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PLANNING AND INITIAL ACTIVITIES FOR THE UTILIZATION OF RENEWABLE ENERGY SOURCES IN THE SOUTHERN UNITED STATES, PUERTO RICO AND THE VIRGIN ISLANDS

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ABSTRACT

This paper presents a summary of goals, planning, and initial program activities aimed at achieving the 20% solar energy goal in the southern region. Special attention is then given to Puerto Rico and the Virgin Islands where heavy dependence on imported oil and high energy costs pose a real threat to social, economic, and governmental stability. The point is made that Puerto Rico oil imports represent a very significant portion of the total oil imports for the entire southern region. An assessment of renewable energy choices is then presented for these Caribbean territories, with attention to the potential for OTEC, biomass, photovoltaics, wind, and solar thermal technology. The general conclusion is drawn that prompt action in developing alternative energy sources is essential from the standpoint of both the Caribbean island communities and the United States which should have a strong interest in the long term well-being of the entire Caribbean region.

The assessment for Puerto Rico is based on a comprehensive energy analysis prepared by the Center for Energy and Environment Research of the University of Puerto Rico.

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INTRODUCTION

Planning efforts for the utilization of renewable energy technologies in the U.S. Caribbean are being undertaken both by Puerto Rico and the Virgin Islands, as well as the Southern Solar Energy Center. This paper reviews some of the planning activities concerning the SSEC region and discussion will ensue regarding the situation in Puerto Rico and the Virgin Islands, drawing upon work done by the Center for Energy and Environment Research of the University of Puerto Rico. Limited observations are also included concerning other portions of the Caribbean. The general conclusion is drawn that prompt action in developing alternative energy sources is essential from the standpoint of both the Caribbean island communities and the U.S. Planning and programmatic activities must reflect both the unique priorities and constraints of the diverse island communities.

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The Southern Solar Energy Center is one of four regional organizations responsible for helping to accelerate the practical application of solar and related conservation techniques. In planning the initial activities of the Center, considerable attention has been given to examination of goals which might be achieved through the use of various types of renewable energy sources. One objective of this effort has been to obtain a perspective of the problem and to have a basis for program planning and for measuring progress. This is certainly a beginning point which must be continuously reexamined as technical developments take place and other factors influence the process.

The southern region consists of the 16 southern states, the District of Columbia, Puerto Rico, and the U.S. Virgin Islands. The stateside area extends through Texas and Oklahoma, and includes Arkansas, Kentucky, West Virginia, Virginia, Maryland, Delaware, and those states lying to the south of this line. With the availability of a reasonable base of data on the continental portion of the region, it was possible to make analyses through the use of computer models such as the SPURR model (Reference 1) which was developed for the Energy Department by the MITRE Corporation.

Consideration of the situation in Puerto Rico and the Virgin Islands is a somewhat separate matter. Island planning is different than stateside planning because of the special characteristics of Island communities. Also, in the case of the U.S. Caribbean Islands, there may, in the future, be very important reasons for comparing their energy situation with other countries in the Caribbean. We mention the importance of this because of the natural linkages throughout the Caribbean and the fact that the economic and social development of the entire area is important and interrelated. With the extensive background analysis that has been done by the CEER, energy data and systems studies for Puerto Rico were available. Also, the Energy Office of the Virgin Islands has contributed significantly to the understanding of the special problems of the Caribbean area.

GOALS AND INITIAL PLANNING ASSESSMENTS

Initial analyses indicate that the southern region's availability of resources, favorable economics, and relatively high growth rates may enable it to provide almost 40% of the national goal of 18.5 Quads[1] from renewables by the year 2000. Table 1 shows the contribution by census region projected by the year 2000. It should be noted that, in this estimate, 7.5 Quads of renewable energy are projected for the region. This table does not include the energy element represented by Puerto Rico and the Virgin Islands. While the amounts of energy are not large by comparison, it will be seen later that the economics of the Caribbean Islands' energy dilemma are extremely serious.

Table II is an estimate of the breakdown by technology area and user sector. Biomass is expected to be a large contributor because of the very significant forest and agricultural resources in the region, with approximately 1.22 Quads now being utilized. This, of course, is primarily in the form of wood combustion by the pulp and paper industry. One observation that can be made from Table II is that every major technology element is expected to make a contribution, including additional hydroelectric generation (with low head applications). We recognize that the timing for the various technologies is very dependent upon progress in current research and development efforts. Thus, one can expect the mix to change with time. However, this type of analysis helps place the problem in perspective and is needed to examine just what is required to obtain the needed impact.

Table III is an estimate of the types of action which must

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[1] One Quad equals 10^{15} BTU or 180 million barrels oil equivalent.

occur in the future if we are to make a reasonable transition to renewable resources as a part of our long term energy strategy. This table simply indicates the numbers of installations which are required based on present concepts of systems for individual residences, commercial applications, and industrial use. This is the result from one of the modeling efforts and is helpful in understanding the scope of the task. Of course, for this or some equivalent mix of renewable use to take place, the technology must be available, the economics must be sound, and the regulatory and institutional situation must encourage the actions to happen. If you will think carefully about past major transitions in our society, you will recognize that changes such as these normally require a very long time span. Thus, a concerted effort by both government and the private sector will be necessary to achieve an effective transition in the limited time which is actually available.

It should be noted that the actual implementation of renewable energy systems on the scale indicated by Table III will require significant amounts of capital. Various estimates of the capital required for meeting a national goal of 20% fall in the range of 700 billion to one trillion dollars. This would be a significant part of the private investment capital available during the period and could be on the order of 15% of the total. For the south, the capital requirements could be approximately 350 billion. This, of course, is only an estimate; however, it does provide another method of placing the matter in perspective. It also helps one realize that the risk must be reasonable, and that the private sector can be expected to be properly cautious about technical performance and the resulting economic benefits as compared to other energy options.

With the initial estimates as shown in Tables II and III, further study was undertaken to develop a viable approach for the near term. An examination was made of the following key factors:

-Current technical status
-Ultimate potential impact

-Economic viability
-Status of the industry
-Knowledge and current acceptance by users.

With the current situation, as generally recognized by those presently working in the field, this resulted in targeting near-term programs within the region in the following approximate order of priority:

1. Passive designs for buildings
2. Active systems with emphasis on solar hot water for domestic and commercial applications
3. Biomass applications with emphasis on wood combustion and gasification techniques
4. Industrial process heat applications
5. Small wind systems

It should be recognized, however, that these near-term priorities are weighted toward commercial readiness which is now concentrated in the buildings market. Such technologies as ocean thermal energy conversion (OTEC), large wind turbines, high temperature solar thermal, and photovoltaics may hold even greater future promise for displacing conventional energy sources if and when technical and cost goals are met by ongoing research programs.

PASSIVE DESIGNS FOR BUILDINGS AS AN EXAMPLE

To provide insight into the initial program activities being undertaken in the region, let us consider the matter of passive designs for buildings. With reference to Table III, it is estimated that a total of 3,600,000 passive applications are needed by the year 2000, with an interim goal of 100,000 by 1985. One rationale for achieving these goals is illustrated in Figure 1. A multiplier, or branching effect, is used to influence the building industry. We assume that for every direct action taken by SSEC, such as design participation and technical assistance, some number of additional projects will be undertaken by builders who become convinced of the feasibility of passive design concepts and proceed on their own. The multiplier used in this instance is five. As depicted in Figure 1, SSEC will be directly involved in the design, construction and monitoring of a small number of passive houses per year. By focusing this direct assistance toward larger builders of both conventional and manufactured residences, supported by heavy education and design tool dissemination, it is anticipated that exponential growth in both the supply and demand sector will result.

It is important to recognize that the process is tenuous and that early progress is absolutely essential if there is to be a reasonable impact by 1985 and a total of 3,600,000 passive applications (primarily residential housing units in this example) by the year 2000. Accomplishing this goal requires a wide range of efforts, including:

- The development of a range of proven and marketable passive designs to meet the various climatic needs of the region. For example, a minimum of 120 basic designs are needed to illustrate the options available for residential and light commercial construction in the widely different geographic areas which are involved.

- Interaction with a large number of design professionals, individuals, and governmental organizations in an effective manner, such as:

1. General contractors and developers (for example, approximately 660 firms account for 20% of the new construction in the region).

2. Design professionals, including the 15,400 architects and over 1000 mechanical designers. Also, over 25 architectural schools and 900 vocational-technical institutions in the region should become involved.

3. A broad range of financial, real estate, insurance and code officials. For example, there are over 2,100 key financial institutions, 615 insurance companies, 1,400 key code officials, and thousands of real estate organizations which need a better understanding of what can be achieved through passive design.

As a first step, SSEC has initiated passive buildings projects which include open inspection periods for professionals and the public in a wide number of locations. Sound progress is being made in getting the best available design tools assembled and in the hands of the user community. Figure 2 shows the initial project activities throughout the region. A number of structures are now being completed and activity is underway or imminent at all of the locations which are shown. You will easily recognize the need to properly treat the different climate and other site-specific requirements over this area.

As a somewhat separate means of evaluating the program planning strategy, one can examine the number of building starts which are projected for the region and ask what the impact might be from this perspective. For example, industry estimates indicate that between 7.0 and 7.4 million housing units are likely to be constructed in the region during the next decade. If a large number of these housing units can be built with good passive features, then the results will be very significant. With an optimistic view of reaching one-half of these units by 1990, the energy savings would be, at a minimum, the equivalent of 27 million barrels of oil annualy. Of equal, or perhaps greater, importance to the occupants would be the savings in costs for heating and cooling.

ACTIVE SYSTEMS, BIOMASS, INDUSTRIAL PROCESS HEAT, WIND AND PHOTOVOLTAICS

In the previous section, the application of Passive Design Technology was used to illustrate the basic planning approach and the rationale used to establish plans for meeting long-term goals. Similar steps have been taken for the remaining technology areas where action is now feasible. The following discussion is intended to provide a brief overview of the initial program activities with comments on some of the practical realities and challenges which are evident.

Active Systems for Buildings

As is generally recognized today, the application of solar techniques for water heating in domestic and commercial applications is technically and economically feasible. Figure 3 presents the estimated economics of using solar domestic hot water systems in the southern region. It should be noted that the key factors which influence the economics are the federal and state tax credits and the utility rates. In fact, it is the relatively high utility rates of 9.3 and 12.1 cents per KWh in Puerto Rico and the Virgin Islands, respectively, which create the favorable economics for solar in these locations.

As an initial step, the SSEC program efforts were concentrated in Florida and North Carolina because of the favorable economics, the market size and the existence of well-developed industry infrastructures in these states at the time. With the recent passage of the tax credit in Oklahoma, this state has become one of those with the most favorable economics. SSEC program efforts have been primarily associated with marketing assistance and promotional activities to aid industry, make the public aware of the potential, and help encourage reasonable consumer assurance and protection steps by industry and by the normal agencies which deal with consumers. As an example, a series of awareness campaigns has been undertaken in Florida. They were conducted with the cooperation of the state agencies and the Florida Solar Energy Center.

Figure 4 summarizes the key program activities which have been undertaken to date. With regard to the media-type promotional campaigns, it should be noted that upwards of 9.0 million mailers were distributed in cooperation with other organizations such as utilities, and over 10,000 radio and TV public service announcements were included. With the evolution of the industry base, it is recognized that a continuing sound working relationship with industry is needed. The SSEC role is that of a catalyst, leaving the marketplace to work with maximum freedom.

With regard to domestic solar hot water systems, it is important to note that there is need for industry to continue its efforts to achieve high performance systems and to lower costs wherever feasible. With the advent of dedicated heat pumps to produce domestic hot water, this is especially important. From the preliminary data available, dedicated heat pumps appear to offer a coefficient of performance (or COP, defined as the ratio of the energy delivered to the energy supplied by electrical input) of 2.0 or greater at moderate cost. Thus, if solar systems are higher in cost, they must offer a higher COP to be competitive.

Of course, service lifetime and projected energy cost increase also enter into the picture. Nevertheless, high performance solar designs, possibly with reduced costs, appear to be needed for the future.

Biomass

Biomass, including combustion, gasification, and other processes such as microbial or enzyme techniques to produce fuels, is one of the most important energy sources available in the region. Today, wood combustion and gasification techniques are economically competitive in a wide range of industrial, commercial, and even utility applications. Other agricultural products, including sugarcane, napier and sordan grasses in the case of Puerto Rico, are equally important sources of energy.

The initial activities within the region include the following:

- A cooperative effort with a state forestry commission and TVA to evaluate pilot wood yard supply methods.

- A general supply system assessment in Virginia as a pilot state.

- A pilot effort with an "assistance team" working with potential industrial users in North Carolina.

- An in-depth case study for a typical brick manufacturing operation in South Carolina.

- Technical assistance in the development of a moderate-sized down-draft gasifier to operate a stationary diesel generating unit for a municipal utility.

- General information activities to encourage the use of wood waste as a combustion fuel.

In order to recognize the potential for wood as an energy source, one factor to consider is the amount of wood waste that is now disposed of at an economic cost within the region. Figure 5 indicates the results of one estimate (Reference 2). It is very important to recognize that this is but a small fraction of the wood materials that are potentially available for use. For example, in the case of Virginia, Figure 5 indicates that the total amount of waste that is disposed of by lumber finishing plants and other similar users is 1.4 million dry tons each year. This waste , which must be deliberately disposed of, has the energy equivalence of 3 million barrels of oil. Reasonably conservative estimates indicate that there is easily the potential in the state to use cull wood, other residues, and the stock associated with sound forest management to produce as much as 28 million tons. This is equivalent to over 60 million barrels of oil.

In the state of Georgia, an assessment made by the state Forestry Commission indicates that if only one-fourth of the logging waste, excess growth (10 million cords annually), and cull trees are used for energy, they could replace 42.5 million barrels of oil annually.

So there is little question regarding the potential; however, the matter is still not simple. Land and forest ownership is diverse, the required harvesting methods are well understood but not widely practiced, the user is not necessarily convinced that the supply system is viable, and the wood combustion and gasification equipment is not a familiar item to many users. Even with favorable economics, considerable effort will apparently be needed to encourage industries and utilities to convert to wood as a fuel source. The benefits are very real. As a matter of interest, the comparative equivalent fuel costs in the Richmond, Virginia area in June 1980 were as follows, with the cost referenced to an equivalent barrel of oil:

Oil	$35.00/BBL
Natural Gas ($3.42 Mcf)	17.90
Coal ($45.00 delivered)	9.90
Pulpwood ($35.00 cord)	7.13
Dry Waste ($20.00 ton)	7.33
Moist Sawdust ($10.00 ton)	5.50

In addition to wood, agricultural products and wastes have significant potential. Combustion is often the best process at hand. However, relatively simple updraft gasifiers can be used to supply low Btu gas for many existing users with relatively simple modifications. Downdraft gasifiers offer good potential for the operation of fixed diesel plants, but careful attention is needed to gas clean-up techniques and other aspects of each specific application.

Industrial Process Heat

As an initial effort within the region, a limited number of specific applications case studies have been initiated in industries which utilize relatively large amounts of moderate-temperature process heat. Wherever possible, applications which are representative of a continuous process are looked at first since costly storage subsystems can be avoided. Efforts are presently restricted to the food processing and textile industries. A total of 17 case studies are in process, with the current work focused in Texas, North Carolina and Georgia.

Although results are not yet available, preliminary indications are that the payback periods are somewhat greater than industry users normally accept. There is a clear need for further development efforts with a view toward simpler, lower cost, or higher performance systems. In certain cases it is expected that some industries will be interested in smaller sized applications. In part, this is with a view to the future, but there are some instances where the user has had his energy supply disrupted, and the solar IPH option can be seen as a justifiable backup or supplement in the case of emergencies.

Wind and Photovoltaics

In the case of wind systems, primary attention is upon small to moderate sized systems. With the recognition of ongoing experimental work through the DOE Rocky Flats facility, emphasis is presently on special situations. The Virgin Islands is one example. Here, the current objective is to examine the wind resource at sites which are both accessible and reasonable for interconnection with the existing power system or a user. The approach being taken is to apply the best available modeling methods for a preliminary analysis of the major islands, and to work closely with the Virgin Islands Water and Power Authority and the local government. The current effort is receiving emphasis because of the relatively critical situation in the Virgin Islands. With imported oil as the sole fuel source, electricity is now at a premium, and is being required for water desalination as well as other uses.

Applications work concerned with photovoltaics has not yet started because of the research nature of the DOE program at this time. Nevertheless, some start up activity is expected during the coming year. With the current progress toward meeting the ultimate cost goals of array prices at 70 cents a peak watt in 1986 and reduction to the range of 15 to 50 cents by the 1990-2000 time frame, some preliminary steps will take place during the next year. These are not well defined at this time. However, applications with utilities and in situations such as Puerto Rico and the Virgin Islands should receive attention at an early date. Other efforts will undoubtedly involve the residential area, including examination of the option for powering modest sized cooling systems in structures where advanced passive and conservation techniques can be applied.

THE SPECIAL CASE OF PUERTO RICO AND THE VIRGIN ISLANDS

In the preceding sections the planning approach and initial activities being undertaken by SSEC have been described. Some initial analysis has been done in Puerto Rico and the Virgin Islands; however, because of their particular characteristics, additional major efforts are needed in these offshore areas. This is essential since both Puerto Rico and the Virgin Islands are almost entirely dependent upon imported oil for all their energy needs. The economic impact is far and above that present in the continental United States. In fact, the economic survival of these areas depends upon rapid and positive action to alleviate the current situation. Thus, it is important to give this matter proper attention.

The Islands in Profile

Puerto Rico and the U.S. Virgin Islands are part of the Lesser Antilles, the crescent shaped chain of islands stretching from the Dominican Republic to Trinidad as shown in Figure 6. The Carib Indians occupied the Lesser Antilles in the period 1000 - 1500 A.D.; however, with the spread of European influence the islands were conquered and then went through a succession of rules by the French, English, Dutch, Spanish and Danes. These historical events have created a diversity of cultures, traditions, languages, and loyalties which have for many years impeded effective direct communication and cooperation; a situation which continues, to some extent, even after many of the islands have achieved self-government.

Although Puerto Rico and the Virgin Islands are neighbors and both territories of the United States, they are quite different in size, culture, demographics, and economy. Puerto Rico has approximately 3.3 million inhabitants while the Virgin Islands has just over 100,000. Puerto Rico experienced rapid industrialization, which begun during the 1960s; the Virgin Islands are largely dependent on tourism and a few industries. Both territories have low median family incomes, relatively high unemployment and are dependent on outside sources of capital investment. The cost of living is generally 25% higher and wages 20% lower than on the mainland.

A Critical Reliance on Oil

One characteristic unfortunately shared by Puerto Rico and the Virgin Islands, as well as most of the Caribbean, is an almost exclusive dependence upon imported oil, the cost of which has increased 30-fold since 1973. With imported petroleum fuel cost equalling 20-25% of GNP for Puerto Rico and the Virgin Islands, there is genuine concern over potential monetary problems which may affect the basic economic system of the offshore areas.

In both territories a large share of imported petroleum is consumed by the utility companies. For example, Table IV compares electric utility data from Puerto Rico and the Virgin Islands to the two southern states having the heaviest dependence on oil for power generation - Florida and Louisiana. Although Puerto Rico's total power production is far less than these states, its oil use is relatively large. In fact, Puerto Rico's oil consumption is a very significant portion of the total imported oil used in the southern region. According to a recent survey of electric utilities using more than five million barrels of oil annually, the Puerto Rico Electric Power Authority (PREPA) ranks among the top ten utilities in the United States (Reference 3). To the Commonwealth of Puerto Rico, this represents a current annual outflow of approximately $1.7 billion per year, with projections that the outflow could exceed $3.0 billion per year by 1985.

While the Virgin Islands oil use is small in contrast to Puerto Rico, its energy problem is by no means less significant. Not only are electrical rates the highest in the southern region (12.1¢/kWh for residential), but service reliability and generation efficiency are poor. During September and October 1980, St. Thomas and St. Croix averaged 14 power outages per month, lasting 15 minutes to 24 hours.

This obviously affects the tourism business and makes it difficult to attract industry to diversify the economy. Power outages also cause water shortages, since many residents rely on electric pumping from rainwater cisterns. In addition, the public water system serving the remaining residents is provided by desalination units operating constantly near capacity. Alternative energy sources are needed for both electricity generation and desalination.

Energy Resources

Even though the area is now primarily dependent upon imported oil, there are substantial renewable energy resources available in both Puerto Rico and the Virgin Islands, including energy from the ocean, the wind, and biomass. Following is a brief summary.

Ocean Energy

Tidal movements in the Caribbean Sea are small, partly because of the enclosed nature of the region. The tides range up to two feet but average only one foot. Surface ocean currents pass strongly through the Caribbean Sea from the Atlantic and continue with increasing speed through the Yucatan channel. The main current flows at an average velocity of about one mile per hour. Also, temperature gradients between the ocean surface and 1000 meters depth are more than 40°F (22°C). Great sources of untapped energy exist in these currents and temperature gradients. The maximum depth of the Caribbean Sea, south of Puerto Rico, is 6150 meters, about 160 km offshore in the Muertos Trough. However, as close as 2 km southeast of Puerto Rico, depths of 1000 meters exist. Consequently, Puerto Rico is one of the best possible sites for the development and application of Ocean Thermal Energy Conversion (OTEC) technology. The Virgin Islands also offer potential sites for OTEC applications. Punta Tuna, in the southeastern coast of Puerto Rico, is a prime site for an OTEC plant; its desirability has resulted in it having being chosen for a CEER floating OTEC laboratory for Biofouling, Corrosion and Heat transfer studies. The floating laboratory and proposed OTEC site lies 4 km. southeast of Punta Tuna. In this area, the insular shelf extends about 2.5 km offshore and the bottom slopes off steeply into the Virgin Islands Basin. The 1000-m contour lies about 3 km offshore. This fact, along with the closeness to a large electric grid and the nearby convenience of the deep port of Yabucoa, testify to Punta Tuna's advantages.

Wind Energy

The northeast trade winds prevail over the Caribbean Sea. The winds blow consistently from the east or northeast more than 60% of the time at mean velocities of about ten miles per hour. Because of this favorable condition, a 200 kilowatt wind power generator has been installed by the U. S. Department of Energy and the Puerto Rico Electric Power Authority on Culebra Island and this energy source is being evaluated.

Solar Radiation

The solar radiation in the Caribbean region is on the order of 2000 KWh/meter^2/year. Average air temperature varies from about 78° in February to 83°F in September. Sunlight and mild temperatures are two valuable assets of the tourist industry and the first is also a great diffuse energy resource. As an example, Barbados received solar energy 426 times greater than the amount of commercial energy consumed in 1977 (Reference 4).

Puerto Rico and the U. S. Virgin Islands have ideal conditions for solar research and development and for the commercialization of solar and renewable energy technologies. Six (6) climatic zones exist, ranging from near desert to tropical rain forest, all with basically high insolation. Insolation data on the Islands compare favorably with that of the southwestern United States.

Because of the high cost of electricity in the U. S. Caribbean, many of the solar technologies will become competitive sooner than on the mainland.

Biomass

Some potential exists for biomass fuel consisting of dried or partially dried forages, grasses, cane and other agricultural products which can be used for combustion and perhaps for gasification. Bagasse has traditionally been used as a supplemental fuel in sugar refineries in the Caribbean. However, given the shortages of useable land, biomass appears to have only limited potential in the Virgin Islands. Significant attention is being given to Puerto Rico's biomass potential, and it is estimated that sugar cane, sordan and napier grasses can yield energy at less than one-half the cost of imported oil at today's prices. However, only a portion of the island's needs could be met under current land use planning.

ENERGY OPTIONS FOR THE FUTURE

With the high cost of conventional energy in the Caribbean, several renewable technologies have potential viability for Puerto Rico and the Virgin Islands. In this section, we will attempt to review some of the key options and will focus on Puerto Rico since CEER has recently completed a thorough assessment of choices for the Commonwealth. While no such thorough assessment has yet been made for the Virgin Islands, observations regarding potentials for the Virgin Islands are included.

Puerto Rico

In order to identify and implement research programs and other initiatives to develop energy alternatives which could take full advantage of the unique resources and conditions in Puerto Rico, the Center for Energy and Environment Research of the University of Puerto Rico was established in 1976. This Institution, from which both the United States and Puerto Rico are benefiting, was organized under a contract between the University of Puerto Rico and the U.S. Energy Research and Development Administration which is now the Department of Energy (DOE). The University, with an enrollment of more than 52,000 and a faculty of 5,000, has ten campuses in different locations in the Island. It is one of the largest and most diversified institutions of higher learning in the hemisphere and is a member of the National Association of State Universities and Land Grant Colleges of the United States (NASULGC); the Oak Ridge Associated Universities (ORAU); the Association of Caribbean Universities and Research Institutes (UNICA); and the Unión de Universidades de América Latina.

In May of this year, CEER completed a comprehensive study entitled Energy Analysis and Socio-Economic Considerations for Puerto Rico (Reference 5). The study indicates that electricity produced by nuclear plants is less expensive by a significant factor (on the order of one and one-half to two) than the electricity produced by commercially available coal plants. The study shows that the cost relationship will be maintained for the rest of the century and beyond. Conservatively <u>high</u> estimates of nuclear plant capital investment and fuel costs were taken from available commercial data.

Coal plants are recognized as a viable alternative in the study, and, in fact, the cost of electricity produced by coal burning plants is used as the cost criteria which must be achieved by other energy alternatives for them to be considered as attractive for development and commercialization. The impact of coal importation on the Island's economy versus the impact of other energy alternatives such as OTEC, biomass and direct solar energy provide some socio-economic credit in favor of these renewable energy alternatives.

Biomass

Excluding nuclear plants, the lowest predicted cost of electricity results from power plants burning biomass. With assumed escalation rates of 8% per year until 1985, the average production cost for the first year of electricity from a biomass fueled plant is predicted to be 4.58 cents per kWh. With an assumed escalation of 5% per year beyond 1985, the levelized cost of electricity during the lifetime of the plant (assumed to be 35 years) is 7.13 cents per kWh. By contrast, the corresponding costs for a coal plant equipped with Flue Gas Desulfurization System is 6.35 cents per kWh for the first year of operation (1985), and 9.59 cents per kWh levelized cost for the lifetime of the plant (1985-2020). The corresponding cost of electricity from residual fuel oil burning plants shows costs on the order of 160% and 320% of those for the coal burning plant. (Oil fuel costs of $57 per barrel are assumed for 1985 and there is a 9% per year escalation thereafter.)

At the request of the Government of Puerto Rico, a major one-year study was conducted by the National Academy of Sciences (Reference 13) to determine Puerto Rico's options for alternative energy sources. The Biomass Program presently being conducted by the CEER Biomass Division is in conformity with the National Academy of Sciences' recommendations for biomass research in Puerto Rico. Among their recommendations, we quote the following:

"Of all the alternatives discussed, biomass cropping based on the present sugarcane industry, has probably the largest potential. It could produce a significant fraction of the Island's electricity, with bagasse as fuel, by the year 2000 ..."

"All in all, energy cropping may in the intermediate term be for Puerto Rico the most important renewable energy source. Given vigorous development, it might provide 10 percent or more of the Island's electricity by the year 2000. Ethanol produced as a coproduct could eliminate the Puerto Rican rum industry's dependence on imported molasses and also supplement gasoline supplies".

OTEC

An Ocean Thermal Energy Conversion (OTEC) plant of 250 MW capacity is shown to be economically competitive with coal by the middle of the next decade. An initial OTEC pilot demonstration project of 40 MW capacity, scheduled to begin operation in 1985, is shown to be non-competitive with coal, but it will have electricity costs much lower than the costs of electricity produced by oil fired steam plants.

Photovoltaics

A 250 MW photovoltaic central power installation with electric battery storage project for operation in 1993 is shown to be highly competitive with coal burning plants. Photovoltaics is emerging as a very attractive possibility for the Puerto Rican scenario and offers a very good energy source along with the OTEC approach. Before this study was undertaken, the competitiveness of photovoltaics was thought to be 20 or more years away; however, rapid progress under the DOE research program is most encouraging.

It now seems that photovoltaics may reach economic competitiveness within ten years. If this does occur, the results will be very significant. For example, all of the electrical energy generated last year in Puerto Rico could have been generated with solar photovoltaic facilities equipped with electrical storage and a total cell surface collection area of less than 1% of the area of the Island at costs predicted to be similar to coal and initially lower than the costs predicted for OTEC power plants. The technical problems associated with photovoltaics appear rather simple when compared with the technical problems associated with OTEC marine plant facilities. Also, a photovoltaic manufacturing industry would be more feasible for Puerto Rico than would an OTEC manufacturing enterprise. On the other hand, OTEC has no impact on the use of land resources which is a great advantage for Puerto Rico. The economic attractiveness of these two alternatives, plus the particular advantages of each, point towards a decision to explore both technologies.

Wind

Evaluation of wind data compiled at several coastal points shows that Puerto Rico's location in the path of the trade winds gives it a high potential for using wind energy. The trade winds are notable for the steadiness of their speed and direction. Measurements on the off-shore island of Culebra, for example, show that the wind velocity exceeds eight miles an hour 85 per cent of the time. Testing and evaluation of the 200 Kw NASA wind generator on Culebra will provide additional knowledge and experience for the further development of wind energy in Puerto Rico at other sites. The results of this experience can be shared with other nations in the Caribbean with similar favorable conditions.

A study has been made by CEER of the possibility of integrating large windpower generators to the existing PREPA thermoelectric network in Puerto Rico. Climatologically, one would expect the highest potential for wind power utilization on the north and east coasts because the sea breeze acts to intensify the prevailing winds in those regions. Estimates of wind power density for other regions, especially the mountainous interior, indicate that no appreciable advantage is found in the mountains over the eastern coastal plains.

A station on the east coast, Roosevelt Roads, was chosen for detailed analysis. Applying the design characteristics of the General Electric 1.5 and 0.5 MW generator to the wind speed distribution for this station reveals that an average power of 288 KW and 236 KW respectively, could be generated throughout the year.

With a theoretical system of 25 turbines, total power costs were estimated at 138 mill/kWh. Three major factors account for such an elevated productions cost:

1. the wind power potential is moderate
2. the capital fixed charges is very high
3. land costs are extremely high

Making a 40 year economic projection, the largest item was the escalation of the already high land cost. If land costs could somehow be minimized, the equivalent cost of each barrel of oil saved could be around 60-70 dollars for the next 25 years, a price that could become competitive in the foreseeable future. The study, therefore, shows the central wind power system to be suitable for fuel oil displacement, but not as an economically viable base (with storage) energy system.

Overall Assessment of Electric Renewables

Figure 7 illustrates the predicted production cost of electricity from the alternatives reviewed above. The levelized cost indicated is the "average" cost during the lifetime of the facility with the inflation of operating costs and fuel costs taken into consideration.

If the current dependence on conventional energy continues, oil price increases will severely worsen the economy of Puerto Rico. Cost increases to industries such as cement, electricity production, construction, mining, alcoholic beverages, transportation and business services will be very large. Analysis shows that the largest impact is in the important industries in terms of output generation and job creation. This study shows that, all prices constant, the increase in oil prices from 1973 to 1979 (assuming a conservative price of $21.00 per barrel of crude in fiscal year 1979) will induce or has already induced an increase of more than 130% in an estimated producers price index, excluding industry mark-ups. This implies double-digit inflation even when there is no increase in other prices. This increase has resulted in an estimated loss of 58,000 jobs and $1,328.2 million in productivity.

In contrast, for two 300 MW biomass plants and one 250 MW OTEC power plant the study indicates an increase in employment of 67,145 workers and an increase in productivity of $1,387 million. This assumes that the reduction in imports will improve the balance of trade, which in turn will increase domestic final demand. The unemployment rate, with other factors constant, could be reduced by about 7% from its 1979 level.

Recommended Scenario

Based on these economic analyses, alternative energy scenarios were prepared for the rest of the century, with corresponding R&D programs and funding requirements. From the present state of development of the various technologies and from the predicted potential of the various alternatives to compete economically with coal, the following program has been suggested:

1. Biomass - A strong effort to make the first (300-450 MW) power plant operational by 1986.
2. OTEC - An experimental plant (40 MW) by 1985 and first commercial plant (250 MW) operational by 1991.
3. Photovoltaic - Large demonstration project in operation by 1993, or earlier if feasible.
4. Wind Power Turbine Generators - A program coupled with the operational experience of Culebra's Wind Turbine so that a 12.5 MW wind turbine farm can be placed in operation by 1988, for fuel oil displacement.

Based on estimated needs for additional electrical generation capacity and the economic potentials of energy alternatives, a possible scenario was prepared. This scenario is indicated in Table V.

Three coal burning plants, one with a 300 MW capacity in 1985 and two with 400 MW capacity each for 1989 and 1990 are included in the scenario which is shown in Table V. It is estimated that biomass burning plants could be placed in operation as early as 1986 and 1987. No additional biomass plants are indicated because of land use uncertainties at this time. The two 400 MW biomass plants will require the planting and harvesting of approximately 75,000 acres of land, about the land acreage actually devoted to sugar cane in Puerto Rico. Coal and biomass plants should be designed to burn either fuel.

No more than 500 MW of power from photovoltaics is shown in the scenario because land use policies are uncertain. It is estimated that the two 250 MW photovoltaic installations will require approximately 10,000 acres of land. To generate with photovoltaics all the electricity produced in 1979 in Puerto Rico a total land area of approximately 100 km square or 25,000 acres would be required.

A wind power farm also has the same type of land requirements. The 12.5 MW wind power installation which is evaluated in the analysis will require approximately 3,000 acres. For these reasons the scenario depends heavily on the OTEC alternative. However, not all of the efforts are placed on this alternative because there are still many questions to be answered. The scenario does not present any fixed alternative to be followed, but rather provides a reference alternative on which to base development programs.

It is very important to recognize that the total fuel oil consumption for electrical generation between the year 1985 and the year 2000 is estimated at 881.9 million barrels and that the savings proposed by this scenario represent only 22% of the energy consumption during the period. This further indicates that the energy situation is so dependent on oil that heroic efforts are required to make a significant reduction in oil importation during the present decade.

Non-Electric Renewables

Three principal non-electrical generation energy alternatives are addressed in the Puerto Rico Office of Energy Document "Política Energética de Puerto Rico", (Reference 14):

1. Solar industrial steam and hot water
2. Fuel synthesis
3. Conservation measures, mainly in transportation

Consideration has been given to these topics in Preliminary Report on R&D Program Needs for Energy Alternatives in Puerto Rico (Reference 6).

It is estimated that ethanol and industrial solar steam can play a substantial role in reducing oil fuel imports. An electric generation project based on photovoltaics can be designed as a cogeneration project (solar steam production and electricity). It has been estimated that a

250 MW electric photovoltaic cogeneration project can produce enough industrial steam to save the equivalent of 3.7 million barrels of oil per year.

Industrial steam can be produced separately by adequately designed solar concentrators, with estimated production equivalent to the savings of six million barrels of oil per year.

Ethanol offers potential help for the transportation industry. An ethanol project at a pilot rum plant is under consideration. The project can be economically designed as a cogeneration facility to provide steam for its rum production and to generate electrical energy from bagasse. Preliminary estimates indicate that a savings of 7.5 million barrels of oil per year can be achieved. Energy conservation measures in the transportation industry also require special attention. It is difficult to assign specific figures to this program. However, it could reach savings as high as 4-10% of oil imports.

Table VI indicates the combined total savings which could be obtained through the proposed scenarios and an aggressive R&D effort. In the electrical sector the reduction in fuel oil consumption is over 26%, and for all sectors the fuel oil equivalent reduction is approximately 21%. When conservation measures in transportation are added, probably a 5-10% additional reduction can be achieved.

It is important to point out that the energy renewable resources scenario concurs in general with the Puerto Rico Energy Policy document (Reference 14), the Puerto Rico Energy Conservation Plan (Reference 15), and the U.S. National Academy Report (Reference 13). Tables VII and VIII include a comparison of the scenarios.

All of the above indicate that a renewable energy program supported by a strong R&D effort in Puerto Rico can achieve an approximately 1/3 reduction in oil dependence while still maintaining the same level of economic development.

The Virgin Islands

With 1/30th of the population and an even smaller fraction of the land mass of Puerto Rico, the Virgin Islands requires a much different approach to renewable energy. It has been estimated by the Virgin Islands Energy Office that 12 MWe of renewable energy capacity would be desirable in the near term for reduction of fuel costs and improvement of power production reliability. Unfortunately, when discussing renewables it is not that simple due to varying capacity factors, resource availability and load match requirements. A much more intensive renewable energy planning process, combined with practical field demonstration projects, appears to be needed if near- to mid-term solutions are to be found for the Virgin Islands' energy dilemma.

Such a program should, at a minimum, address the following matters:

1. Resource assessment, principally solar insolation and wind energy.
2. Utility interface, including load match, buyback, etc.
3. Unique requirements imposed by the Caribbean climate.
4. Initial engineering experiments to refine the technology.
5. Land and environmental impacts.
6. Economics assessment and financing.

Although available data is sparse, it is possible to draw some preliminary conclusions regarding the best renewable choices for the Virgin Islands. They are:

1. Wind. While some discrepancies exist in available wind data, it does appear that sites exposed to winds from the southeast and northeast possess good potential for wind energy conversion systems (WECS). SSEC's current assessment of the Virgin Islands' wind resource should enhance our understanding of this resource. The economics of WECS as demonstrated in Figure 8, would be attractive for sites having average wind speeds of 13 mph or higher. While the economics of WECS in comparison to conventionally generated electricity are better than many mainland locations, the initial capital expense may impose real barriers to widespread decentralized use. In addition, the small land

mass combined with steep topography may impose some restrictions on location and size of WECS.

2. Solar Hot Water. Solar hot water heating has economics which compare quite favorably to the mainland states of the southern region. As depicted in Figure 3, cash purchase (with 40% tax credit) of a solar water heater providing 50% of hot water needs yields a return on investment of 26.1% for Puerto Rico and 33.6% for the Virgin Islands. It should be cautioned, however, that cash purchase of a currently available factory-built system is probably beyond the means of many residents. Substantial cost reduction or expanded financing will be necessary for any meaningful penetration of the residential retrofit market. Incorporating solar hot water systems in new housing has the advantage of long term mortgage financing and thus may find a market in San Juan where annual housing starts average 1,300; however, the low level of annual housing starts (100) in the Virgin Islands does not provide comparable potential. Solar hot water systems designs in the Caribbean should be based on the high insolation value throughout the year, lower average household demand for hot water, and the absence of need for freeze protection. Reduction in collector and tank size and piping plus "sweat equity" should make the technology quite viable in the future.

3. Photovoltaics. While not yet ready for commercialization, photovoltaic cells may find a prime early market in the Virgin Islands. Advantages include the high cost of conventional energy, abundant sunshine, lower per capita power demand (which could make roof-mounting more practical) and the fact that approximately 60% of electrical power is used during daylight hours. Initial system engineering experiments are essential in order to be ready for adaption when cost goals are met.

4. Solar Steam. Again, the solar radiation in this region may provide unique opportunities for central station and intermediate load center applications for solar steam, both for process heat and power generation.
5. OTEC. Although little work has been done in the vicinity of the Virgin Islands regarding thermal gradients and OTEC, long term potential does exist. With appropriate technology support, OTEC could become a viable energy source in the 1990's.

The answers to the Virgin Islands' energy dilemma are needed now but unfortunately the renewable technologies discussed above are not yet fully available. Near-term relief will have to come through conventional system improvements, improved management practices, and conservation measures. The Virgin Islands Energy Office has recognized this reality in its Energy Conservation Plan (Reference 7) by recommending management practices and facility improvements which could account for $.683 \times 10^{12}$ Btus of annual savings (i.e., 9% of fuel consumption for electricity and desalination). In the meantime, a pragmatic renewable energy plan supported by well-conceived field tests must precede wide-spread use of solar, wind, and ocean resources.

CONCLUDING REMARKS

In the first part of this paper, insight is provided into the initial planning related to the use of renewable energy sources in the stateside portion of the southern region of the United States. Much work lies ahead to properly apply solar and other renewable energy sources; however, this effort is underway and is expected to progress through a concerted effort by both the private sector and government.

The Caribbean region poses a very real and urgent energy problem which is perhaps more crucial than most people appreciate. The problem is typified by the conditions in Puerto Rico and the Virgin Islands. Being almost totally dependent upon imported oil, and without coal or substantial forest resources, the situation is one of the most serious in the United States or its territories. The 3.5 million residents of these two island communities increasingly find their employment, their living situation, and their government dependent upon energy availability and cost. Oil, which once was viewed as the "life line", now has a "strangle hold" on their long term existence. The economic and social impact will be severe if oil imports are interrupted. Thus, it is imperative that a long term solution be found and implemented. Some of the possible options have been explained and discussed. Continued effort is essential.

Solving the energy problem is of utmost importance to these communities in order to attain self-sufficiency and socio-economic progress. The United States government also has a vital interest in the Islands' energy problem since foreign oil dependence makes them subject to political instability and intervention by anyone guaranteeing continual flow of oil. Also, there are a large number of other island governments who stand to benefit through technology transfer from progress made in Puerto Rico and the Virgin Islands. Thus, there are numerous beneficiaries of steps toward energy self-sufficiency.

While the islands are limited in supplies of fossil fuels, they are rich in indigenous renewable energy resources. The islands are ideal areas to test renewable concepts because of their limited geographic areas, ample solar, wind, ocean resources and the higher cost of conventional energy. Puerto Rico and the Virgin Islands provide a valuable testing and development site and could be made into a showcase for renewable energy options, including OTEC, Solar Thermal, Photovoltaics, Biomass and Wind.

This was recently confirmed by the U.S. National Academy of Science (Reference 6), which stated that:

> "Puerto Rico, in dealing with its own energy problems, should grasp its opportunity to become an international energy laboratory, seeking and testing solutions especially appropriate to the oil-dependent tropical and subtropical regions of the world. The Island's geographical position and its established energy research and development facilities enhance this potential, which should be called to the attention of agencies and institutions with investments to make in accelerating development overseas".

It is not enough that an energy resource is available; the technology, the capital, and the management resources must also be present. The development and transfer of renewable technologies must be a joint effort of government and the private sector in which development priorities of the island communities are respected and in which private industries enjoy proper return on their investment and inventiveness. There is a strong historical tendency to look toward the mother country for guidance and, of course, technology transfer. However, islands are not chips off a mainland block but unique entities with their own priorities. Stated in other terms: "Ocean islands are not mainlands in miniature anymore than a cat is a miniature tiger". (Reference 16). Being cognizant of the unique priorities and constraints of the island communities, government's role should be geared toward:

1. development of adequate data bases, energy plans, and policies;
2. research, development, and demonstration;
3. field tests; and
4. support of industry's technology and market development programs.

While the electric utilities and subsequently the consumers will bear the cost of any energy, the involvement of the private sector is critical to the need for initial investment capital. Government cannot alone finance the transition to renewable energy.

External technical assistance and support is essential to the islands. Such support is needed from the U.S. Department of Energy and other agencies as well as international organizations, such as World Bank, IDB, and AID. These organizations should be prepared to give high priority to supporting such efforts, using regional approaches where possible for the mobilization of human and technical resources.

At this time, analyses and planning studies have been completed for Puerto Rico and considerable work has been accomplished, which is applicable to the Virgin Islands and other portions of the Caribbean. We now need to press for increased government action and support, along with the full participation of the private sector in order to achieve results. The time is quite limited and the stakes are high. If we can provide the leadership, the impact in terms of economic progress and stability will be very important to the United States and all its neighbors. Not to provide the leadership is simply out of character with the skills, resources, and dedication of the people of this country.

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TABLES AND FIGURES

TABLE I. REGIONAL CONTRIBUTION TO NATIONAL GOAL THE YEAR 2000

CENSUS REGION		ENERGY SAVINGS (QUADS OF FOSSIL FUEL EQUIVALENT) 18.5 QUAD/YEAR SCENARIO	
SOUTH ATLANTIC	SSEC REGION	3.4	7.5 QUADS
SOUTH EAST CENTRAL		1.8	
SOUTH WEST CENTRAL		2.3	
NEW ENGLAND		.7	
MID-ATLANTIC		1.8	
NORTH EAST CENTRAL		2.4	
NORTH WEST CENTRAL		1.0	
MOUNTAIN		1.2	
PACIFIC[1]		3.9	

[1] THE LARGE SOLAR ENERGY PRODUCTION HERE IS DUE PRIMARILY TO HYDROELECTRIC PRODUCTION, MUCH OF WHICH IS IN EXISTENCE TODAY.

TABLE II. ONE ESTIMATE OF THE SOUTHERN U.S. CONTRIBUTION TO THE 20% GOAL

(ASSUMING 7.5 QUADS OF 18.5 TOTAL FROM RENEWABLES)

	USER SECTOR \ TECHNOLOGY	ACTIVE & PASSIVE	BIOMASS	WIND	PV	SOLAR THERMAL	OTEC	HYDRO ELECTRIC	TOTAL
NEW	RESIDENTIAL	.39	.18	.12	.14				.83
	COMMERCIAL	.20		.01	.02				.23
	INDUSTRIAL		1.49			1.04			2.53
	UTILITIES		.08	.48	.17	.79	.25	.44	2.21
EXISTING	RESIDENTIAL		.07						.07
	INDUSTRIAL		1.15						1.15
	UTILITIES							.48	.48
	TOTAL	.59	2.97	.61	.33	1.83	.25	.92	7.50

NOTE: 1 QUAD EQUALS 10^{15} BTU, OR 180 MILLION BBLS OIL EQUIVALENT

TABLE III. A TYPICAL ESTIMATE OF THE NUMBER OF SOLAR AND RENEWABLE ENERGY INSTALLATIONS NEEDED IN THE SOUTHERN REGION

	BY 1985	BY 2000
BUILDING SYSTEMS		
PASSIVE (WITH CONSERVATION)	100,000	3,600,000
ACTIVE, INCLUDING HOT WATER	1,500,000	12,300,000
INDUSTRIAL PROCESS HEAT	2,800	38,000
WIND ENERGY CONVERSION SYSTEMS	6,000	700,000
INDUSTRIAL BIOMASS	540	6,000

TABLE IV. ELECTRIC UTILITY DATA FOR SELECTED AREAS

	POPULATION (thousands)	INSTALLED CAPACITY (MW)	MILLION BARRELS OF CRUDE OIL	% OF TOTAL ELECTRIC PRODUCTION FROM OIL	SALES (billion kWh)	ELECTRICITY Per CAPITA in 1978 (thousand/kWh/) capital	RESIDENTIAL RATE for ELECTRICITY (¢/kWh)
FLORIDA	8,957	27,979	93.4	50%	83.6	9.3	5.5
LOUISIANA	4,028	12,865	29.6	28%	53.0	13.1	5.5
PUERTO RICO	3,213	4,199	23.9	99%	11.7	3.6	9.3
VIRGIN ISLANDS	98	239	1.5	100%	0.6	6.1	12.1

Note: Source Data from References No. 6, 7, 9, 10, 11, and 12

Table V A PROPOSED SCENARIO FOR PROVIDING ELECTRIC PLANT CAPACITY

Year	Biomass	OTEC	Photovoltaic	Wind	Coal
1980-84	......	.....	......	200KW	.....
1985	......	1-40MW	......	......	1-300MW
1986	1-300MW	.....	......	......	.....
1987	1-300MW	.....	......	......	.....
1988	......	.....	......	12.5MW	.....
1989	......	.....	......	......	1-400MW
1990	......	.....	......	......	1-400MW
1991	......	1-250MW	......	......	......
1992	......	1-250MW	......	......	......
1993	......	......	1-250MW	......	......
1994	......	10250MW	......	......	......
1995	......	......	1-250MW	......	......
1996	......	......	......	......	......
1997	......	......	......	......	......
1998	......	1-500MW	......	......	......
1999	......	1-500MW	......	......	......
2000	......	......	......	......	......

Table VI POSSIBLE OIL EQUIVALENT SAVED WITH PROPOSED SCENARIO

(CUMULATIVE MILLIONS OF BBLS. - 1985 THRU 2000)

	ELECTRICAL GENERATION				NON-ELECTRICAL			
YEAR	BIOMASS	OTEC	PHOTOVOLTAIC ELECTRIC	WIND	GASOHOL FUEL	GASOHOL COGEN (ELECTRIC)	SOLAR INDUSTRIAL	
1985	---	.438	---	---	---	---	---	
1986	3.285	.438	---	---	1.87	1.24	---	
1987	6.57	.438	---	---	1.87	1.24	---	
1988	6.57	.438	---	.09	3.74	1.25	2.0	
1989	6.57	.438	---	.09	3.74	1.25	2.0	
1990	6.57	.438	---	.09	5.61	3.7	4.0	
1991	6.57	2.74	---	.09	5.61	3.7	4.0	
1992	6.57	5.48	---	.09	5.61	3.7	4.0	
1993	6.57	5.48	2.74	.09	5.61	3.7	4.0	
1994	6.57	8.22	2.74	.09	7.48	5.0	4.0	
1995	6.57	8.22	5.48	.09	7.48	5.0	6.0	
1996	6.57	8.22	5.48	.09	7.48	5.0	6.0	
1997	6.57	8.22	5.48	.09	7.48	5.0	6.0	
1998	6.57	13.70	5.48	.09	7.48	5.0	6.0	
1999	6.57	19.20	5.48	.09	7.48	5.0	6.0	
2000	6.57	19.20	5.48	.09	7.48	5.0	6.0	
Totals:	95.275	101.308	38.36	1.17	86.02	54.78	60.0	436.9

TABLE VII

Contribution to Electrical Needs in Percent (%) of Total Electrical Use. Estimates of Puerto Rico Office of Energy (PROE), National Academy of Science, (NAS) and CEER Studies

	1990			2000		
	PROE Term	NAS[1] % Annual	CEER Production	PROE Term	NAS[1] % Annual	CEER Production
Biomass	----	10.4/3.2	13.8	----	30/9.9	8.5
Wind	Short	.8/.2	.19	----	1.8/.5	.12
Photovoltaics	Medium	----	----	Medium	.1/0	7
OTEC	Medium	0	.3	Medium	1.3/.6	24.7
Hydro	----	1/.6	----	----	1/.6	----
Solar Water Heater Residential	Short	1/.6	----	Short	2/1.1	----
Industrial Water Heater	Short	2/1.1	8.4	Short	3.8/2.3	7.7

1. Optimistic/Conservative Projections Based on High Energy Demand Growth Assumption.

TABLE VIII

Contribution to Non-Electrical Needs in Percent (%) of Total Electrical Use. Estimates of Puerto Rico Office of Energy (PROE), National Academy of Science (NAS) and CEER Studies.

	1990			2000		
	PROE Term	NAS[1] % Annual Production	CEER % Annual Production	PROE Term	NAS[1] % Annual Production	CEER % Annual Production
Industrial Heat	Short	2/1.1	17.9[2]	Short	3.8/2.3	15.7[2]
Ethanol	Short	10.2/3.1	23.7	Short	40.7/13.4	26.5

1. Optimistic/Conservative Projections Based on High Energy Demand Growth Assumption.
2. Includes a Cogeneration Component.

FIGURE 1 PASSIVE PROGRAM CONSTRUCTION IMPACT: CUMULATIVE DIRECT AND MULTIPLIER EFFECTS FOR SOUTHERN REGION (Single Family Housing Only)

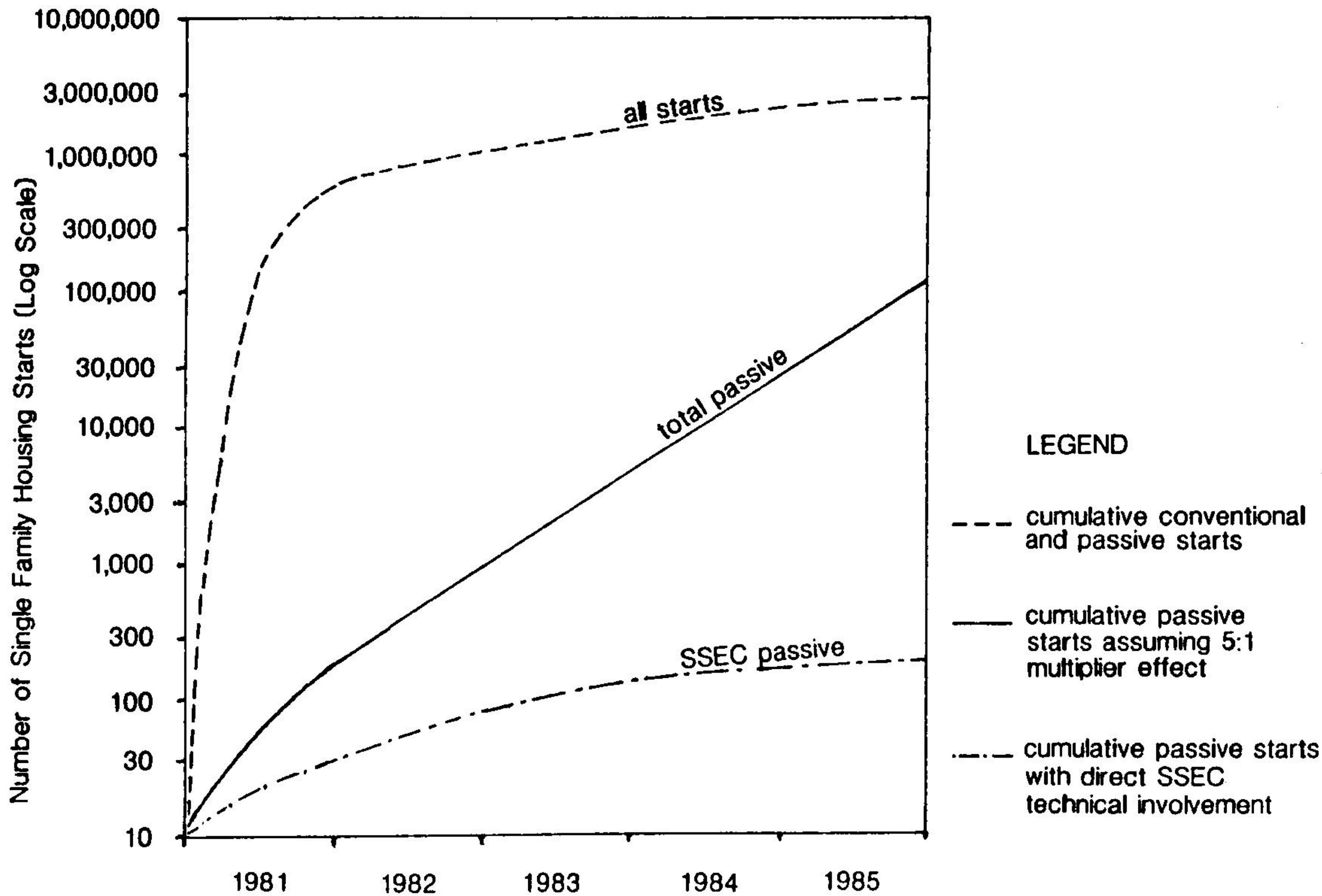


Figure 2 CURRENT PASSIVE BUILDINGS ACTIVITY WITHIN THE SSEC REGION

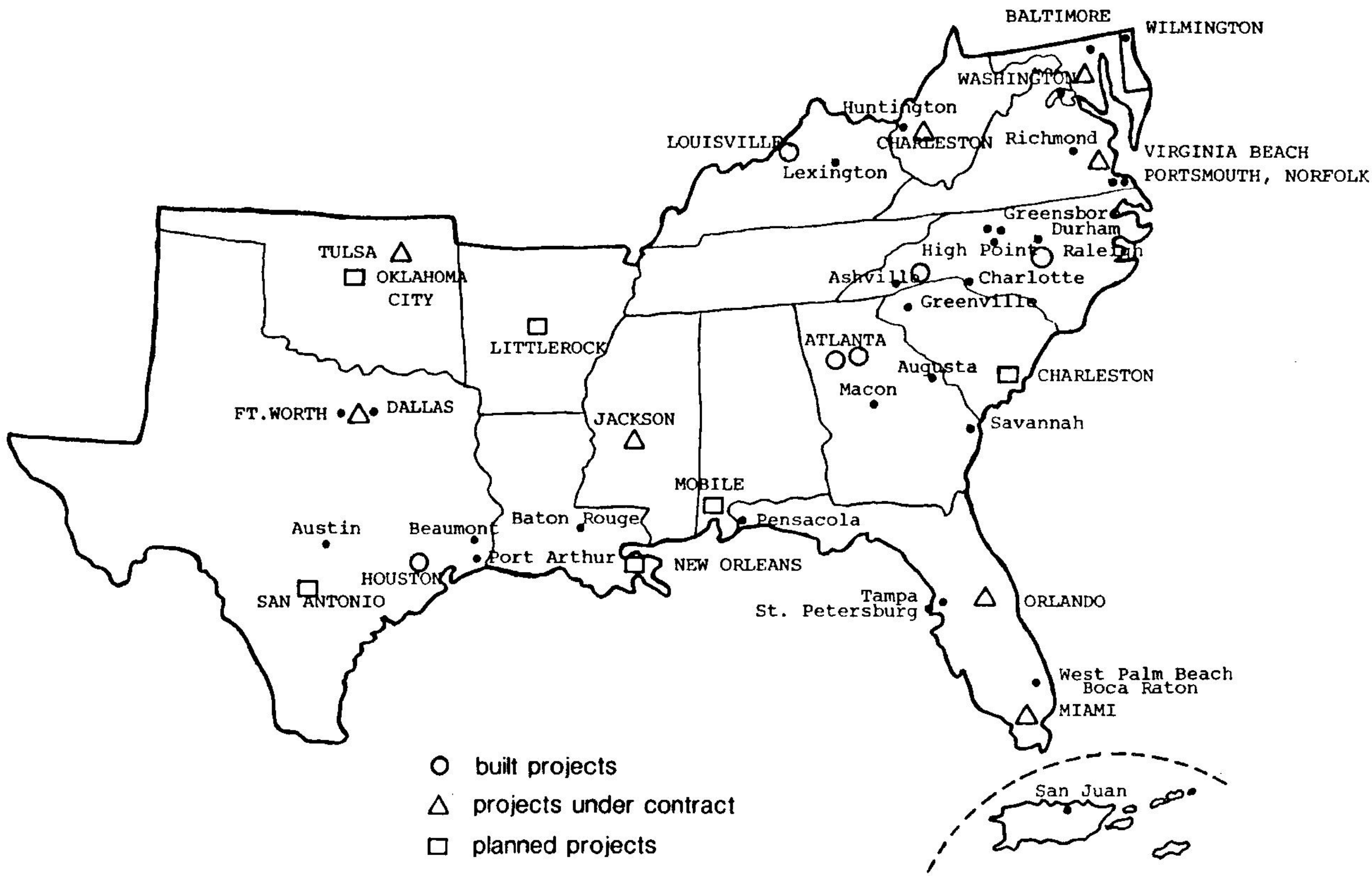
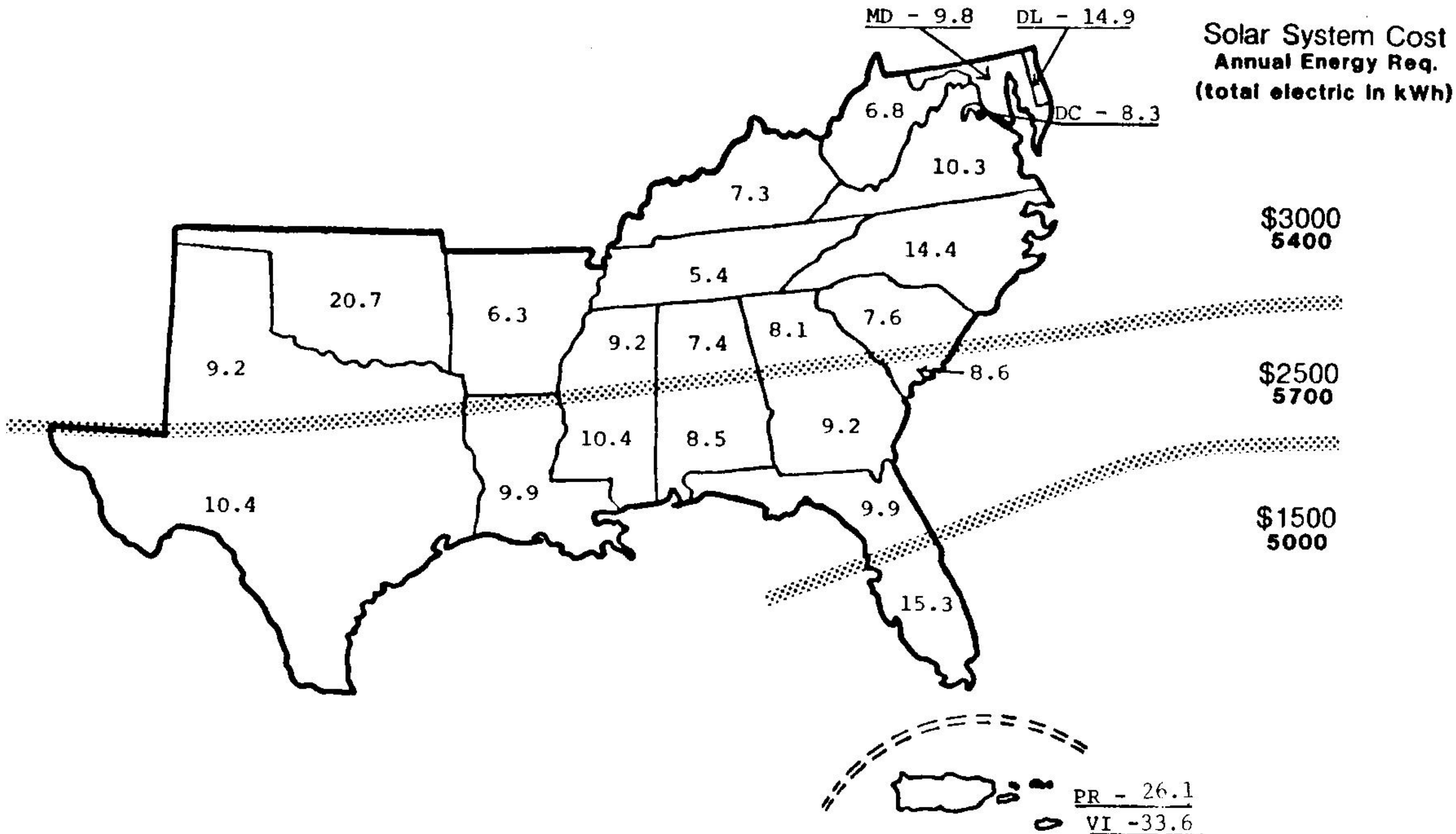


Figure 3 SOLAR HOT WATER RETURN ON INVESTMENT (%)



ASSUMPTIONS: Return on Investment = $\frac{\text{First Year Electricity Savings}}{\text{Solar System Cost, Less Tax Credits}}$

Solar System provides 50 percent of hot water requirements

FIGURE 4. TYPICAL PROGRAM ACTIVITIES RELATED TO ACTIVE SYSTEMS

RESIDENTIAL

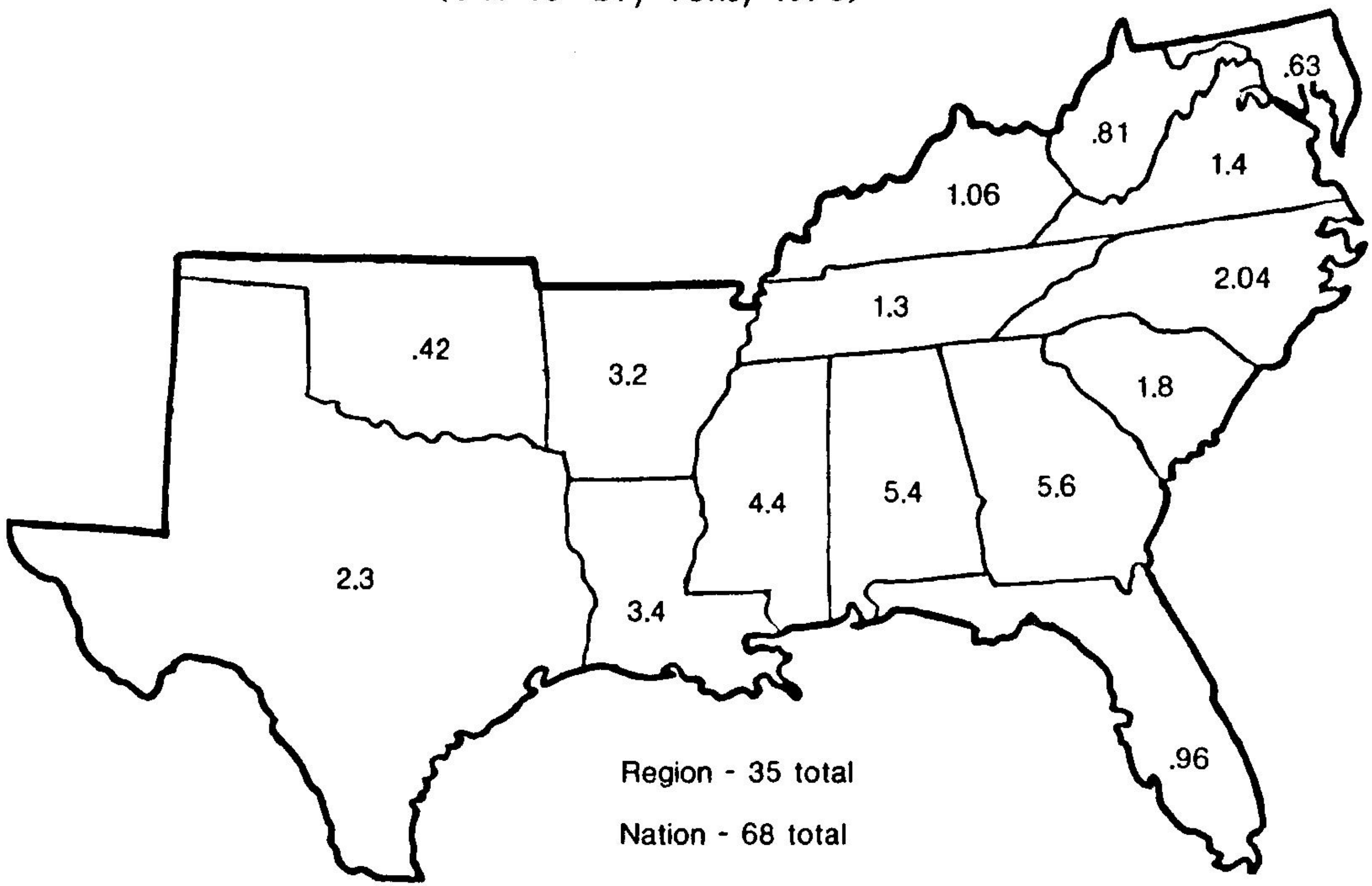
- MASS MEDIA CAMPAIGNS TO CREATE PUBLIC AWARENESS, EDUCATIONAL AND PROMOTIONAL MATERIALS TO INDUSTRY, PARALLEL ACTIVITIES WITH CONSUMER ASSURANCE AGENCIES
    - THREE MAJOR EFFORTS IN FLORIDA, ONE IN NORTH CAROLINA
    - OVER 9 MILLION INFORMATION FLYERS, EXTENSIVE TV AND RADIO TIME (ESTIMATED 90 HOURS)
- INFORMATION ACTIVITIES WITH SOLAR INDUSTRY IN PREPARATION FOR THE UPCOMING RESIDENTIAL CONSERVATION SERVICE (RCS) TO BE CONDUCTED THROUGH THE MAJOR UTILITIES
- DIRECT CONTACTS WITH MAJOR TRACT BUILDERS TO ASSURE CONSIDERATION OF SOLAR, WITH DECISIONS IDENTIFIED RESULTING IN THE USE OF OVER 7,500 SYSTEMS
- EDUCATION ACTIVITIES FOR LOCAL BUILDER ASSOCIATIONS IN 2 PILOT STATES
- TRAINING ACTIVITIES FOR 38 KEY CODE OFFICIALS IN ONE PILOT STATE

COMMERCIAL

- CONTINUOUS ACTIVITIES TO PROVIDE TECHNICAL INFORMATION TO INDUSTRY MEMBERS INTERESTED IN THE FEDERAL BUILDINGS PROGRAM
- DIRECT CONTACTS WITH MAJOR ELEMENTS OF THE HOTEL AND MOTEL INDUSTRY WITHIN THE REGION TO ASSURE CONSIDERATION OF THE SOLAR OPTION. BACKGROUND ECONOMIC ANALYSIS PROVIDED IN SOME INSTANCES.

Figure 5 DISPOSAL CLASS WOOD WASTE IN THE SOUTH

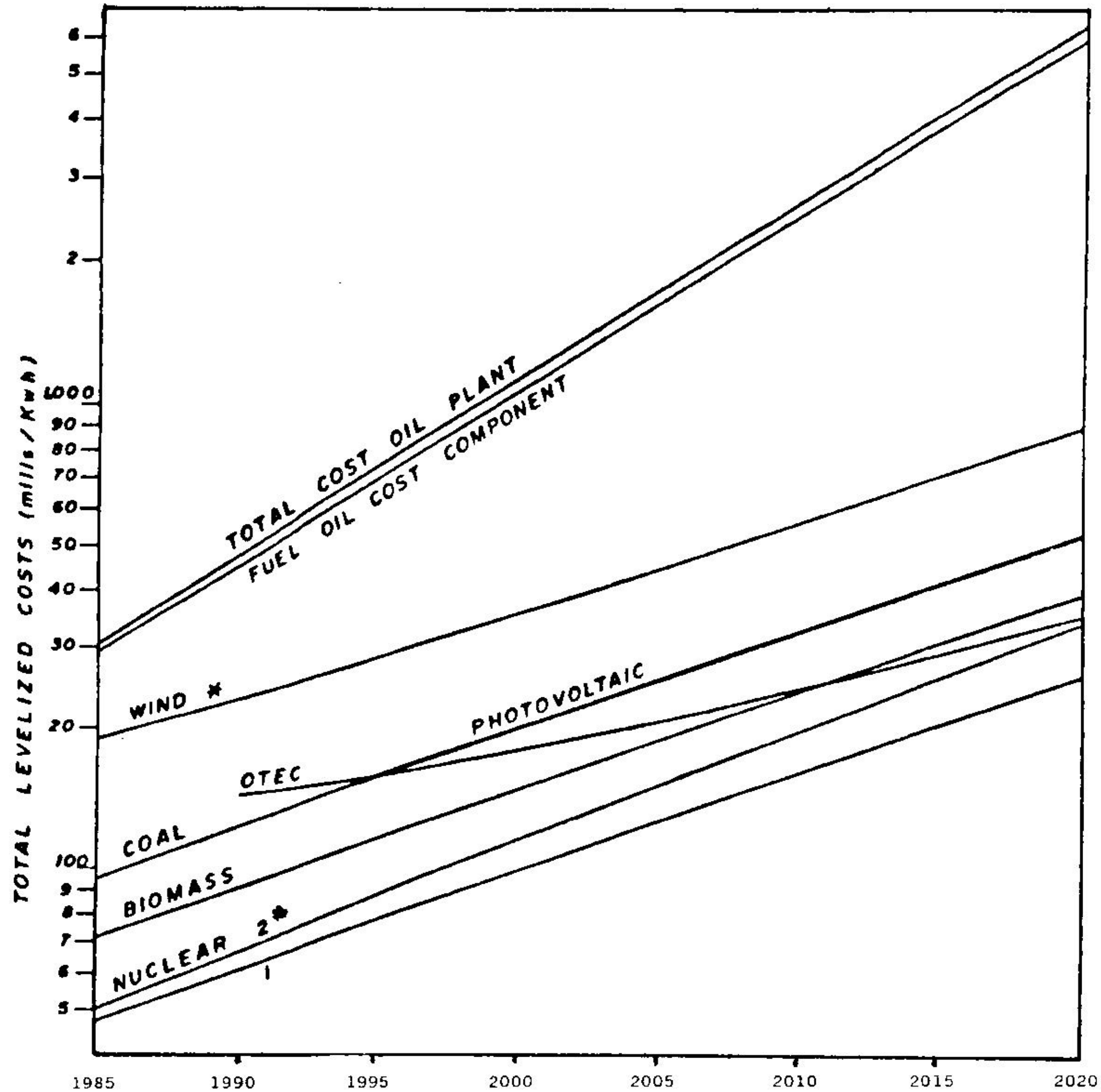
(1×10^6 Dry Tons, 1976)



"Disposal waste" - That portion of the available residue that must be disposed of at an economic cost

Figure 6 LESSER ANTILLES OR CARIBBEAN ISLANDS

Figure 7 TOTAL LEVELIZED GENERATION COSTS OF ALTERNATIVES FOR ELECTRICAL ENERGY PRODUCTION IN P.R.



*NOTES: 1. Wind energy alternative assumes no storage for this comparison.

2. All costs escalated 5 1/4% per year, except oil is at 9% and yellow cake in nuclear 2 is at 7 1/4%.

Figure 8 WIND ENERGY ECONOMICS: VIRGIN ISLANDS

(BREAKEVEN ANALYSIS AND RETURN ON INVESTMENT)