterior colors of walls and roofs; and 3. building orientations for conserving energy in heating and cooling residential buildings are presented. The effectiveness of each landscaping feature for concrete block and wood-frame houses is evaluated on the basis of its present worth in terms of energy savings that accrue because of the adoption of the landscaping feature. Present worths are calculated for interest rates ranging from 5 to 20% and annual energy cost escalation rates ranging from 0 to 30% for 10 year and 20 year life periods. Detailed analyses are presented in this paper**

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for Orlando with several comparative evaluations with the other eight Florida locations in the statewide program.

The computer simulation results are summarized by evaluating the annual expenditures for cooling and heating a specified concrete block house with "low energy" and "high energy" landscaping designs. The "low energy" landscape consists of heavy shade on light-colored walls and roof and an east-west orientation. The "high energy" landscape refers to a house with no shade on dark-colored walls and roof and a north-south orientation. The differences in present worths in Orlando of the "low energy" and "high energy" landscape for a 20 year life are $2,467, $5,624, and $14,820 for annual energy cost escalation rates of 10, 20 and 30%, respectively, and for an assumed interest rate of 15%. For a 20 % energy cost escalation rate, an interest rate of 15% and a 20 year life period, the present worths of the low energy versus high energy landscape designs vary from $3,939 in Tallahassee to $9,010 in Miami. Similar results are also presented for a wood frame house.

A national study has concluded that approximately 32% of the energy used in the United States is consumed for heating and cooling buildings occupied by people (13). Much energy can undoubtedly be saved in comfort conditioning buildings by incorporating energy conservation principles into the design, construction, maintenance, and operation of the system. Retrofitting existing buildings with insulation, weather-stripping, and periodic maintenance of mechanical equipment can potentially save 20 to 25% of the energy used for comfort conditioning buildings (9). Other engineers (10) estimate that 50 to 60% energy savings can be realized in new buildings that are properly designed, constructed, and operated with energy conservation as a major design criterion. These energy savings can be obtained with little, if any, discomfort or inconvenience to the occupants of the building.

Landscaping features of a residential building can be designed to save energy required for comfort conditioning a building throughout the year. The use of different types of trees, vines, and espaliered plants for protecting buildings from intense solar radiation was presented by Black (2). Discussions of the qualitative means by which plants can reduce energy expenditures for comfort conditioning have been presented by others (2, 8, 12).

An economic evaluation of residential landscaping designs for energy conservation was presented by Buffington (4) for the location of Jacksonville, Florida based on the actual hourly weather data for the entire year of 1965. The results indicated differences in present worths of defined "low energy" and "high energy" landscapes for a 20 year life of $3,080, $8,683, and $27,277 for energy cost escalation rates of 10, 20, and 30%, respectively, and for an assumed annual interest rate of 10%.

To experimentally evaluate the effects of different energy conserving alternatives on energy expenditures for heating and cooling buildings would involve constructing several identical structures incorporating various energy conserving features. The energy expenditures for heating and cooling could then be monitored over an extended period of time in order to evaluate the effectiveness of each design and operation feature. Such experimental evaluation would be prohibitively expensive and time consuming. Furthermore, if the structures were occupied, then the differences in operating schedules and management practices could easily mask the effectiveness of the energy conserving alternative being evaluated in the structures.

Computer simulation can be an efficient, accurate method for evaluating the thermal performance of structures as a function of many different design and structural modifications of buildings.

The objective of this reported research was to determine the economic effectiveness of various landscaping features and designs for reducing energy expenditures for comfort conditioning residential buildings for nine different locations—Pensacola, Panama City, Tallahassee, Jacksonville, Daytona Beach, Orlando, Tampa, West Palm Beach and Miami—in the State of Florida. The landscaping features and designs considered were: 1. wall and roof shading levels; 2. wall and roof exterior colors; and 3. building orientation.

Methodology

The computer analysis for simulating the heat gains and losses of a residential building over a one year period was based in part on the transfer function method as presented in ASHRAE Handbook of Fundamentals (1). The transfer function coefficients for walls and roofs of buildings were calculated for the specific construction details of each building section according to the computer program by Mitalis and Arseneault (11). After heat gains and losses through the building were simulated, heating loads, cooling loads, heat extraction rates, and heat addition rates were simulated (1). The consumption of utilities was calculated from heat extraction and addition rates on the basis of system performance of the specified mechanical heating and cooling equipment. The utility expenditure was then related to dollars using current prices of the utilities for each location. Full details of the application of the transfer function method to the thermal analysis of residential buildings were presented by Buffington (3).

To properly evaluate the thermal performance of any building, it is essential to perform detailed simulations on an hour-by-hour basis over an extended period of time of at least one year (1). It is not sufficient to simply use one summer design day and one winter design day for the analysis, regardless of when the design days are selected to occur. Using a unique design day for each month of the year is also not sufficient to simulate energy consumption for heating and cooling a building.

The weather data set used as input for the simulation model was the Typical Meteorological Year (TMY) as developed by the National Oceanic and Atmospheric Administration (NOAA) (14). The TMY consists of hourly climatic data for representative months selected over a 25 year period. Each selected representative month is then joined together with a smooth transition to create the TMY (14). For example, the TMY for Orlando was created as follows:

January, 1968	July, 1957
February, 1953	August, 1958
March, 1964	September, 1965
April, 1973	October, 1966
May, 1964	November, 1961
June, 1962	December, 1966

The TMY was specifically developed by NOAA to be used to evaluate the performance of heating and air conditioning systems in the same building or in buildings with different design features (14). The hourly data from the TMY used in the computer simulations were: dry-bulb temperature, dewpoint temperature, solar radiation, and wind speed and direction.

For the purpose of evaluating the various landscaping features in each of the nine Florida locations, two rather typical Florida residential buildings were used as control houses for the computer simulation studies—one was a concrete block house and the other was an insulated wood frame house. Details of the concrete block control house were:

–139 m^2 (1500 ft^2) floor area (9.1 m x 15.2 m) (30 ft x 50 ft)
–2.4 m (8 ft) wall height
–White exterior walls
–Asphalt shingle roof (1/3 slope)
–Dark color roof
–Window area 14.5% of floor area
–Single-pane windows
–1.5 air changes per hour (ACPH) building infiltration
–3 ACPH attic ventilation (natural)
–0.61 m (2 ft) roof overhang
–No shade on exterior walls and roof
–Carport on North end of house
–Building occupied by 2 adults and 2 children
–Wall construction
  20 cm (8 in.) concrete block wall
  1.9 cm (0.75 in.) air gap
  1.3 cm (0.50 in.) plaster board
–Ceiling construction
  9 cm (3.5 in.) mineral wool insulation
  1.3 cm (0.50 in.) plaster board
  3.8 cm x 8.9 cm (2 x 4) joists on 61 cm (24 in.) spacing
–Floor construction
  10 cm (4 in.) concrete slab
  carpet and rubber padding
–Gable construction
  1.59 cm (0.625 in.) siding
  3.8 cm x 8.9 cm (2 x 4) studs on 41 cm (16 in.) spacing
–Roof construction
  asphalt shingles
  building paper
  1.3 cm (0.50 in.) plywood sheathing
  3.8 cm x 8.9 cm (2 x 4) rafters on 61 cm (24 in.) spacing
–Air handling duct construction
  2.5 m (1 in.) duct board

The air temperature maintained inside the building was 25°C (77°F) during the cooling period and 21°C (70°F) during the heating period. Relative humidities inside the building during the cooling and heating periods were 60% and 40%, respectively.

Floor plan and side views of the concrete block control house used in this simulation study are shown in Fig. 2. The wood frame control house was the same as the concrete block structure, except that the walls were constructed of 1.59 cm (0.625 in.) exterior plywood, 9 cm (3.5 in.) mineral wool insulation and 1.3 cm (0.50 in.) plaster board on the interior. The wall studs were 3.8 cm x 8.9 cm (2 x 4) on 41 cm (16 in.) spacing.

In all the computer analyses performed, the energy expenditures were simulated for heating and cooling the control house with different landscaping features and designs. Other energy expenditures for heating water, lighting, powering appliances, etc. were not included in any of the analyses because these energy expenditures were assumed to be independent of landscaping features.

Results and Discussion

Yearly expenditures for comfort conditioning the concrete block and wood frame control houses were simulated using the computer model discussed earlier in this paper. Expenses were simulated for required energy for cooling and heating throughout the TMY for each of the nine Florida

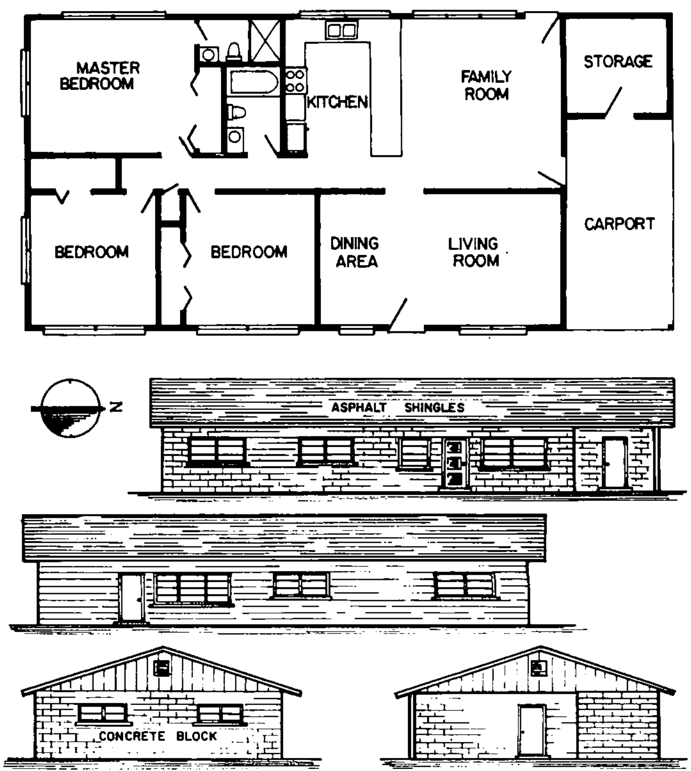

Fig. 1. Floor plan and side views of concrete block control house.

locations. (Actually, the TMY of Apalachicola was used for the Panama City location and the TMY of Mobile, Alabama for Pensacola, since TMY's were not available for Panama City or Pensacola). The energy expenditures for comfort conditioning were simulated for current prices (Autumn, 1981) for electricity for cooling and natural gas or No. 2 fuel oil for heating for each location as tabulated in Table 1.

Table 1. Prices of utilities for each location included in the simulation analyses for Autumn, 1981.

Location	Electricity $/kw-hr	No. 2 fuel oil $/gallon	Natural gas $/therm
Pensacola	0.065	—	0.60
Panama City	0.064	—	0.38
Tallahassee	0.070	1.21	—
Jacksonville	0.075	1.34	—
Daytona Beach	0.077	1.31	—
Orlando	0.060	1.35	—
Tampa	0.070	1.35	—
West Palm Beach	0.073	—	0.42
Miami	0.072	—	0.42

The cooling system used in the analyses was an air conditioner (air-to-air) with an energy efficiency ratio (EER) of 7.5 at rated environmental conditions. In the analyses, the EER fluctuated as a function of ambient temperature. The heating system was a direct-fired furnace with 75% combustion efficiency for No. 2 fuel oil and 85% combustion efficiency for natural gas.

Detailed analyses were performed for each of the nine Florida locations. However, because of space limitations in this paper, results of the detailed analyses will be presented only for Orlando, Florida with general comparisons of several variables for all nine Florida locations.

The simulated yearly expenditures for comfort conditioning of the concrete block control house and for twelve different modifications to the control house are presented in Table 2 for Orlando. The simulated yearly energy expenditures for the insulated wood frame house in Orlando are presented in Table 3. Whenever a landscaping feature was being evaluated, all other alternatives remained the same as in the control house. For example, when the modification of heavy roof shading was considered, all the features remained the same in the control house as specified, except that the roof was assumed to be under heavy shade. In analyzing the results tabulated in Tables 2 and 3, one can realize the large impact that various landscaping features can have upon the total expenditures for comfort conditioning concrete block or wood frame structures. In each case, the total energy expenditure for comfort conditioning the wood frame structure is less than for the concrete block structure, with nearly all the savings accruing during the heating period.

Table 2. Simulated yearly expenses for comfort conditioning concrete block structure.

	Cooling $	Heating $	Total $
Control house	728	134	862
Modification			
Orientation			
East-West	680	140	821
Wall shading			
Light shading	684	137	821
Heavy shading	632	139	771
Roof shading			
Light shading	703	135	838
Heavy shading	681	132	813
Full shading	664	134	799
Wall and Roof shading			
Light shading	665	138	803
Heavy shading	589	140	729
Exterior colors			
Dark-colored walls and roof	804	126	930
Light-colored walls and roof	683	139	822
Overall comparison			
High energy landscaping	804	126	930
Low energy landscaping	565	156	721

The yearly requirements of electricity for air conditioning the concrete block house in each of the nine localities are shown in Fig. 2. The yearly requirement ranges from a low of 9,290 kw-hr in Tallahassee to a high of 15,750 kw-hr in Miami, a 70% increase. The yearly requirements of gallons of No. 2 residual fuel oil for each of the locations is shown in Fig. 3. The fuel requirements for heating are all expressed in terms of gallons of No. 2 fuel oil so that comparisons can be easily made, although it must be recognized that some locations do not use fuel oil for heating purposes. The yearly requirements for heating range from a low of 35 gallons of fuel oil in Miami to a high of 362 gallons in Tallahassee, more than a 10-fold increase. The yearly expenditures for comfort conditioning the concrete block control house for the nine Florida locations are shown in Fig. 4. These expenditures are based on the price of the utilities in each of the localities as given in Table 1 and the simulated energy use of the concrete block house for each of the localities. Although the individual heating and cooling expenditures vary tremendously throughout the state (Figs. 2 and 3), the total yearly expenditure for comfort conditioning (heating and cooling) varies modestly from a low of $862 for Orlando to a high of $1152 for Miami, representing a 34% increase.

Table 3. Simulated yearly expenses for comfort conditioning wood frame structure.

	Cooling $	Heating $	Total $
Control house	721	113	835
Modification			
Orientation			
East-West	658	122	779
Wall shading			
Light shading	673	117	791
Heavy shading	626	119	745
Roof shading			
Light shading	697	116	813
Heavy shading	669	116	785
Full shading	642	116	759
Wall and Roof shading			
Light shading	648	118	766
Heavy shading	586	120	707
Exterior colors			
Dark-colored walls and roof	762	115	877
Light-colored walls and roof	675	119	794
Overall comparison			
High energy landscaping	762	115	877
Low energy landscaping	563	121	684

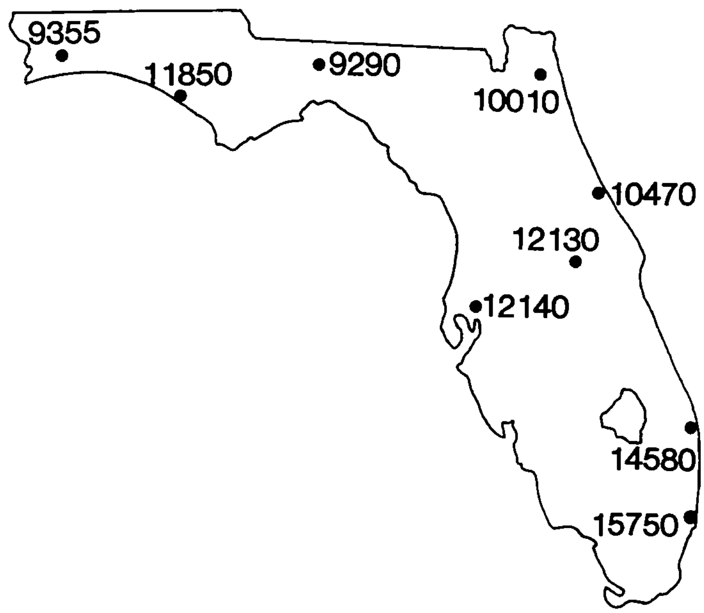

Fig. 2. Simulated yearly consumption of electricity (kw-hr) for air conditioning concrete block control house for each Florida location.

Light, heavy, and full shade as used in this manuscript correspond to approximately 33%, 67%, and 100% shading, respectively, during the cooling period. During the heating period, the shading levels correspond to 10%, 20%, and 25% shading, respectively. The reduction of shading levels during the heating period is based on the shading being provided primarily by deciduous trees. Orientation of a building is defined as the direction of the major axis of a building. If a building is described as having an east-west orientation, then the long sides of the building will be running east-west, or in other words, facing north and south.

To evaluate the economic effectiveness of the various landscaping features being considered, the present worth

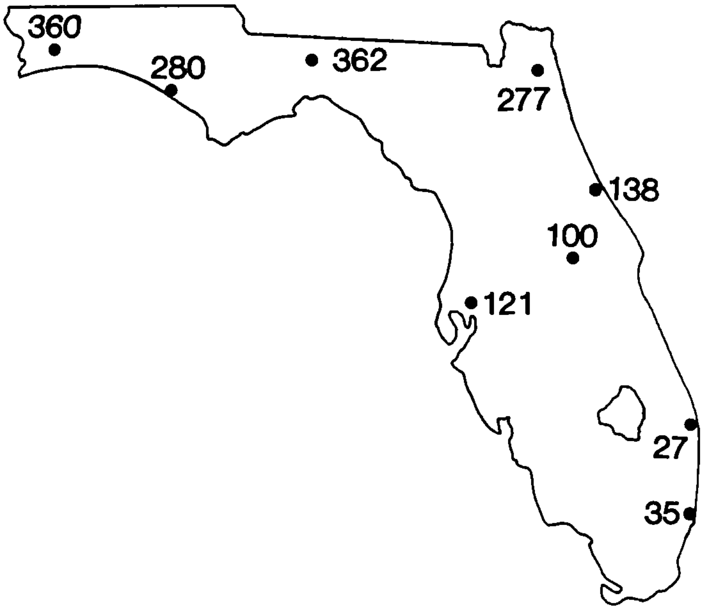

Fig. 3. Simulated yearly consumption of No. 2 residual fuel oil (gallons) for heating the concrete block control house for each Florida location.

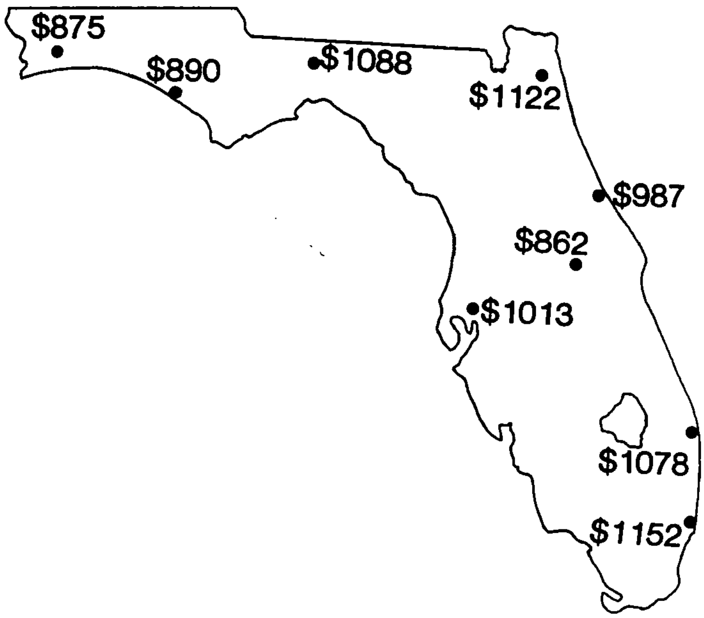

Fig. 4. Simulated yearly expenditures for comfort conditioning the concrete block control house for each Florida location.

of each feature for each type of structure was analyzed for interest rates of 5, 10, 15, and 20%. and assumed 10 year and 20 year life periods. Present worths of each landscaping feature for a 10% annual energy cost escalation rate for the concrete block house are presented in Table 4. For assumed annual energy cost escalation rates of 20 and 30%, present worths are given in Tables 5 and 6, respectively. Present worths for the landscaping features for the wood frame house for energy escalation rates of 10, 20 and 30% are provided in Tables 7, 8, and 9, respectively.

The economic concept of present worth is interpreted as the additional present value of one alternative compared to another alternative on the basis of annual monetary savings attributed to the adoption of the alternative. For example, the present worth of a concrete block residential building with an east-west orientation compared to north-south orientation is $1,115 for an interest rate of 15%, annual energy cost escalation rate of 20% and a 20 year life (Table 5). The interpretation is that one could justifiably spend $1,115 additional for the concrete block control house with an east-west orientation compared to north-south orientation on the basis of the amount of money saved annually in utilities for comfort conditioning over the next 20 year period. The data in Tables 4-9 indicate that as the annual energy cost escalation rate increases, the present worth of each landscaping feature increases. Also, as the life periods increase, the present worth increases for each landscaping feature. However, for an increase in interest rates, the present worth of each landscaping alternative decreases. The most desirable landscaping feature is obviously that feature which yields the highest present worth for a given interest rate and energy cost escalation rate.

To summarize the results of the economic efficiencies

Table 4. Present worths for various landscaping alternatives for concrete block structure (10% annual energy cost escalation rate).

	10 Year Life				20 Year Life			
	Interest Rate				Interest Rate			
Alternatives	5%	10%	15%	20%	5%	10%	15%	20%
	$	$	$	$	$	$	$	$
East-West orientation vs. North-South orientation	492	377	298	241	1275	755	489	342
Heavy wall shading vs. No wall shading	1082	830	656	531	2805	1661	1076	753
Heavy roof shading vs. No roof shading	582	446	352	285	1508	893	578	405
Light wall and roof shading vs. No wall and roof shading	706	542	428	346	1829	1083	702	491
Heavy wall and roof shading vs. No wall and roof shading	1579	1212	957	775	4094	2424	1570	1099
Heavy wall and roof shading vs. Light wall and roof shading	874	670	529	429	2265	1341	869	608
Light-colored walls and roof vs. Dark-colored walls and roof	1282	984	777	629	3323	1967	1274	892
Low energy landscaping vs. High energy landscaping	2482	1904	1504	1217	6433	3809	2467	1727

Table 5. Present worths for various landscaping alternatives for concrete block structure (20% annual energy cost escalation rate).

Alternatives	10 Year Life				20 Year Life			
	Interest Rate				Interest Rate			
	5%	10%	15%	20%	5%	10%	15%	20%
	$	$	$	$	$	$	$	$
East-West orientation vs. North-South orientation	775	576	440	346	3722	1951	1115	692
Heavy wall shading vs. No wall shading	1706	1267	969	761	8191	4292	2453	1523
Heavy roof shading vs. No roof shading	917	681	521	409	4402	2307	1318	818
Light wall and roof shading vs. No wall and roof shading	1112	826	632	496	5341	2799	1599	993
Heavy wall and roof shading vs. No wall and roof shading	2490	1849	1414	1111	11953	6264	3579	2222
Heavy wall and roof shading vs. Light wall and roof shading	1377	1023	782	615	6612	3465	1980	1229
Light-colored walls and roof vs. Dark-colored walls and roof	2021	1501	1148	902	9701	5084	2905	1803
Low energy landscaping vs. High energy landscaping	3912	2906	2223	1746	18783	9843	5624	3491

Table 6. Present worths for various landscaping alternatives for concrete block structure (30% annual energy cost escalation rate).

Alternatives	10 Year Life				20 Year Life			
	Interest Rate				Interest Rate			
	5%	10%	15%	20%	5%	10%	15%	20%
	$	$	$	$	$	$	$	$
East-West orientation vs. North-South orientation	1239	896	666	509	11729	5657	2937	1643
Heavy wall shading vs. No wall shading	2727	1971	1466	1120	25808	12446	6463	3615
Heavy roof shading vs. No roof shading	1466	1059	788	602	13871	6689	3474	1943
Light wall and roof shading vs. No wall and roof shading	1778	1285	956	731	16828	8116	4214	2357
Heavy wall and roof shading vs. No wall and roof shading	3980	2876	2140	1635	37662	18164	9431	5275
Heavy wall and roof shading vs. Light wall and roof shading	2202	1591	1184	904	20834	10048	5217	2918
Light-colored walls and roof vs. Dark-colored walls and roof	3230	2334	1737	1327	30568	14742	7655	4282
Low energy landscaping vs. High energy landscaping	6254	4520	3362	2569	59182	28542	14820	8290

of the various landscaping alternatives, "low energy" and "high energy" landscaping designs were simulated for the concrete block and wood frame control houses. The high energy landscaping corresponded to each control house with north-south orientation, no shading on the walls or roof, and dark-colored exterior walls and roof. The low energy landscaping corresponded to each control house with east-west orientation, heavy shading on walls and roof, and light-colored exterior walls and roof. For an interest rate of 15% and energy cost escalation rates of 10, 20, and 30%, the corresponding present worths of the low energy landscaping are $2,467, $5,624, and $14,820, respectively, compared to the high energy landscape for the concrete block structure for a 20 year period (Tables 4-6). Over the same period with a wood frame structure, the corresponding present worths are $2,275, $5,186, and $13,666, respectively (Tables 7-9).

The present worths of the low energy versus high energy landscapes for the nine Florida locations are shown in Fig. 5 for the case of a 20% annual energy cost escalation rate, 15% annual interest rate and a 20 year period. For all locations, the low energy landscape provides for a substantial present worth value compared to the high energy landscape design. The present worths vary from a low of $3,939 in Tallahassee to a high of $9,010 for Miami.

Tables 10 and 11 summarize the simulated energy consumption and the mechanical system requirements of these two landscaping designs for the concrete block and wood frame control houses, respectively. Although the low energy landscaping results in higher consumption of fuel for heating than the high energy landscaping, the extra heating expense is more than offset by the much lower cost of utilities required for cooling. The savings in the purchase of the smaller air conditioner necessary for the

Table 7. Present worths for various landscaping alternatives for wood frame structure (10% annual energy cost escalation rate).

Alternatives	10 Year Life				20 Year Life			
	Interest Rate				Interest Rate			
	5%	10%	15%	20%	5%	10%	15%	20%
	$	$	$	$	$	$	$	$
East-West orientation vs. North-South orientation	656	503	397	322	1700	1007	652	457
Heavy wall shading vs. No wall shading	1062	815	643	521	2752	1630	1056	739
Heavy roof shading vs. No roof shading	582	447	353	286	1510	894	579	405
Light wall and roof shading vs. No wall and roof shading	815	625	494	400	2112	1250	810	567
Heavy wall and roof shading vs. No wall and roof shading	1517	1164	919	744	3932	2328	1508	1056
Heavy wall and roof shading vs. Light wall and roof shading	702	539	425	344	1820	1078	698	489
Light-colored walls and roof vs. Dark-colored walls and roof	982	753	595	482	2545	1507	976	683
Low energy landscaping vs. High energy landscaping	2288	1756	1386	1122	5932	3512	2275	1593

Table 8. Present worths for various landscaping alternatives for wood frame structure (20% annual energy cost escalation rate).

Alternatives	10 Year Life				20 Year Life			
	Interest Rate				Interest Rate			
	5%	10%	15%	20%	5%	10%	15%	20%
	$	$	$	$	$	$	$	$
East-West orientation vs. North-South orientation	1034	768	587	461	4964	2602	1487	923
Heavy wall shading vs. No wall shading	1674	1243	951	747	8036	4211	2406	1494
Heavy roof shading vs. No roof shading	918	682	522	410	4408	2310	1320	819
Light wall and roof shading vs. No wall and roof shading	1284	954	730	573	6166	3231	1846	1146
Heavy wall and roof shading vs. No wall and roof shading	2391	1776	1359	1067	11480	6016	3438	2134
Heavy wall and roof shading vs. Light wall and roof shading	1107	822	629	494	5314	2785	1591	988
Light-colored walls and roof vs. Dark-colored walls and roof	1547	1149	879	691	7430	3894	2225	1381
Low energy landscaping vs. High energy landscaping	3607	2679	2049	1610	17319	9076	5186	3219

low energy landscaping will compensate for some of the expenses required for providing the low energy landscaping features.

Detailed results of all of the analyses for each of the nine Florida locations are available in a series of circulars from your County Extension Office (6). The circular for each location contains the site-specific results as shown in Tables 1-11 in this paper. Results are also provided for present worths for the case of 0% annual energy cost escalation rate.

In order to achieve the potential benefits from vegetation, the plants must be sited to properly shade the residence. Or in the case of new construction, the residence must be properly sited with respect to existing vegetation to achieve the desired shading benefits. A series of circulars are available to provide the necessary factors for easily determining shading patterns for each sunlit hour of the 1st, 8th, 15th and 22nd days of each month throughout the year (5). The circulars are available for eleven locations in Florida from your County Extension Office.

Landscaping features and designs have profound effects on the energy requirements for heating and cooling residential buildings. Computer simulation analyses were used to document the economic feasibilities of various landscaping design alternatives for residential energy conservation on a statewide basis for nine Florida locations. The results presented in this paper indicate the economic feasibilities of the landscaping features of wall and roof shading, wall and roof exterior colors and building orientation. Results are presented for various interest rates, energy cost escalation rates, and life periods.

The following paper in this Proceedings focuses on incorporating the purchase price and annual maintenance costs (pesticides, water, fertilizer, etc.) of shading materials into the analysis of the economic feasibilities (7). Economic analyses are reported in the form of effective interest rates

Table 9. Present worths for various landscaping alternatives for wood frame structure (30% annual energy escalation rate).

	10 Year Life				20 Year Life			
	Interest Rate				Interest Rate			
Alternatives	5%	10%	15%	20%	5%	10%	15%	20%
	$	$	$	$	$	$	$	$
East-West orientation vs. North-South orientation	1653	1195	889	679	15642	7544	3917	2191
Heavy wall shading vs. No wall shading	2676	1934	1439	1099	25320	12211	6341	3547
Heavy roof shading vs. No roof shading	1468	1061	789	603	13890	6699	3478	1946
Light wall and roof shading vs. No wall and roof shading	2053	1484	1104	843	19429	9370	4865	2721
Heavy wall and roof shading vs. No wall and roof shading	3822	2763	2055	1570	36174	17446	9059	5067
Heavy wall and roof shading vs. Light wall and roof shading	1769	1279	951	727	16745	8076	4193	2345
Light-colored walls and roof vs. Dark-colored walls and roof	2474	1788	1330	1016	23410	11290	5862	3279
Low energy landscaping vs. High energy landscaping	5766	4167	3100	2369	54570	26318	13666	7644

Table 10. Comparison of low energy and high energy landscaping designs for concrete block structure.

	Low energy design	High energy design
Electricity consumption, kw-hr/yr	9411.	13401.
Fuel oil consumption, gallons/yr	116.	94.
Cooling system capacity, tons	3.0	4.5
Heating system capacity, btu/hr	52000.	52000.

Table 11. Comparison of low energy and high energy landscaping designs for wood frame structure.

	Low energy design	High energy design
Electricity consumption, kw-hr/yr	9380.	12705.
Fuel oil consumption, gallons/yr	89.	85.
Cooling system capacity, tons	3.0	4.5
Heating system capacity, btu/hr	44000.	44000.

earned on the capital investment required to provide heavy levels of wall and roof shading.

Continuing research activities will include defining optimal tree location to maximize shading benefits on residential buildings for various species of trees, designs of buildings, and climatic zones in the state.

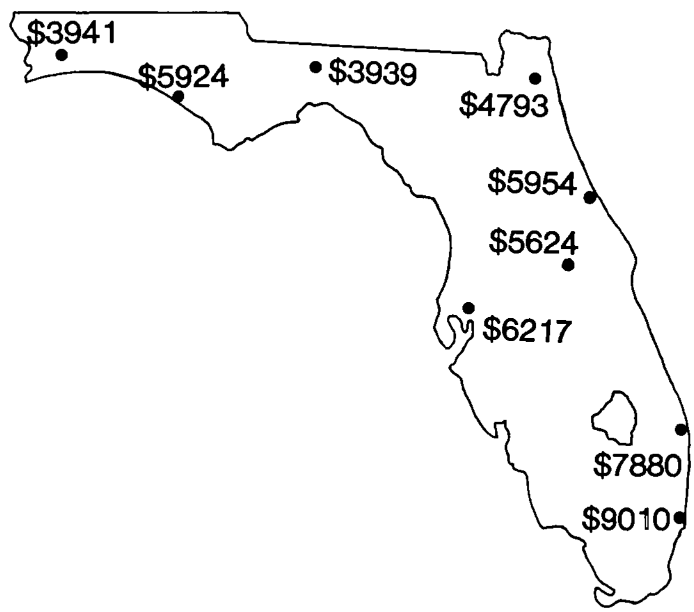

Fig. 5. Presents worths of low energy versus high energy landscaping designs for each Florida location for 20% annual energy cost escalation rate, 15% annual interest rate and a 20 year life period.

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THE PROPAGATION OF CYCADS—A GAME FOR YOUNG PEOPLE?

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Additional index word. seed.

Abstract. **Cycads deserve to be more widely used in Florida gardens, but have always been expensive and difficult to find. Nurserymen do not like them as a crop since they are slow growing and have a reputation for being difficult to propagate. Seed set in most species can be improved by hand pollination using either fresh or stored pollen. The seed of some species needs a period of storage before it is ready to plant; others can be planted immediately and germination is often enhanced by scarification or cutting the seed coat. Gibberellic acid has also proved beneficial in shortening germination time. Other methods of stock increase include division, and cutting the stem into pieces which are then treated to regenerate roots and shoots. Nitrogen and potassium fertilization have been found to speed up growth.**

A few cycads have been widely used in Florida gardens for a number of years including 2 species of *Cycas* as specimen plants and the Florida zamia or coontie as a ground cover. They have been valued for their ease of culture and low maintenance needs, and, in the case of coontie, for its tolerance of rocky soil and dry conditions.

In recent years, other cycads have become available which have proved to be just as valuable and decorative. They are frequently seen in private gardens and public plantings but have never realized their full potential as landscape material due to their cost. They are slow to propagate and there are restrictions on their collection and importation from the wild, so that nurseries have found it difficult to grow them for sale at a price competitive with other plants in general use.

Propagation is usually by seed, but vegetative methods are also successful.

Growing from Seed

Cycads are dioecious with the pollen and ovules formed on scales making up cone-like structure in most genera. The exception is the genus *Cycas* in which the female plants form the ovules on loosely aggregated "seed leaves". Cones in the male plants are much more typical. The pollen from cones on male plants is carried mostly by the wind to fertilize the ovules in cones on the female plants and form the embryos of the seeds. Thus, the development of seeds with viable embryos depends on two things; having pollen produced in male cones in a location from which air movement can transfer it to the females, and having it produced at a time when the female cones are receptive. This happens often enough in the wild that cycads have survived as a group for about 300 million years but in gardens the populations are often too small for these conditions to be met. Norstog & Stevenson (6) report evidence that insects may be helpful or even essential to pollen transfer in some species and are now testing their observations on this. In some genera the seeds will enlarge whether or not they contain a viable embryo but, of course, will not germinate to give a seedling. The percentage of viable seeds in collections from wild populations is often low.

Pollen can be harvested from male cones and transferred to a female. It can also be stored for a year or more until a receptive female cone is available. The scales of the male cone open slightly when the pollen is ready to be shed. About 4 to 7 days after the scale separation begins, the cone may be cut and wrapped loosely in smooth surfaced paper. During the next 2 or 3 weeks, the pollen will be shed and may be shaken loose from the cone. It is ready to use immediately or may be screened free of debris and stored in a tightly-capped, clean, dry jar at a few degrees above freezing (the temperature found in the fresh food section of a refrigerator).

The female cone shows a similar growth of the central axis and separation of the scales when it is receptive to pollen. In many species, this is accompanied by the formation of a sticky gel that glistens in the small opening between the scales. Later, as this gel dries, it shrinks back between the scales, carrying with it pollen that has been caught on its sticky surface. The pollen may be carried to the entrance to the ovule or may begin to grow in the gel before reaching the ovule which soon begins to swell. The gel seals the entrance to the ovule and the opening between the scales is closed so that after this time pollination can no longer occur. The time when the scales of a particular part of a cone are receptive may be only a few days but in a large cone, such as those of the genus *Encephalartos*, the progressive development of scales along the axis may give a period of a few weeks when some part of the cone is receptive. In other genera such as *Dioon*, it seems probable that only certain scales collect the pollen, and then only for a limited period, so that timing is more critical. In the genus *Cycas*, where the "seed leaves" form a loose mass rather than a cone, the ovules are fully exposed. They appear to be receptive for several days after they reach the size of a small olive.

Most artificial pollination is done by simply dusting the pollen between receptive scales but Oostuhysen (7) describes more elaborate techniques that have given good results which include cutting the top off the female cone and packing the spaces between the scales with a mixture of pollen and sand.

The actual fertilization of the egg may not occur for