Texas Energy Development Fund

The Plan
VOLUME 1
PERSPECTIVES

TEXAS
ENERGY
ADVISORY
COUNCIL

December 1977

TEXAS ENERGY DEVELOPMENT FUND

Volume I

Perspectives for RD&D

Adopted by

Texas Energy Advisory Council

December 2, 1977

Report No. T-77-008

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

PREFACE

The Texas Energy Development Act of 1977 creates the Energy Development Fund "to support research in and development of solar, geothermal, lignite, biomass, wind, conservation and other alternate abundant energy resource technologies." The Act requires that a plan be promulgated for purposes of administering the fund.

The Plan developed for purposes of the Act consists of two volumes. The first volume provides an overview of the outlook to the year 2000 from conventional sources of energy in Texas, primarily oil and gas, and further, describes the prospects from developing energy technologies. Legal, technological, economic and institutional problems impeding the development of each of the developing technologies are identified, and the rationale for project solicitation implied from this overview is described.

Volume II describes the procedures for administering the Fund: submission and solicitation of proposals, evaluation and selection of proposals by an impartial group of technical experts, the disbursement of contracted funds, project cost accounting, project reporting requirements, and dissemination of results.

ACKNOWLEDGEMENTS AND CONTRIBUTORS

Many individuals have contributed to the development and writing of the two volumes that form the Energy Development Fund Plan. The opinions of members of the Texas Energy Advisory Council expressed individually in private meetings, and cooperatively in Council meetings, formed the general philosophy upon which the specifics of the Plan rest.

Several task forces met on separate occasions to advise the staff on functional project descriptions which would meet the general criteria for funding. These individuals are listed in Appendix C to Volume II.

Many individuals made written comments on the early draft of Volume II and still others presented public testimony at the public hearing on October 28, 1977. These comments formed much of the basis for the final draft presented to the Council on December 2, 1977. The names of these individuals are listed in Appendix E to Volume II.

Three members of the Advisory Committee to the Council, Frank Cooksey, Dr. Herbert McKee, and Laura Keever, presided at the public hearing, and as a group helped assemble the opinions from the meeting for use by the staff. Those Committee Members also contributed individual comments on the Plan.

Individual staff members of TEAC contributed to the research, development and writing of the two volume Plan. Robert J. King, David White, and Bill Cepeda developed the materials, held task force meetings and wrote report sections on, respectively: (1) solar, wind and biomass; (2) lignite and geothermal; and (3) conservation. Dr. Milton Holloway provided materials for the outlook from conventional sources. Dr. Roy Ray provided overall supervision and guidance for development and writing of the Plan, as well as the scheduling and completion of the public hearing. Charles Mueller and Susan Conway provided survey information from development funds administered by other states and rules for guiding the contractual and patent obligations and rights for Volume II. Marla Stevens provided editing and organizational comments, and Ginny Cumming and Brenda Sanders provided data and technical support for quantitative portions of Volume I. Vickie Everhart and Melody Timmons provided typing for this and earlier drafts of the report.

INTRODUCTION

Texas and the rest of the nation are at a turning point in the history of energy resource production and utilization. Crude oil and natural gas have been both plentiful and increasingly inexpensive for half a century prior to 1970. The prospects for crude oil and natural gas prices declining for any sustained period in the future seem remote, and supply disruptions will be possible at any price level. Americans will have to adjust to higher oil and gas prices and depend on other fuels for many uses.

Throughout most of the twentieth century, Texas and the United States have been net exporters of energy, reflecting not only the quantity of resources, but also their quality. In the past the American energy industry was able to produce oil, natural gas and coal at a relatively low cost compared to that in other parts of the world and therefore played a dominant role in world fuel prices and trade. The Texas oil and gas fields have been the major contributors in the United States energy supply picture, providing roughly 40% of the nation's oil and gas production. The prospects for the future, however, are for an increasing dependency on imported crude oil. The United States is now importing nearly 50% of its crude oil consumption and this percentage probably will continue to increase. Unless major changes are made, Texas will become a net importer of energy before the year 2000.

Texas consumers have found that even though Texas produces a major portion of the nation's oil and gas, they have not been exempt from higher prices, especially in the case of natural gas. The rapid development in the 1950s and 1960s of nationwide markets for clean-burning natural gas, combined with the reduction of gas exploration and development beginning in the mid-1950s, has resulted in the current sharply rising prices of natural gas in the intrastate market. Since prices are controlled at artificially low levels by the Federal Power Commission (FPC) in the interstate market, Texas consumers are paying much higher prices than out-of-state consumers. These prices are reflected not only in gas consumers' monthly bills, but also in monthly electricity bills, since almost 90% of the state's electricity is generated from natural gas.

Moving from a heavy dependency on oil and gas to other sources of energy will not be easy. Many years of experimentation, testing and construction are required to make use of developing sources such as solar, wind, solid and liquid waste recovery, geothermal, fusion, hydrogen and others. Environmental threats from the use of nuclear materials and coal could be potentially great, and wide differences of opinion regarding the economic and environmental trade-offs will exist during the transition from oil and gas. Changes in institutional arrangements defining the way we produce and use energy may facilitate this adjustment, but these will be difficult because of the tendency toward maintaining the status quo.

New sources of energy supply or new techniques of energy use do not hold immediate promise for reversing the rising prices or for decreasing the dependency on foreign supplies of crude oil. Except for the expanded mining and use of coal, other changes will come slowly and with great uncertainty.

The following sections of this report are intended, (1) to show the outlook for energy from conventional sources in Texas, and (2) to lay the groundwork for defining the most promising new energy development options for Texas. The complex of oil and gas related industries can no longer be expected to provide the basis for long term economic growth in Texas.

However, energy from other sources will not be easy to develop. Informational, technological, environmental, economic and institutional barriers exist and must be overcome before development will occur. In some cases basic data need to be collected to provide accurate information on the availability of the resource. In other cases, hardware must be constructed and tested to determine performance; some developed technologies need to be put in place and demonstrated in order for potential users in a market economy to learn of their existence. In still other cases new institutions may need to be developed, or old ones modified, in order to create an atmosphere for markets to develop.

The first major section of the report describes the outlook in Texas for conventional oil and gas sources of energy and current technology. The second major section discusses the possibilities from alternative sources and new or developing technologies. The major barriers to development are discussed , and based on this information, implications are drawn for the best use of energy development funds from Texas state government.

OUTLOOK FROM CONVENTIONAL ENERGY SOURCES

The energy problem in Texas and the nation is basically a problem of transition. It appears that major changes must be made in order to accommodate the shift from an oil and gas-based economy to one based on coal and eventually other developing energy resources. Our challenge is in making this transition quickly, at a price that consumers can afford, and in a way that provides adequate protection for the environment.

The crude oil embargo of 1973 by Arab nations and a subsequent three-fold price increase by the OPEC (Organization of Petroleum Exporting Countries) nations forced a premature, though inevitable, rise in crude oil prices upon the United States and the remainder of the world. Such price increases would have eventually occurred as world supplies of crude oil became more and more expensive to discover, develop, and produce. Our current difficulties are the result of the requirement to adjust to the sudden three-fold crude oil price increase; such an increase otherwise would have occurred over a span of at least 10 to 15 years. Our long-term adjustment problem suddenly has become a short-term adjustment problem with the added risk of future embargoes.

Economic factors underlie the increase in foreign crude oil development and the parallel decrease in domestic development of crude oil and natural gas during the mid-1950s through the early 1970s. Foreign crude was easy to find and inexpensive to develop. Government policy also encouraged foreign development by providing tax shelters for foreign activity and maintaining a ceiling on the domestic market price for natural gas sold in the interstate market.

These policies and the availability of inexpensive foreign crude oil have shaped the entire picture of energy development in the United States. Under these conditions, alternative sources of energy were not economically competitive. Even the production of coal with current techniques decreased between 1950 and 1960 and did not begin increasing until the late 1960s.

But even if government policies are adopted to encourage maximum development of Texas oil and gas, the long term prospects are for a decline in production as is shown in the following section.

Oil, Gas and Coal Reserves and Production

The economic reserves of crude oil in Texas and the United States during 1950-1975 are shown in Figure 1. The reserves of crude oil and natural gas liquids peaked in Texas during 1963 and in the United States during 1970. Reserves have steadily declined since these dates. The main reason for this decline is that production has continually exceeded additions to reserves from new exploration, although these reserves are also influenced by the current market price of the product and the changing technologies of recovery. At current production levels Texas economic reserves constitute a 10-year supply of crude oil and natural gas liquids. If current production levels continue to exceed additions to reserves, the 10-year quantity of reserves will decrease.

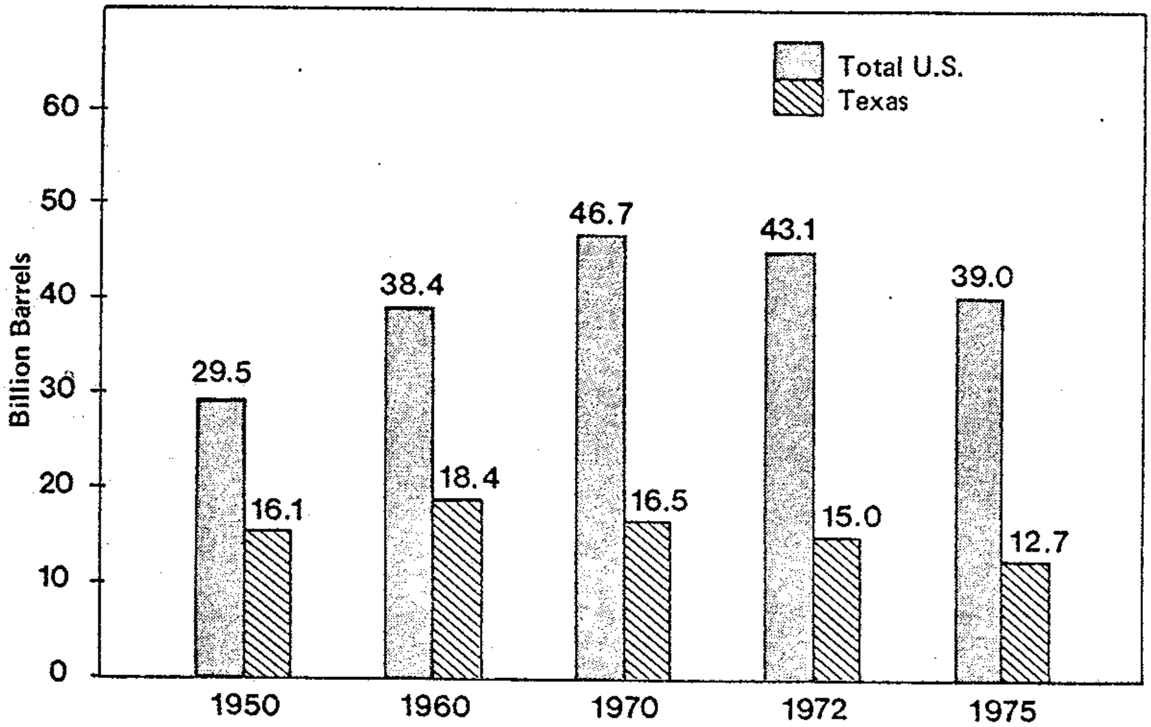

Fig. 1. Texas and U.S. Crude Oil Reserves (Total Liquids)

The Texas portion of U.S. reserves of total liquids has declined from 54.6% in 1950 to 32.6% in 1975. Although the discovery of oil and gas in Alaska accounts for a major portion of the Texas percentage decline, prospects are that the percentage will continue declining since Texas fields are older and chances for major new additions smaller than for the nation as a whole.

Natural gas reserves show a similar pattern of decline beginning about four years later than crude oil (Fig. 2) Gas reserves reached a peak in Texas and the United States during 1967 and have declined steadily since that year. The Texas proportion of United States oil and gas reserves has declined steadily since 1950, reflecting the favorable economics of exploration and development in other parts of the United States and elsewhere in the world. Total Texas economic reserves of gas constitute a 10-year supply if production remains at current levels. If production levels for natural gas continue to exceed additions to reserves, the 10-year supply will decrease.

The Texas portion of U.S. natural gas reserves has declined from 55.2% in 1950 to 31.1% in 1975. Additions to reserves in Alaska and off-shore areas have contributed to the Texas percentage decline and the prospects are that the decline will continue as new areas account for greater additions to reserves than do older areas such as Texas. Federal pricing policies will greatly affect the additions to reserves, however, since deep gas is known to exist and will be added to reserves when the price is higher.

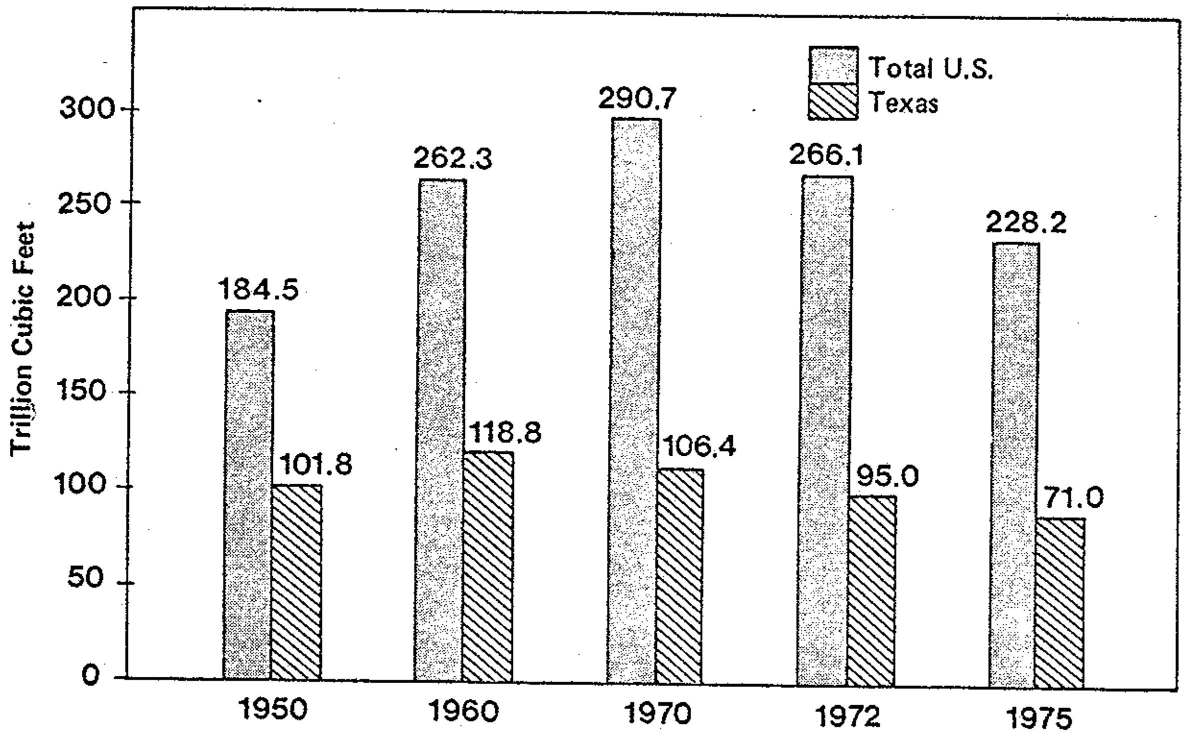

Fig. 2. Texas and U.S. Natural Gas Reserves (Total Gas)

The mining and consumption of coal in the United States have been greatly affected by the price of crude oil and natural gas. Coal is the most abundant United States energy source and economic reserves in 1975 equaled more than 20 times the reserves of crude oil and natural gas on a Btu basis. Texas economic reserves of coal were considered insignificant until the crisis of 1973, but now equal nearly one third of the remaining crude oil and natural gas economic reserves in Texas (Fig. 3).

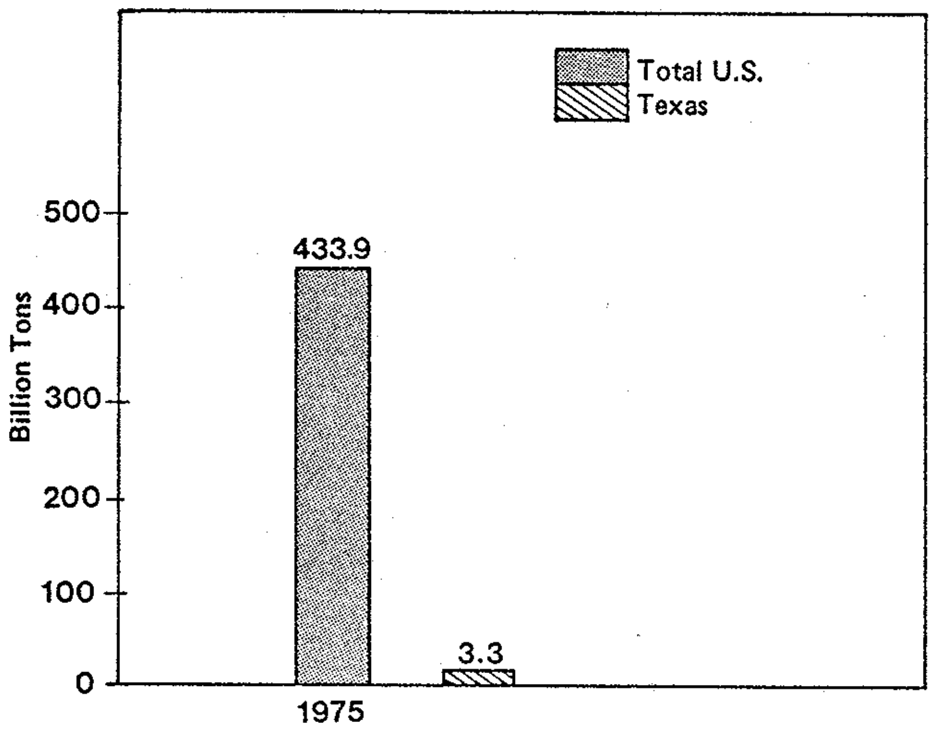

Fig. 3. Texas and U.S. Coal Reserves

Further study, drilling and mining are required, however, to better estimate the Texas lignite resource. Since lignite development has been limited to surface mining in Texas, current estimates of reserves are obtained from geologic data from water, oil, and gas well logs. Indications are that throughout most of Texas, lignite is of low Btu content and air and water quality problems are likely to ensue from the mining and use of much of the resource. All of these factors will determine the size of the resource that is economically recoverable.

The production of crude oil in Texas and the United States from reserves acquired by prior years' exploration continued to increase until 1972 and has continually decreased since that year (Fig. 4). Under a continuation of current energy policies, Texas crude oil production will continue to decrease at 4.7% per year through the year 2000. Deregulation of wellhead prices could significantly increase production levels during the years 1977-2000. If enacted, deregulation would slow the decline rate to 3.1% per year and provide the potential for additional oil from enhanced recovery. Enhanced recovery operations could add 290 million barrels per year to Texas supplies by the year 2000.

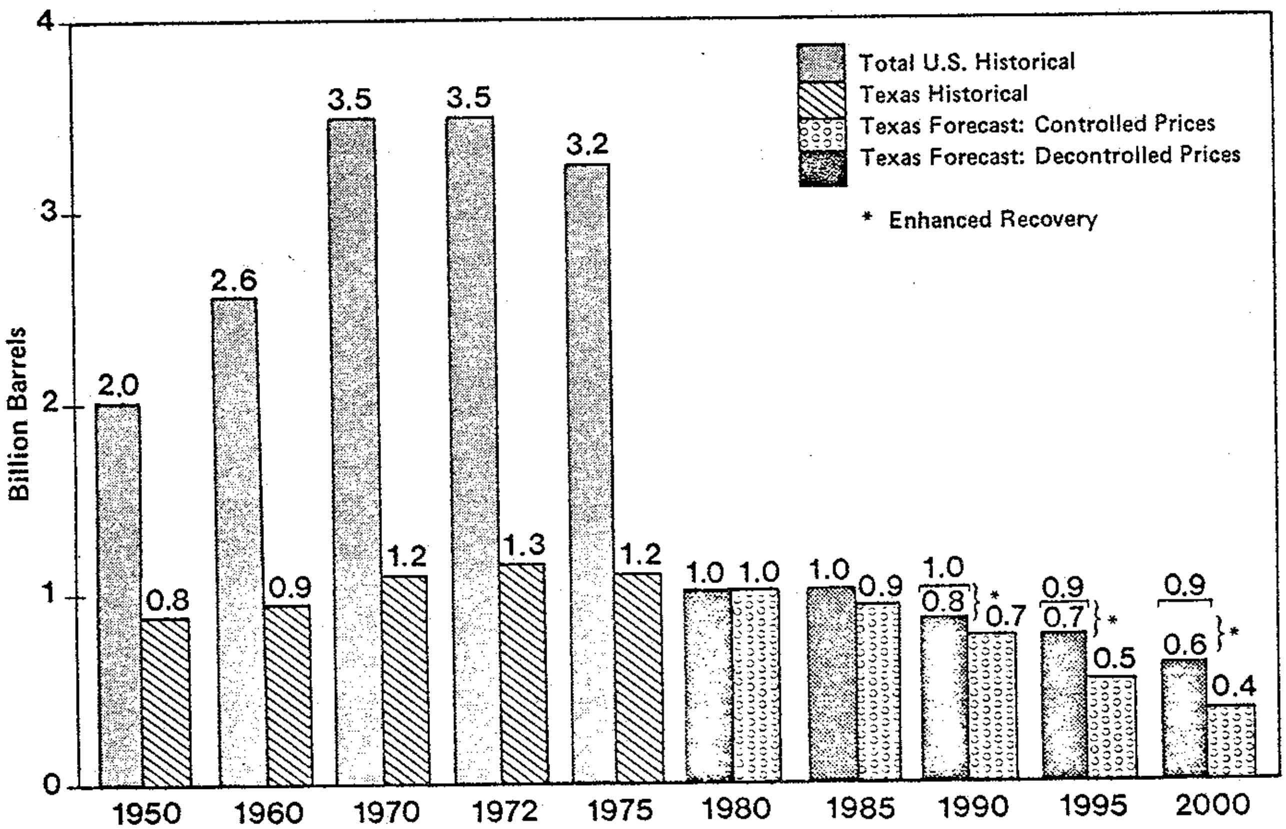

Fig. 4. Texas and U.S. Crude Oil Production: Historical and Forecasts

The Texas portion of U.S. oil production has declined from 40.0% in 1950 to 37.5% in 1975. This trend is likely to continue and it is unlikely that the 1972 production levels will ever be achieved again, even with substantial contributions from enhanced recovery operations. Pricing policies by the Federal government will make a significant difference, however, and will indirectly affect the level of imported oil requirements to the state. It is clear that the opportunity exists for development of an industry capable of producing substitutes for this commodity in refining processes, if the costs of production can compete with foreign crude oil prices.

The production of natural gas in Texas and the United States from accumulated reserves added by prior years' exploration continued to increase until 1972 and has continually declined since that year (Fig. 5). Production will continue to July, 1976 action by the Federal Power Commission (FPC) raising the new gas recent policy change by the Federal Power Commission (FPC) raising the new gas price to $1.42 per thousand cubic feet. Deregulation would slow the decline to 1.4% per year. Further controls, such as a 75-cent ceiling on intrastate natural gas at the wellhead, would increase the production decline to 6.8% per year.

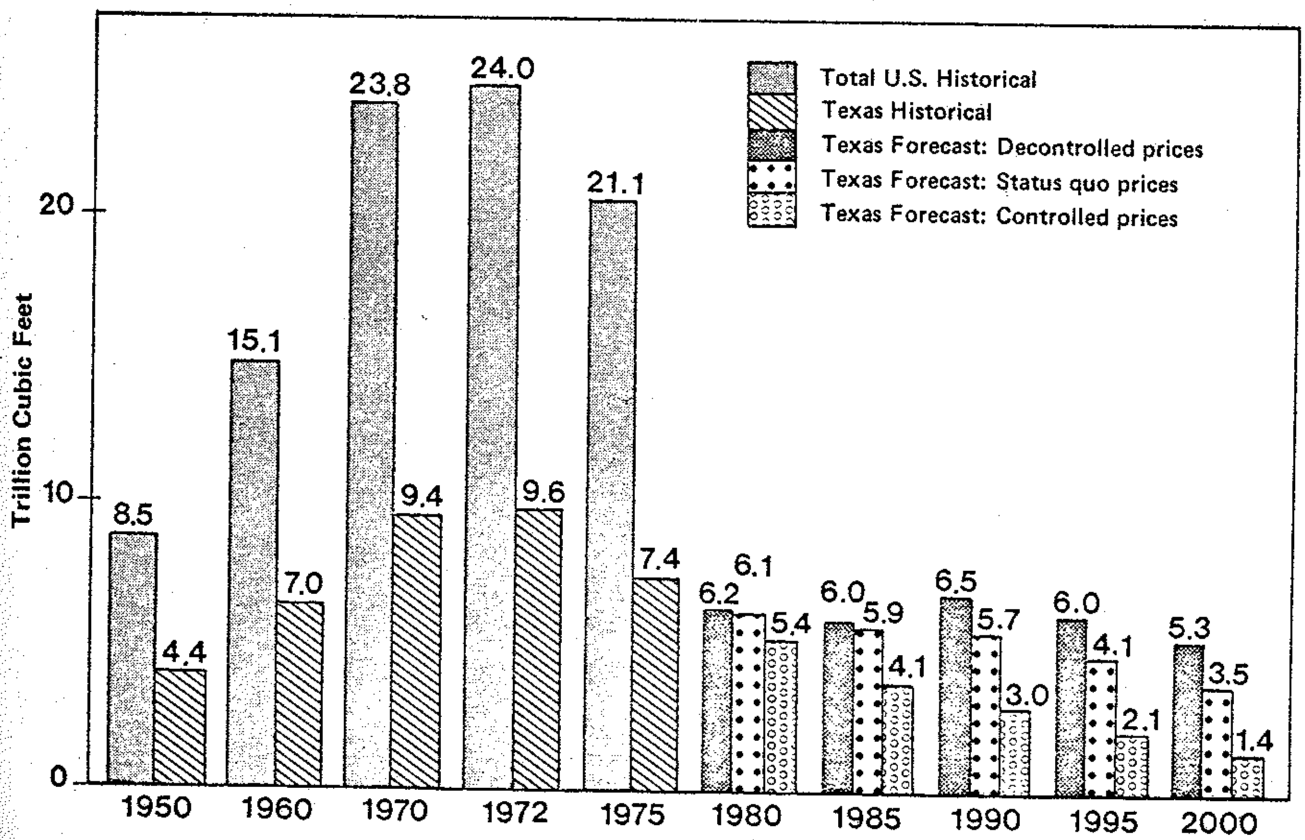

Fig. 5. Texas and U.S. Natural Gas Production: Historical and Forecasts

The Texas portion of U.S. natural gas production declined from 51.8% in 1950 to 35.1% in 1975. This trend is likely to continue and it is unlikely that the 1972 production levels will ever be achieved again, even if prices are decontrolled. It is clear, however, that new gas price ceilings near the current average price of 75¢ per mcf would encourage this rapid decline of natural gas production.

These supply prospects, the large current capital investment in natural gas burning facilities, and the growing use of natural gas products as petrochemical feed stocks indicate the possibility of a very large industry to produce synthetic gas or methane gas from geothermal wells as substitutes for natural gas if the costs of production can be made competitive.

Coal production in the United States declined during the 1950s and early 1960s as many consumers substituted clean-burning and inexpensive natural gas for coal. Prospects for continually increasing natural gas shortages, however, have reversed this trend during the 1970s, and the rate of production must rise sharply in the future to replace declining natural gas and crude oil supplies. Texas lignite production is expected to contribute significantly to Texas energy supplies in the future with production levels near 86 million tons or 8.5% of Texas energy consumption by the year 2000 (Fig. 6). Federal secondary ambient air quality standards for particulate matter prevent coal and lignite use in most areas of Texas. The reason is that these areas have high natural dust levels. However, lignite can be produced and used without major environmental problems if these standards are revised to allow differing local air conditions. Strict enforcement of non-significant deterioration regulations of air quality would severely limit potential sites in Texas for coal and lignite power plants.

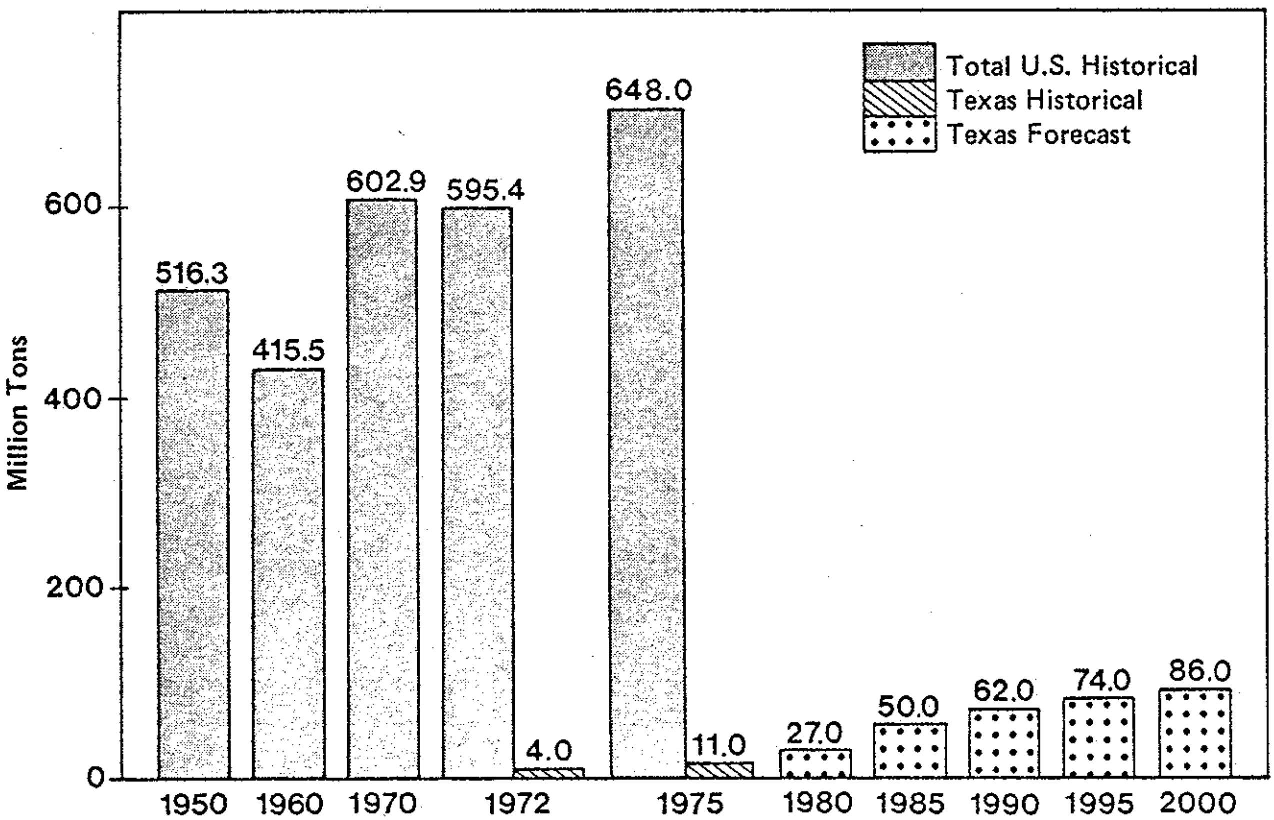

Fig. 6. Texas and U.S. Coal and Lignite Production

Additional research is needed to determine the quality of Texas lignite, to investigate problems of water and air quality and to understand the problems of local community development impacts. These and other factors will determine the actual level of production in future years; the estimates shown in Fig. 6 are therefore speculative.

Uranium production in Texas is mostly dependent upon the development of the U.S. nuclear power industry. Current licensing delays are discouraging many utilities from developing nuclear plants. This uncertainty makes estimation of future Texas uranium production very speculative.

Total production of energy in Texas from conventional sources, for both Texas use and export, is shown in Figure 7. These projections, shown in aggregate Btu, are from oil, gas and lignite sources, under favorable conditions of decontrolled prices for oil and gas and no major restrictions to the mining and use of Texas lignite. Price ceilings for oil and gas and limitations on the mining and use of lignite because of water and air quality problems would significantly decrease the total supply from these sources.

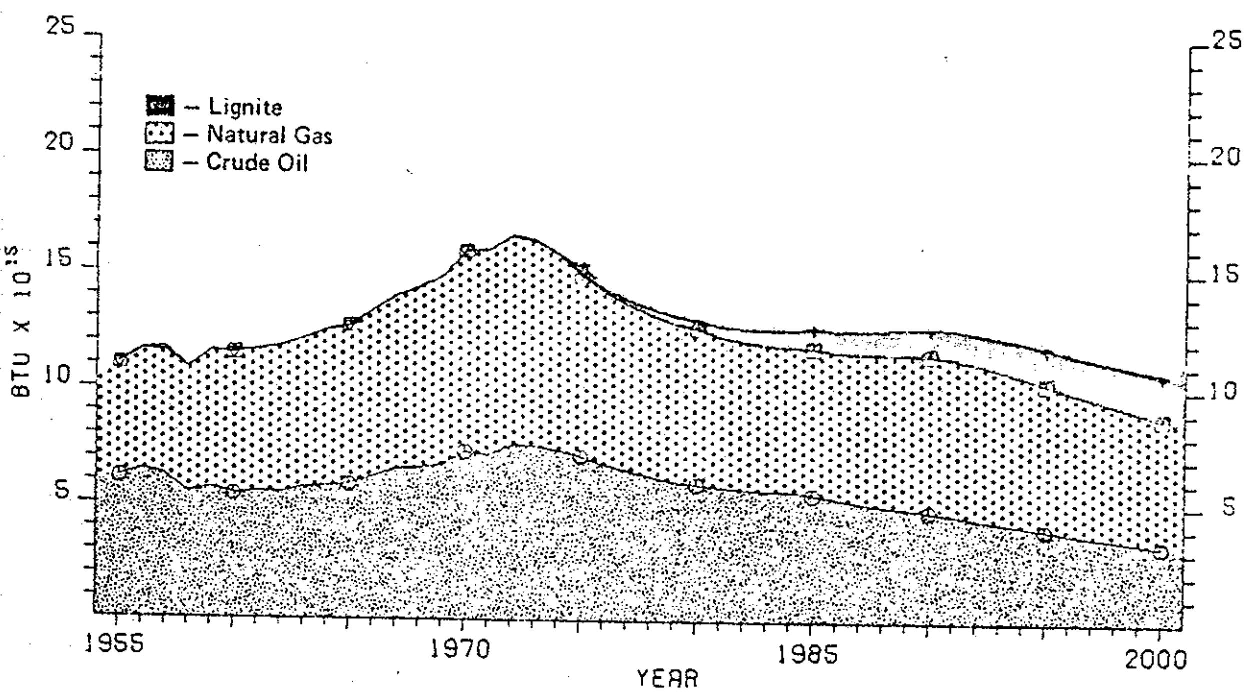

Fig. 7. Total Texas Energy Supply (FM)

The primary implications of these data are that a significant market potential exists for alternative energy sources if the costs of production can be reduced to compete with the price of imported crude oil and/or deep reserves of natural gas.

Energy Consumption

Texas and United States energy consumption has increased rapidly during the past 15 years (Fig. 8). Energy has been an increasingly good buy compared to the cost of other consumer goods. It has also been a good buy for industry, which has used more and more new machines to replace labor and less efficient machines. Declining production in the United States and drastically increased prices for imported crude oil have resulted in sharp increases in energy prices, which are causing major changes in energy consumption. For instance, consumption in Texas will grow at a slower rate in the future. The rate of increase in total consumption will decline from the past decade rate of 3.7% per year to 2.7% per year during 1977-2000, due to increased efficiencies and changed consumption patterns resulting from rising energy prices. Conservation studies indicate that 1985 consumption levels could be reduced by 13-23% compared to the historical growth levels if energy efficiency alone is maximized. Public information programs which inform consumers of alternatives, along with public investment in testing and evaluation of energy-efficient processes and new techniques, can help reach this potential.

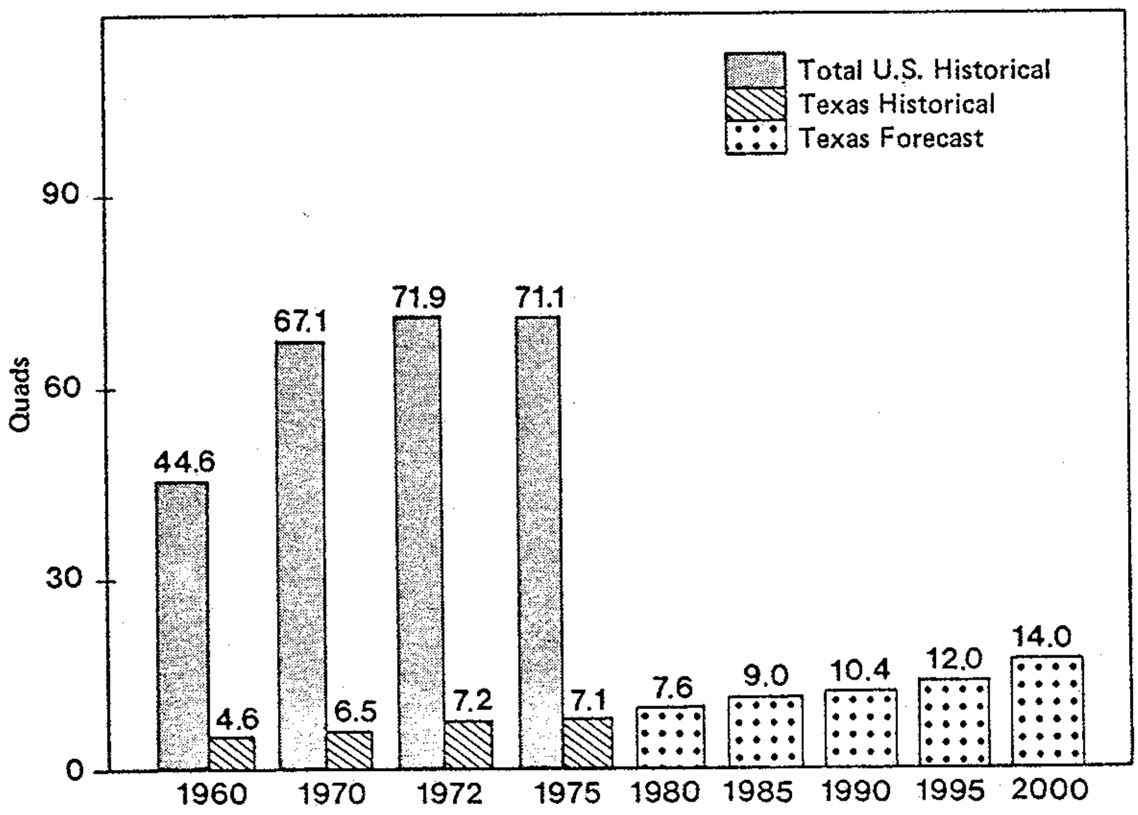

Fig. 8. Texas and U.S. Total Energy Consumption

Both technological and institutional developments need to be encouraged in Texas to bring about maximum reduction in energy consumption growth, consistent with continued economic growth.

Texas and the United States have been heavily dependent upon natural gas and crude oil products (Fig. 9). Texas is even more dependent upon oil and gas products in final consumption for transportation, industrial and residential/commercial uses than is the rest of the nation. While Texas now consumes proportionally less coal, nuclear and hydro-power than the national average, coal and lignite will play an increasingly important role by 1985. Figure 9 indicates that coal and lignite will make up 12.8% of Texas consumption; however, the percentage could reach 30.3% if strict boiler fuel restrictions on the use of natural gas are enforced, requiring large boiler uses to approach zero natural gas use by 1985.

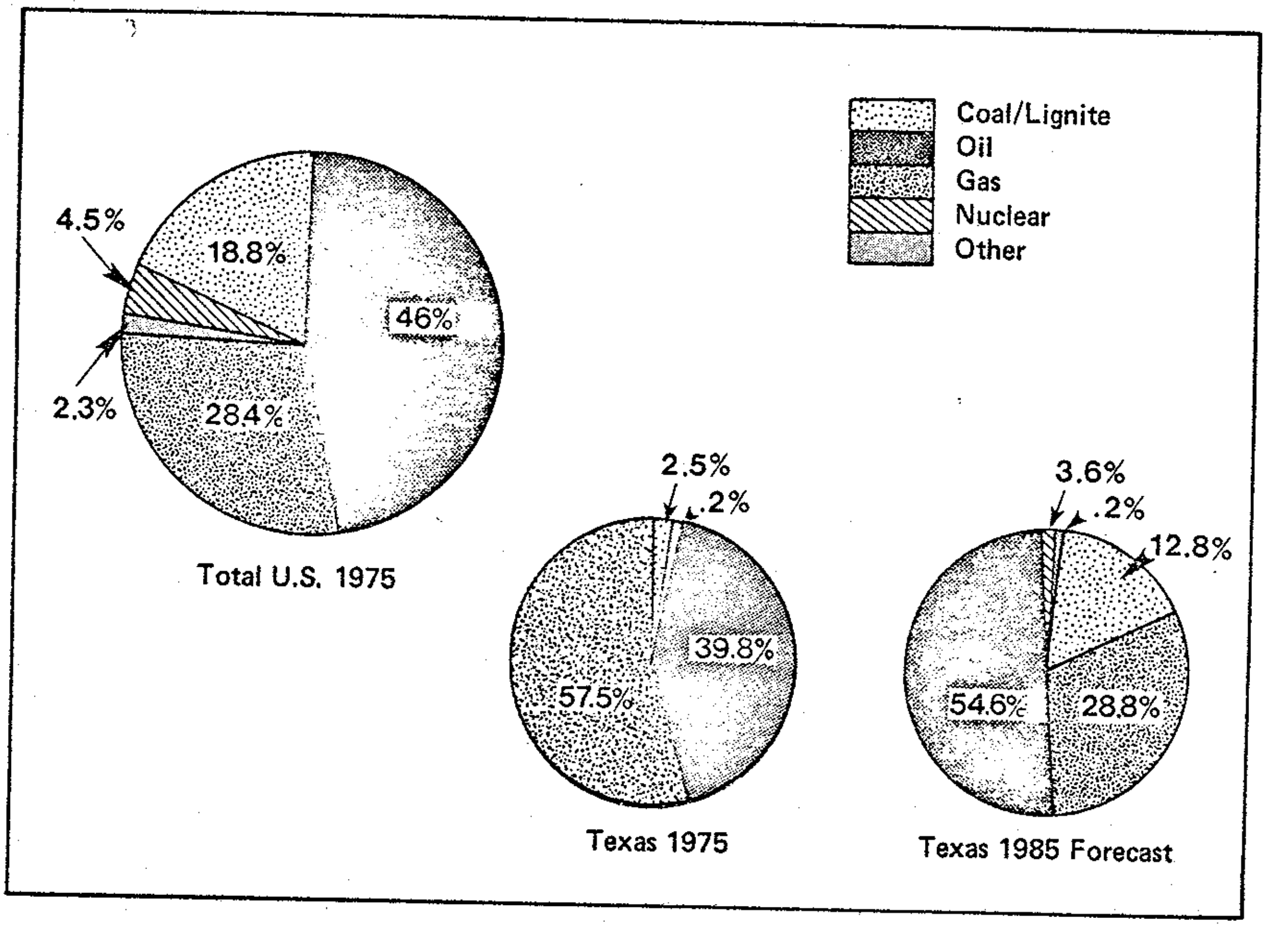

Fig. 9. Texas and U.S. Energy Consumption Patterns

The "other" category could grow significantly after 1985 if specific uses of solar, wind and biomass become competitive with conventional sources at higher prices. Further expansion of the "other" category will occur if geothermal sources, particularly along the Gulf coast, prove economical. Expansion of lignite use could occur at significantly faster rates after 1985 if gasification and liquefaction technologies become competitive with oil and gas prices.

Energy Imports

The prospects are that recent trends in crude oil imports will continue unless major energy policy changes are made (Fig. 10). Texas imports will continue to rise sharply to meet growing demands for crude oil, refinery products and chemicals. The growth rate can be decreased but import levels to Texas will not decline unless major policy changes occur and significant nationwide contributions are forthcoming from new energy sources *and* conservation efforts.

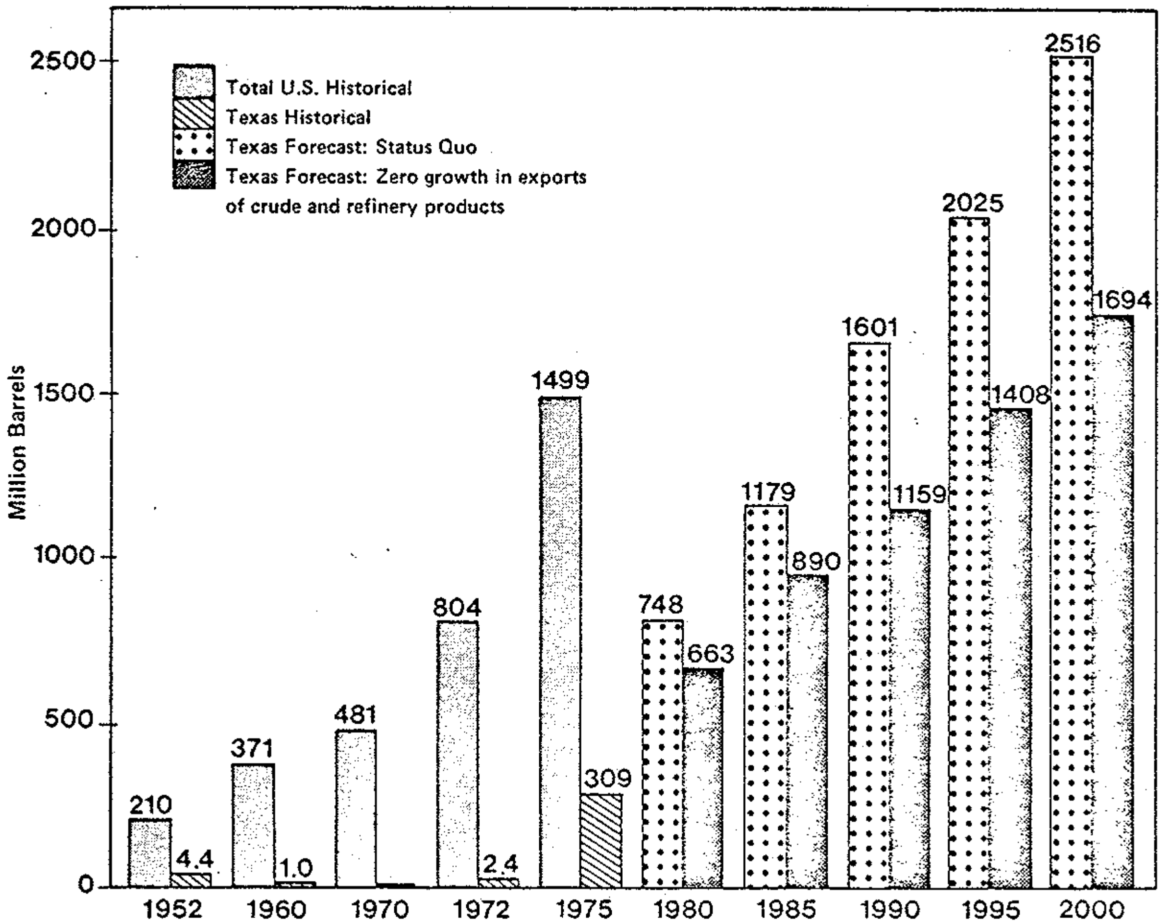

Fig. 10. Texas and U.S. Refinery Receipts of Foreign Crude Oil

Such growth levels of imported crude oil indicate a growing economic threat from supply disruptions *and* a growing potential for new source market development if new source costs can be reduced to competitive prices.

A rapid growth in coal imports will be required to replace the declining availability of natural gas for boiler fuel uses. Future levels of coal imports will be greatly dependent upon the extent of mandatory restrictions on the use of natural gas as a boiler fuel, the level of standards for air quality and the development of nuclear power. With significant future development of nuclear power, current air quality standards and moderate restrictions on natural gas as a boiler fuel, import levels for coal could be as small as 7 million tons in 1985 and 33 million tons by the year 2000 (See Fig. 11). With restricted nuclear power development and a complete phaseout of natural gas as a boiler fuel in large boilers by 1985, the import level for coal will be 125 million tons in 1985 and 225 million tons in the year 2000.

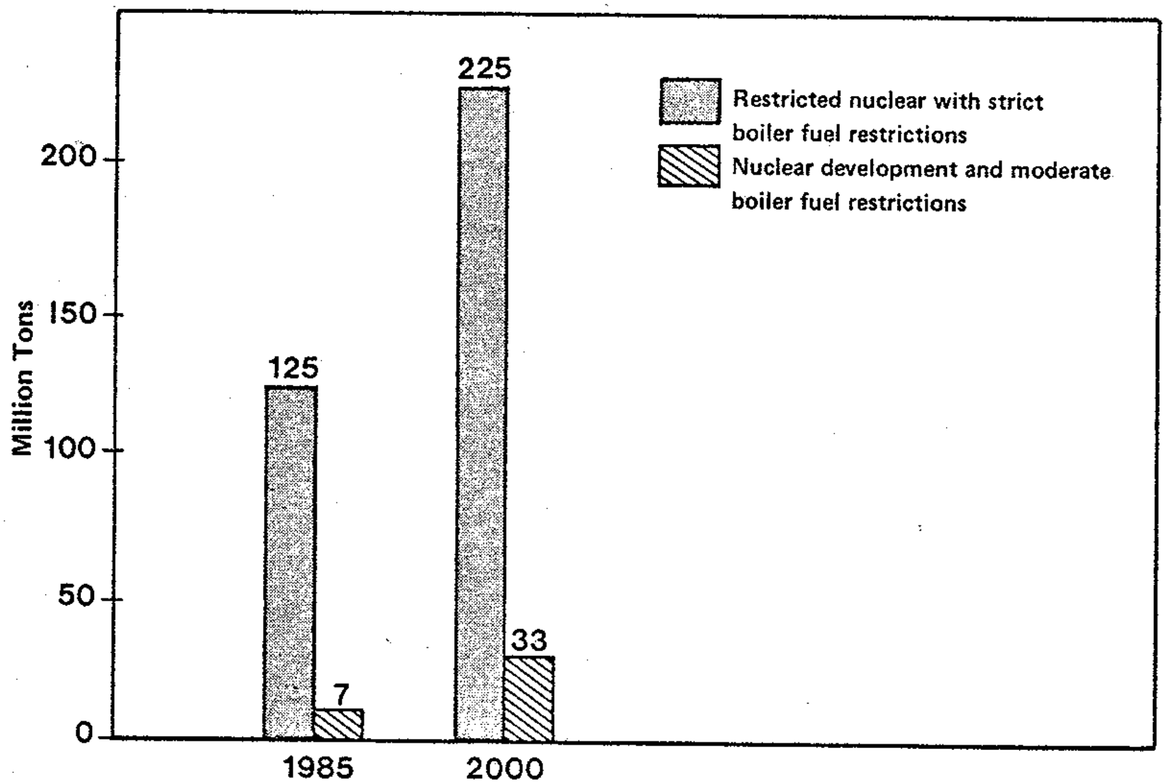

Fig. 11. Texas Coal Imports

These import levels are also dependent upon the production levels of Texas lignite. Air and water quality problems from use and mining of lignite may impede its development and lead to greater use of higher quality imported coal. Research to better identify the resource, investigate water and air quality problems and develop gasification and liquefaction technologies could drastically affect Texas' future reliance on imported coal.

Energy Impacts

Energy policy decisions will have a significant impact on Texas economic growth and cost of living (Fig. 12). Policies which encourage the further development of oil, gas, lignite and nuclear power will stimulate employment and income growth and at the same time provide a slower growth in total energy costs in the long run than policies which discourage oil, gas, and nuclear development and attempt to artificially suppress energy prices. Decontrolled prices will encourage the development of new technology, especially solar, wind, biomass, geothermal, lignite, and enhanced recovery of oil and gas.

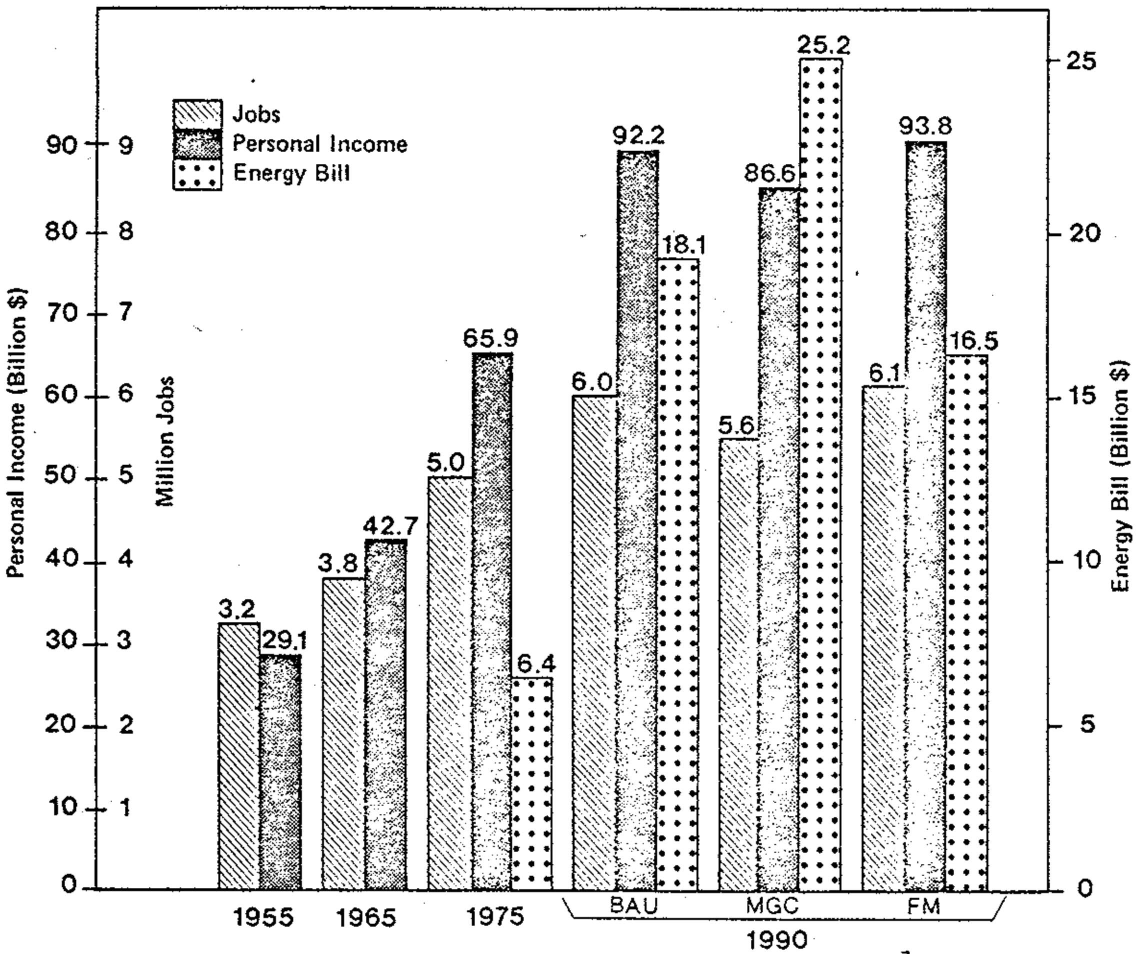

Fig. 12. Texas Employment, Incomes and Energy Bill [1]

The development of new industries could add significantly to income and employment growth *and* potentially slow the growth rate in energy costs. Such development could occur in the production and marketing of solar, wind, and biomass technologies and of conservation techniques and materials for residential, commercial, or industrial uses. There would also be the potential for geothermal development for electric power generation and methane gas production and for enhanced use of lignite for direct combustion, gasification, and liquefaction.

1. Three scenarios are shown in Figure 12. BAU means government policy of the status quo or "business as usual." MGC means "maximum government control" indicating low price ceilings on oil and gas and restrictive air quality standards. FM means "free market" indicating decontrolled prices for oil and gas and current environmental standards.

OUTLOOK FROM DEVELOPING ENERGY SOURCES AND CONSERVATION

This section discusses the potential contribution from alternative, developing energy sources. Technological, economic, environmental, and institutional impediments to development are also discussed.

SOLAR

As previously indicated, the economic well being of the state today is heavily dependent upon its position as an exporter both of agricultural goods and energy. As fossil fuels become scarce, exports of manufactured goods or synthetic fuels will have to fill the gap if economic growth is to be maintained. In order to continue to draw industry, the state must develop other indigenous resources to meet its energy needs. The potential impact of contemporary solar technologies on the state of Texas as a partial replacement for oil and gas-based industry is very great, not only in terms of Btu delivered but also in the broader economic sense.

It is well known that the use of solar energy is capital intensive. With the adoption of solar energy, use of many other raw materials replaces the consumption of fossil fuels. In turn this requires greater labor and energy inputs in the production of solar energy conversion equipment. In addition, because solar conversion systems are suited to both dispersed and centralized use, capital investment patterns can be expected to change and a wide range of employment opportunities to occur. Particularly in the heating and cooling of buildings, and in the provision of industrial or agricultural process heat, can expansion of the highly diverse and competitive building industry be anticipated. The impact would be less significant, of course, if one were to assume that solar products are manufactured elsewhere and imported to Texas, although the service sector would still receive a boost.

Setting aside the question of exports, what energy supplies can be expected from the solar resources in Texas? The methods by which solar energy can be used vary greatly but fall into the following basic categories based on energy quality or end use:

1. low to moderate temperature heat for heating and cooling of buildings or domestic water;

2. moderate to high temperature heat or steam for industrial or agricultural processes;

3. electricity for use in residential, commercial, or industrial sectors; and

4. synthetic fuels for use in any of the various sectors, including transportation.

Solar Heating and Cooling and Process Heat

The first two categories are the easiest to discuss in terms of state impact. Heat energy, over a wide range of temperatures, can be provided by contemporary solar technologies at economic or near-economic rates today. About 11% of the state's total energy requirement is for heating, ventilating, and air conditioning *of residential, commercial, and governmental buildings. Approximately three-fourths of the energy demand by the chemical industry and nearly half of the total demand by other industry is for process steam or heat. Contemporary solar technologies can clearly make a substantial impact in these areas by the year 2000.*

If total consumption for the year 2000 in Texas reaches a projected level of 14.045 Quad (see Holloway, 1977 BAU case), .027 Quad, or .2% of this total could reasonably be expected to come from solar heating and cooling of buildings. At present prices this represents a cumulative investment (or capital commitment) of approximately $3.34 billion, or an average annual investment of $134 million in the residential, commercial, and governmental sectors. In addition, by 2000 this represents yearly fuel savings of $55 million (at $2.00/MMBtu). Net capital outlay by these sectors then becomes approximately $2.66 billion (all investments are in 1977 dollars).

It is also reasonable to expect that by 2000 10% of industrial process steam or direct heat requirements could economically be met by moderate to high temperature solar derived heat (DOE/ERDA estimate). The potential market penetration in the chemical industry represents .288 Quad and in other industry .089 Quad annually by the year 2000. This total of near .344 Quad would require a cumulative capital commitment of $32 billion, reaching close to $2.6 billion annually in the year 2000. By that time however, this investment would result in yearly fuel cost savings of $750 million from installed solar systems (again at $2.00/MMBtu, 1977 dollars).

These large investments will have a major impact on employment in Texas. Certainly the causal relationships are too numerous to detail, but the initial impact can be roughly estimated if certain simplifying assumptions are made. First, assume that the equipment required for this level of solar contribution is manufactured in-state, or at least that the net import level of solar equipment is zero. Second, assume that the employment effect of manufacturing of solar components and systems is equivalent to present experience in a composite of other similar manufacturing sectors. And third, assume that the primary sector in which fewer new jobs are created is in electric and gas services which are replaced by solar employment. As solar becomes competitive in the market place, the net increase is approximately 20,000 jobs as a result of solar heating and cooling of residential, commercial, and governmental buildings. From the industrial demand for solar goods, the net increase in employment is roughly 175,000 jobs by the year 2000. Table 1 shows roughly to what degree labor will be increased in the 10 major economic sectors as a result of solar industry expansion by the year 2000.

The total labor increases from anticipated solar energy expansion are approximately equivalent to the level of employment provided today by the energy industry in Texas. And, although employment in the oil and gas industry, for example, is projected to decline, solar market penetration is not likely to impact this rate. Even in the most optimistic solar scenario, markets will likely be present for all the oil and gas produced either in Texas or in other states. It should be noted that these figures include indirect employment as well as direct employment. But the employment figures presented do not attempt to address changes in other sectors for unrelated reasons (e.g., an unexpected slump in the widget industry). There also was no inclusion of potential heating and cooling of industrial plant space. lthough this would require some additional investment, and would be a likely dditional use of process heat capacity, its exclusion insures that the figures ed are conservative regarding fuel saved and jobs created. Also not taken into ount are the secondary impacts created by the new solar manufacturing sector erms of energy.

Economic Sector	Net New Jobs Resulting From Solar Heating & Cooling of Buildings Applications	Net New Jobs Resulting From Solar Industrial & Agricultural Process Heat Applications
Agricultural	447	3,952
Mining	307	2,717
Construction	669	5,909
Manufacturing (all kinds)	9,578	84,645
Transportation	753	6,650
Utilities	471	4,161
Wholesale	832	7,358
Retail	2,862	25,289
F.I.R.E.	731	6,460
Services	3,309	21,241
TOTAL	19,959	176,382

Table 1. Labor Increases From Solar Energy Expansion

Commercialization

The Texas Industrial Commission predicts that Texas will lead all other states in construction of new manufacturing plants in the next three years. Perhaps the atmosphere in the state is already conducive for such development. But, what are the major factors affecting the rate of market penetration by contemporary solar heating and cooling technologies?

Naturally the relative price of alternate fuels is a major factor, but the inevitable escalation of fuel prices will only shift the dates of implementation forward or backward depending on the nature of government regulation. The oil equalization tax, gas user taxes and environmental constraints on coal use, although creating other problems, are likely to enhance the early economic feasibility of solar energy use. This, coupled with government tax incentives for solar investment, makes the above mentioned impacts all the more conservative. In the residential and commercial buildings area, several studies performed for ERDA (now DOE) show that solar water heating and space heating are presently competitive with electricity at some level less than 100% of building load, assuming no significant alteration of life styles. At current prices for solar systems, natural gas prices would have to rise to three to four times present average rates, however, so solar does not now compete with gas. An increasing number of buildings are now using, and will in the future use, electricity because of gas supply limitations, safety, or convenience considerations. In addition, the expansion of the solar industry, increased capacity for mass manufacturing techniques, and increased numbers of experienced service employees will likely bring the cost of solar systems down substantially.

The advent of economic solar cooling/dehumidification systems in the mid-to-late 1980s will provide a substantial boost to the heating and cooling industry.

The same collectors used for heating would then generate savings for a significantly greater part of the year, thereby making solar heating systems more competitive also.

In the industrial sector, the potential is even more pronounced for several reasons. Industry installations can take advantage of economies of scale for system accessories, use low temperature waste heat as well as steam, or even possibly use solar co-generation systems. Industrial demand tends to be more constant daily and seasonally. Although higher temperatures required may necessitate more expensive concentrating collectors, tracking allows interception of greater total insolation and Btu collected per dollar investment are greater than for residential, commercial, or governmental use generally. DOE is only now beginning to receive data on several federally funded industrial installations. A study performed for the GEAC in 1976 showed solar derived heat as a feasible source for certain agricultural heat processes (Strickland, 1976). The Industrial and Agricultural Process Heat Branch of ERDA/DOE supplied the 10% replacement estimate used for this study.

Barriers to Development

Even if the question of economics is not a perceived hindrance for many applications, accessibility of capital to the various sectors could well be. Although a homeowner might profit (over a period of 3 to 10 years) by investment in solar equipment, he may not be able to obtain the initial capital required to realize that relatively long-term return. Even in industry, where such investment horizons are dealt with daily, many other opportunities compete for available capital.

Another barrier is simply one of education. Individuals will be slow to shift away from past practices, such as gas or electric heating, to conceptually new methods such as solar heating. The building industry itself is so diverse that transferring new technology to its many components and participants is a major task. Because the building industry is so competitive, there is still incentive to keep initial costs low, even at the expense of high operating and life-cycle costs.

From the perspective of the consumer, there are other sociological or pshychological barriers. A natural suspicion of claims made by a new industry, sometimes justified, is already felt. Federal systems for rating and certifying solar components are only now being developed. Although many solar installations have been completed in Texas there is a lack of concrete operating data upon which to clearly assess the benefits of applied solar energy. The industry must build a track record of demonstrable successes before either homeowners, businesses or industry will see it as a reliable alternative.

Last of all, although no significant institutional barriers have been experienced, as the market penetration of solar thermal technologies increases, several problems will likely arise. Utility rates which discriminate against the solar user are a prime example. Unless or until more substantial economic storage capacities can be developed for solar systems, supplemental solar use by utility customers will increase the swing in demand levels and decrease the load factor experienced by central utilities. At least one utility has addressed this real cost by raising the price of electricity to solar customers by a factor of four. The result is that savings by such customers are little if anything in terms of their total bill.

In the case of industrial use of solar heat, a similar problem is created. Utilities now rely heavily on industrial demand as a fairly stable base load. Again, solar supplementation of industry demand creates load factor problems at the central utility plant.

Another problem likely to become more acute with time is the lack of any mechanism to insure solar rights (or the right-to-light). Local governments will have to provide licensing procedures for installation and service technicians as is now done for plumbers, electricians, and other traditional service sectors. They will also have to adopt or develop building codes to cover the new features of solar systems. The City of Austin Energy Conservation Commission is presently working on methods of insuring solar rights through zoning measures. The Commission is also developing a model code and licensing procedures (primarily addressing health and safety issues) for installation and maintenance technician licensing. The real experience gained in this pioneering effort will be most useful for other local governments, where these efforts are likely to be most effective. The Commission is receiving expert assistance from the Texas Solar Energy Society, local trade and professional organizations and other interested individuals.

Solar Electric Technologies

Electricity can be provided through several different technological approaches, any of which might also be used to generate synthetic fuels. Excluding for the moment wind and biomass sources, and concentrating on radiant solar energy alone, there are three basic approaches currently receiving attention:

1. Solar Thermal Electric Conversion - in which solar energy is concentrated to produce a high-grade heat source for use in Rankine, Brayton, Stirling or other cycles for generation of electric power;

2. Ocean Thermal Energy Conversion (OTEC) - in which the ocean's surface provides a low temperature, but very large, collection system for low efficiency organic or open cycle generation of electric power; and

3. Photovoltaic Conversion - in which single cell or amorphous semiconductors directly generate electric power when exposed to either normal or concentrated insolation.

Development of these technologies suggests that research work is still required in most cases. In every case, a great deal of empirical data is needed before concrete statements can be made regarding performance and reliability of any given system configuration. Thousands of variations of the three categories outlined can be envisioned, and a great deal of subsystem optimization must be done to eliminate alternatives. Possibly even more significant, however, is the relative position of the three basic approaches. Development is progressing so rapidly in these three areas that major breakthroughs in any one could significantly alter the potential impact of each. Particularly in the case of photovoltaics, in which user-owned, dispersed systems are highly possible, investment and other economic impacts would be entirely different from what they would be under an OTEC scenario.

It has been projected that electric power capacity in the form of either solar thermal, ocean thermal or photovoltaic systems could cost as low as $1,300 per kw(e) peak by 1990. If 5000 mw(e) were installed by 2000, given this level of cost reduction, the investment required would be near $7.8 billion. Intensified federal or private research efforts in any one of these technologies showing promise might well reduce installed cost even further. This would result in less capital required per kw(e) and likely a greater installed capacity in that technology. Presently photovoltaics seems to hold the largest potential for significant cost reductions below the $1,300 per kw(e) level.

Another factor which should be included here is that the capital commitments required do not reflect annual costs after financing. Further, capital costs on a yearly basis, in the form of principal and interest, will be compensated for or reduced by the yearly savings on fossil fuels that would have been required for conventional generation of like amounts. Saving 240 bcf of gas is a yearly saving of nearly $500 million at $2/mcf.

While the figures discussed are highly speculative, they are not unrealistic. For example, the U.S. Energy Research and Development Administration (ERDA, now DOE), lead federal agency for solar energy development, has said (1975) that the solar electric technologies discussed could provide 3.75 Quad of energy annually by 2000. This represents about 4% of total U.S. energy demand projected for that year. Of that contribution, 1.25 Quad is from terrestrial solar thermal, 1.88 Quad is from photovoltaic, and 0.63 Quad is from ocean thermal conversion systems. Since that time, DOE/ERDA has expressed an interest in stepping up development of photovoltaics further, due to promising research results.

Other estimates or predictions alternately call these optimistic or pessimistic. The Electric Power Research Institute (EPRI), 1976, for example, claims solar may be able to supplant 1 to 2% of U.S. electrical energy demand and 2% of total energy demand. This utility group notes that lack of long-term storage systems is the major drawback of most solar electric methods. Because of this, EPRI says the maximum load that can be taken up by solar on any utility network is 15 to 20%, which is actually a substantial contribution. EPRI adds, however, that available capital will limit development to the 1 to 2% level.

Texas use of solar electric technologies in the future will likely exceed the national average. The ERDA programs to develop terrestrial solar thermal are referred to often as the Southwest Program because this is the most realistic region for its development based on insolation.

Perhaps it is too early to be talking about commercialization of solar electric technologies, but certainly there is potential for moving in this direction. As has been mentioned, both DOE/ERDA and EPRI have programs for developing and refining systems for commercial exploitation. In order to do this, however, they have chosen to limit somewhat the kinds of systems to be supported. The vast majority of national efforts are directed toward large scale, centralized solar thermal electric. Increasing interest in photovoltaics and OTEC are reflected in growing budgets for these technologies. Only recently has much effort been aimed toward exploration of small to moderate scale solar electric systems (1 to 50 mw(e)) that might be considered community size.

Several factors besides development of working, reliable systems, of course, will influence the rate of commercial use of solar electric systems. Among these are utility interest and available capital, rate structure used, network load profiles and generating plant mix, and relative costs of alternative fuels including environmental, siting, and safety costs. At present the most substantial barrier to widespread use of solar electric power is extremely high costs. The high technology involved, the custom-made components required, and the shortage of technically trained personnel contribute to these high costs.

GEOTHERMAL

Geothermal resources occur within the earth's crust at locations of abnormally high heat flow from the earth's core. Over the centuries, geothermal resources have been used for a variety of purposes, primarily recreational and therapeutic. With recent improvements in exploration and well drilling and expanded demand for energy, geothermal resources are now of interest for a broad range of uses.

Occurring in a variety of forms, inferred geothermal resources in the United States exceed 4,000 quadrillion Btu. The best known but least common form of these resources is hot, dry steam as occurs at the Geysers in northern California. In Texas, geothermal resources are located throughout much of the state. Along the Gulf Coast, extending from Mexico into Louisiana, geothermal resources exist in confined, geopressured reservoirs. In addition to their value as hot fluids of up to 400° F, geopressured resources are also valuable because they exist at unusually high pressures (up to 13,000 psi) and are expected to be saturated with natural gas. Along the Rio Grande River between El Paso and Big Bend National Park hydrothermal geothermal resources at temperatures up to 375° F are known to exist but have not been investigated adequately to justify their development. Another hydrothermal resource is known to exist along the Balcones and Luling-Mexia-Talco fault systems of central Texas, but again resource knowledge is limited. Fluid temperatures in this area are believed to be near 150° F. Another geothermal resource in Texas is the hot rock resource of the Trans-Pecos area in west Texas. Although potentially significant in size, technology to recover its energy is not likely to be available for at least the next decade.

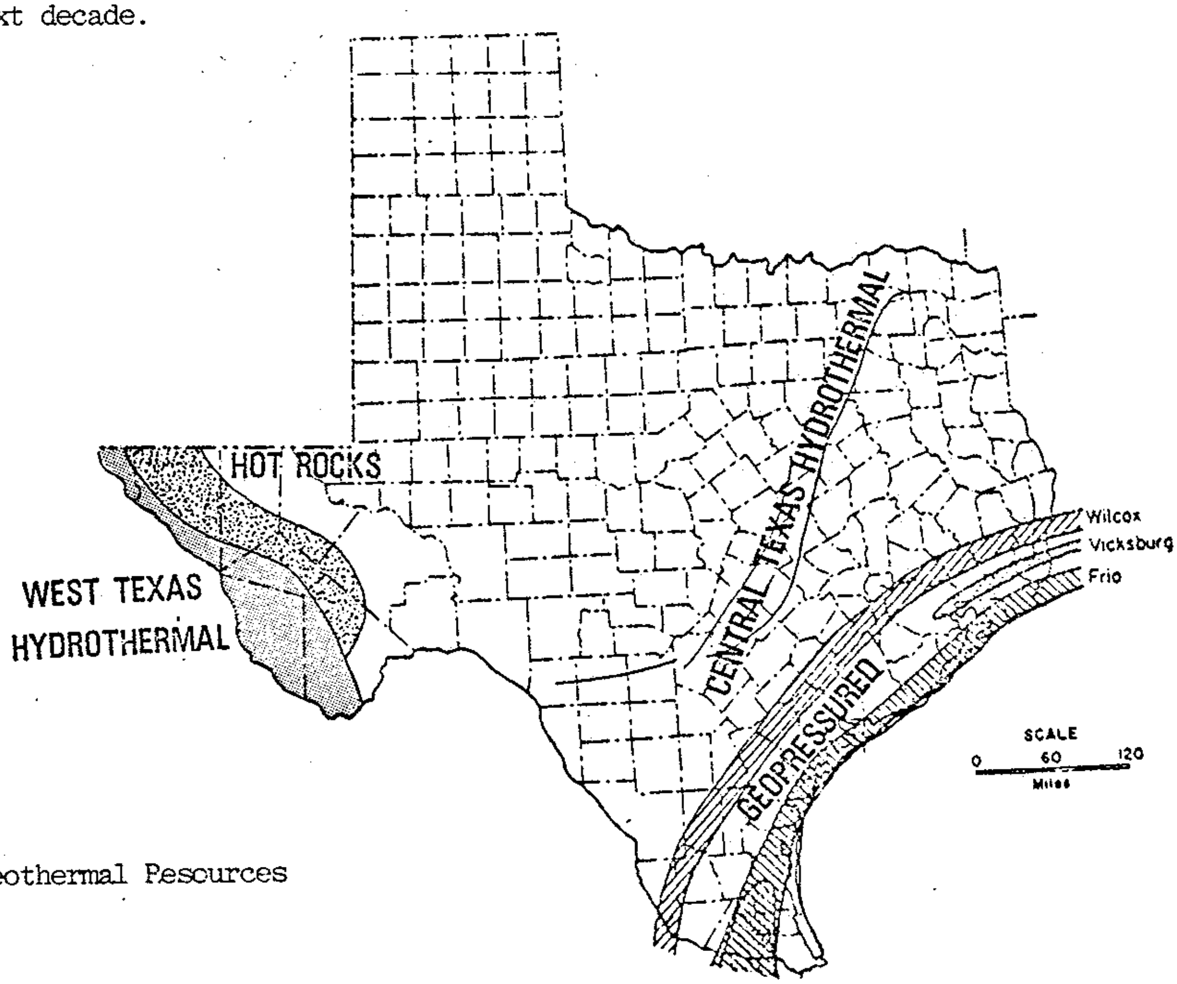

Fig. 13. Geothermal Resources

Resource Potential

The most significant of the state's geothermal resources are the geopressured resources of the Gulf Coast. Resulting from the fault partitioning of ancient sedimentary basins, individual geopressured reservoirs exist up to several thousand feet thick and several hundred square miles in areal extent. In a 1975 study of geothermal resources, the U.S. Geological Survey reported that known hydrothermal resources in the U.S. totaled 100 quadrillion Btu while known geopressured resources in Texas and Louisiana alone totaled 600 quadrillion Btu. Natural gas found in geopressured reservoirs may account for 80% of this total. (Texas' proven reserves of oil and natural gas combined currently equal approximately 130 quadrillion Btu.) Unlike the thermal energy in geothermal resources which is considered renewable, natural gas is a finite resource. The primary question with regard to development of this resource is whether it can be economically produced. An extensive research effort is currently underway to develop needed information. A major activity in this effort will be the drilling in early 1978 of a 16,500 foot test well in Brazoria County to demonstrate long-term producibility of a geothermal reservoir. The U.S. Department of Energy has as a stated objective the annual production of 4 - 9 quadrillion Btu of geothermal energy by 2000, at least half of which will come from geopressured reservoirs in Texas and Louisiana. The accomplishment of this objective will in large measure depend upon the success of the Brazoria County test well and the rest of the research program. The basic technologies for geopressured resource development--well drilling and operation, energy conversion equipment, and gas separation technology--are similar to those already in use by the oil, gas, and electric utility industries. Technology advances which are needed—drilling of relatively large wells into high pressure and temperature reservoirs, equipment to handle fluids high in significant quantities of solids and dissolved minerals, high flow and pressure gas separators--are believed to be within the capability of current engineering knowledge. The basic technological uncertainty is within the reservoir itself. Given the potential magnitude of the resource, early efforts running parallel to the above reservoir studies, should be made to systematically investigate development alternatives.

The state's hydrothermal resources in west and central Texas are not of the potential magnitude of the geopressured resources but may be of major significance to the areas in which they are found. These resources may be suitable for electricity production (west Texas only) and for direct thermal utilization in space heating and cooling, water heating, process applications, and other uses. The technology for hydrothermal development is in large measure already available. Numerous locations throughout the world are currently using hydrothermal resources to produce electricity and for direct thermal applications. Development of improved and additional technology is already underway by the federal government and industry. The basic need regarding Texas' hydrothermal resources is to define the resources' extent and potential for commercial development.

Economic Potential

The successful development of geothermal resources will be of substantial economic significance to Texas. Because of similarities with oil and gas development, much of the technology, manpower, and expertise needed in the prospective geothermal industry already exists. Although many questions must be resolved prior to commercial development, the hesitancy industry has toward expanding into new and unfamiliar resources may not be as great with geothermal as with some alternative energy sources. In fact, if the economics for private development of the resource can be established, geothermal resources may provide significant economic stimulus to the Texas economy, including employment opportunities for experienced workers in related industries.

The geopressured resource has special economic significance to Texas because of its proximity to the energy intensive industries of the Gulf Coast. The Gulf Coast is also an area whose future economic growth may be inhibited by environmental limitations, particularly by air quality. The development of geopressured resources in this area may provide a source of environmentally clean energy and feedstocks which are of significance to economic growth in the region.

The less extensive hydrothermal resources may be of equally important local significance. These resources are potentially usable for commercial and residential purposes and for low-temperature industrial purposes. Especially significant in west Texas is the potential agricultural use of geothermal energy as a substitute for natural gas.

Barriers to Development

Major deterrents to the development of documented geothermal energy resources are (1) insufficient experience with geothermal energy which results in investor hesitancy and (2) uncertainty over geothermal economics which in part results from insufficient operating experience and in turn results in increased investor hesitancy. Geothermal demonstration projects, tax incentives to developers, and federal policies which reduce development risks are needed to reduce investor uncertainties. Major investment uncertainties with regard to any geothermal development currently result from several regulatory and taxation policies. The future impact of Federal Safe Drinking Water Act regulations on waste water injection and on geothermal (as well as oil and gas) development is a regulatory issue of special importance. Credit for intangible drilling costs and a resource depletion allowance for geothermal wells are of importance if geothermal developers are to effectively compete for financing in existing capital markets. Inclusion of intangible drilling costs as a business expense is one of the President's energy proposals.

LIGNITE

Coal is widely recognized to be the world's most abundant fossil fuel resource. Perhaps surprisingly, Texas, a state noted for its relative abundance of oil and natural gas, also has approximately 130 billion tons of coal resources, equal to roughly 7% of total U.S. resources. To emphasize the magnitude of Texas' coal resources, Figure 14 illustrates that if 25% of this resource could be recovered, coal would represent more than triple the energy potential of the state's proven oil and gas reserves combined. Coal reserves recoverable by existing technology, although considerable, equal only 1 - 5% of total Texas coal resources, substantially less than the 25% recovery factor mentioned above. Even if significant quantities of coal could be mined, many technical, economic, environmental, and institutional barriers would constrain its use. The magnitude of these barriers is indicated by the fact that in 1976, Texas, the nation's greatest energy consuming state, derived less than 3% of its total energy supply from coal. The energy potential of Texas' coal and the need for research to develop new mining and utilization technologies so that this potential can be used are self-evident.

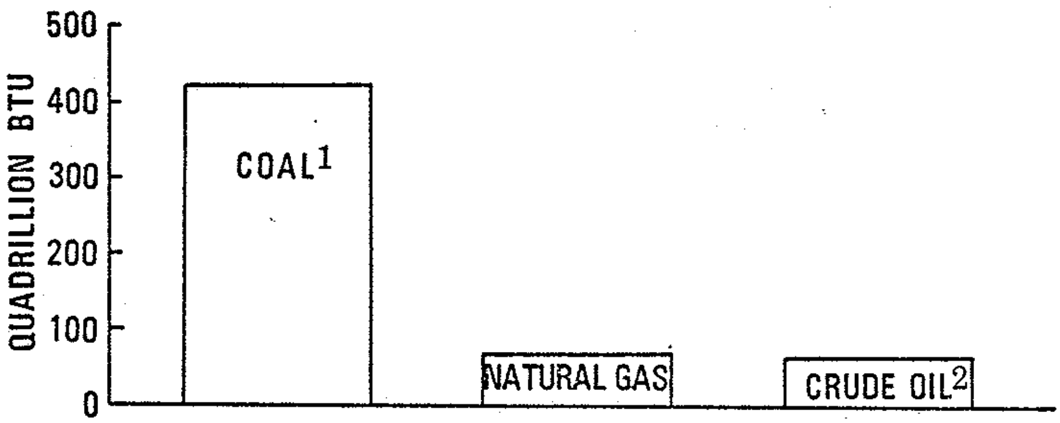

Fig. 14. Comparison of Potential Coal Reserves and Proven Gas and Oil Reserves (1976)

[1]Assuming 25% recovery and an average heat value of 13 million Btu per ton

[2]Includes natural gas liquids

The majority of coal in Texas is lignite, a low rank coal found in two parallel bands running from south Texas northeasterly through central Texas to the Arkansas and Louisiana borders. Lesser amounts of bituminous coal are also found in Texas, primarily in the north-central portion of the state. In 1976, coal production in Texas exceeded 14 million tons, making Texas the nation's eleventh largest coal producing state. By 1985 Texas production is expected to quadruple.

The rapid growth in lignite use is attributable to several different factors: oil and gas reserves are declining and prices rising, technology already exists for specific methods of coal production and use, manpower skills associated with oil and gas use are similar to those required for coal use, capital and operating costs for many existing coal technologies are competitive in today's marketplace, and current government policy is directed toward expanded coal use.

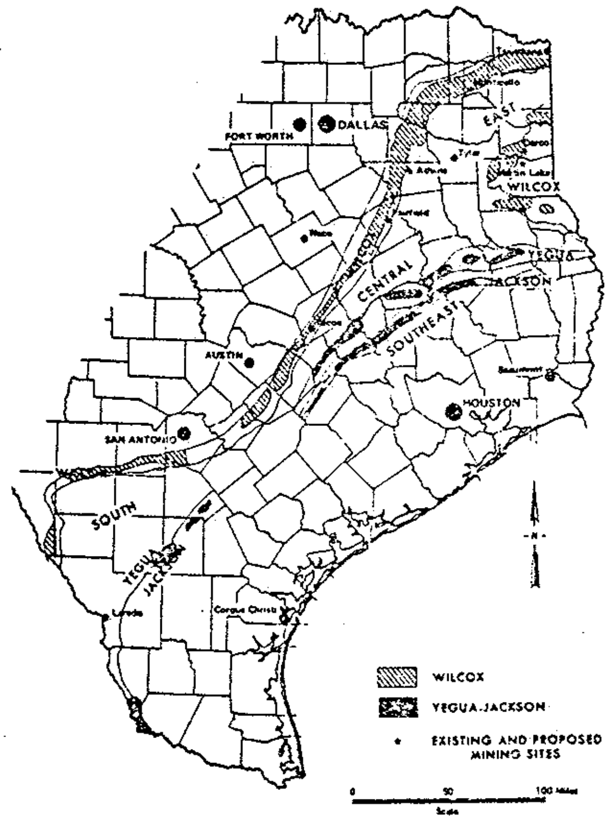

Fig. 15. Texas Near-Surface Lignite

Because of lead time requirements associated with large-scale energy projects, coal use in Texas through 1985 is well defined. The potential for increasing coal use after 1985 is much less certain, however. To provide a better understanding of the possibilities for expanded coal use in Texas, it is useful to identify and discuss the sectors of the economy which will be influenced most by the use of coal.

Mining

By 1985 it is anticipated that lignite production in Texas will reach 55 - 60 million tons per year. Of this production, almost all will come from conventional surface mining technology as is in use today. (Because of hydrological and structural problems associated with Texas lignite geology, conventional underground mining cannot be used.) Lignite seams up to 10 feet thick overlain by unconsolidated and undifferentiated overburden will allow most surface mining to occur at a cost of under $5.00 per ton (equal to approximately $0.40 per million Btu). As compared to other regions of the country, reclamation of mined lands in most areas of Texas can be readily accomplished with minimal environmental impact. The major issue of concern in surface mining is the potential impact of surface mining on water quality and supply. Recent regulatory changes require that greater attention be given to these potential impacts prior to mining. Significant quantities of lignite may be removed from production unless these impacts can be minimized.

Given the projected demand for lignite, the magnitude of the state's recoverable reserves is of major importance. Given 1985 production levels, surface mineable reserves may be depleted as early as 2010 (U.S. Bureau of Mines IC 8531). Other sources contend, however, that reserves are substantially greater and may last for more than a century. It should be noted that expansion of production levels to in excess of those projected for 1985 will reduce the projected lifetime of these reserves. If Texas is to place significant future dependence on lignite, a more definitive understanding of the extent of near-surface reserves is essential.

Only 10% of the state's lignite resource is believed to exist at surface mineable depths. Ninety percent of the total resource is located at more than 200 feet below the surface, too deep for economical recovery with existing technology. In order to recover these deeper resources it will be necessary to develop new technology. The potentially most important technology is the conversion of the in place (*in situ*) resource to a more readily recoverable gas or liquid. Significant interest currently exists in *in situ* gasification to produce a low to medium Btu (100 - 350 Btu/scf) gas. Although similar technology has existed in the Soviet Union and is being tested at several locations in the U.S., substantial technological and environmental questions must still be answered before commercialization of this process can occur in Texas. Development of this technology could allow recoverable reserves to approach 25% of total resources as discussed earlier and would significantly expand the future role of lignite in Texas.

Electric Utilities

As a result of the factors identified earlier, the electric utility industry in Texas is moving rapidly to convert from the use of natural gas to dependence on alternate fuels, primarily coal. In 1970, the state's electric utilities were essentially 100% dependent on natural gas. By 1976, dependence on natural gas had declined to 86%; coal accounted for 12% with oil and hydroelectric accounting for the balance. According to the utility industry, by 1985 the fuel mix will be as shown in Table 2.

Fuel Source	Percent
Natural Gas	20
Oil	21
Coal	43
Nuclear	16
Hydro	<1
Total	100

Table 2. Texas Electric Utility Fuel Distribution (1985 Projected)

In terms of actual natural gas use, 1985 gas use will equal approximately 42% of the volume used in 1975. At the same time, lignite use will quadruple and total coal use will increase sixfold.

The conversion of the utility industry to alternate fuels is in large measure a function of the relationship between fuel price and electricity price, the growth in demand for electricity, and commercial availability of proven combustion technology. Given these three factors, utilities have moved rapidly to build coal-fired generating capacity as a supplement to and replacement for existing natural gas-fired facilities. The major need for electric utility-related research is not to improve economic viability, but rather to demonstrate environmental acceptability.

As is widely recognized, coal is less environmentally desirable than natural gas. Even assuming the mandatory use of stringent air pollutant emissions control technology, statewide utility and industrial emissions of particulates, sulfur oxides and nitrogen oxides are projected to cause an increase in total emissions of these pollutants of 7%, 28%, and 32%, respectively. Localized increases in emissions and their impacts on ambient air quality and public health and welfare are not known. It is well known, however, that any plans to increase the use of coal, will also have to comply with state and federal environmental policies. An objective assessment of the environmental effects of increased coal development and methods and policies for mitigating adverse impacts is essential if the state is to develop an understanding of the relationship between energy development and environmental quality.

Industrial Users

As opposed to electric utilities, industrial consumers (e.g., petrochemical plants, refineries, pulp and paper mills) face significantly different problems in converting to coal. This recognition is especially important in Texas because industrial energy consumption accounts for almost one-half of the state's energy demand and roughly double the energy demand of the electric utility industry. Also of importance is the concentration of much of the state's industry along the Gulf Coast and the interdependent complexity of these coastal industries.

The problem facing coal use by industry is that environmental and logistical problems can make conversion of existing facilities to coal or construction of new facilities impossible while industrial interdependence and capital intensity of these same facilities frequently make relocation economically infeasible. Significantly, the Gulf Coast region in which much of Texas industry is located is also in non-attainment of national ambient air quality standards. As a result, industry, although faced with the same increases in natural gas prices and the same regulatory programs to restrict natural gas consumption as the utility industry, has not moved quickly to other fuels. Conformance with Railroad Commission Docket 600 requirements to reduce natural gas consumption in 1985 by 25% below 1974-75 levels would require replacement of 0.95 quadrillion Btu of natural gas by other fuels (assuming 2.9% annual growth in industrial energy demand). If petroleum products are also curtailed by 25%, 1.3 quadrillion Btu of alternate fuel will be required. If coal were the sole substitute fuel, the demand would be 60 - 80 million tons. Total elimination of oil and gas by 1990 would require the replacement of 3.4 quadrillion Btu (210 million tons of coal). To date, announced and anticipated plans for the use of coal total less than 10 million tons. What can be done to reduce the gap between conversion requirements and plans?

Major options for reconciling the conflict between demands for reducing natural gas and petroleum use and improved environmental quality are increased efficiency in energy use and application of environmentally superior technologies. One such technology is the gasification or liquefaction of coal at an environmentally and logistically acceptable site and transporting the product fuel to existing facilities which could not use coal directly. Such a process would allow the continued use of existing facilities with only minor modifications. Another alternative technology might be the use of fluidized bed combustion processes which promise to reduce air pollutant emissions.

Commercial, Residential and Transportation Uses

The potential for direct utilization of lignite by the commercial, residential and transportation sectors is small. Preferred approaches to coal use by any of these sectors is the conversion of coal to electricity or synthetic fuel at a large industrial facility and transportation of the product to the consumer. The advantages of this approach include greater ability to benefit from economies of scale and ease of controlling emissions from a single, large plant as opposed to multiple, small units. The major factor inhibiting development of synthetic fuel technology is the high cost of the synthetic crude and gas products, normally estimated at the equivalent of $18 - 25 per barrel of oil.

Barriers to Development

The impact of coal development on the Texas economy will be enormous. In 1976 lignite satisfied approximately 4% of the state's industrial and electric utility energy demand. By 1985 utilities and industry will be using lignite and imported coal for approximately 25% of their fuel needs. The National Energy Plan suggests that by 2000 roughly 4 Quad, one-half of the state's projected industry and utility energy requirements, will come from lignite and coal. The total cost for mining equipment, transportation facilities, boilers, and other equipment needed to allow this development is conservatively estimated at $30 billion (1977 dollars). By 1985 the increased use of coal will directly result in approximately 12,000 new jobs. Indirect impacts will be even greater. Coal conversion programs of this magnitude and related activities will result in significant demands on the state's financial resources.

Production and utilization of substantial quantities of lignite will not only affect the state's economy, but will also force environmental and institutional changes. The environmental consequences of developing coal, a dirtier fuel than oil or natural gas, will be significant. Water pollution, land disturbance, and air pollution will occur. Air pollutant emission increases will be especially significant for sulfur and nitrogen oxides. The extent of these impacts can be reduced by the development of control technology, however. Siting restrictions on the location of new coal facilities near urban areas will force most new facilities to locate in rural areas. The influx of workers into these areas will strain existing social and economic structures and will provide a major challenge to local governments. The success of coal conversion programs will in significant measure depend on the ability of local governments to meet these challenges.

BIOMASS

John Quarles, former administrator of the EPA, has said bioconversion "may provide short-to-medium term increment to energy supply while reducing a major environmental problem--solid waste--and may become in the longer term a substantial, clean source of energy supplies." More specifically he predicted one home or office out of ten could receive electricity generated from municipal solid waste (MSW) by 1980. By 1985, 1 to 3 Quad/yr. (quadrillion Btu/yr.), and, by 2000, 6 Quad/yr. could be produced from MSW (Quarles, 1976). Based on ERDA projections of demand in that year, this estimate represents 5 to 6% of total U.S. energy demand by 2000, from MSW alone. Donald Klass, the Institute of Gas Technology, Chicago, Ill., approached it differently, saying the potential oil production from U.S. wastes, including agricultural wastes, was 1.098 billion barrels in 1971, about 15% of the oil consumed and 77% of the oil imported in that year. For 1980 he projected 1.33 billion barrels of oil or 10.6 tcf of SNG could be generated from wastes.

The ERDA (now DOE) also made an effort to estimate reasonable potential for bioconversion. Calling biomass conversion a "near-term" fuel source (between now and 1985), ERDA stated it should contribute 2.5 Quad/yr. by 1985, generally agreeing with the EPA and 4.5 to 9.0 Quad/yr. by 2000 (ERDA, 1976).

Recent stirrings in ERDA indicate, however, that the long-range potential may be much larger. Hearings were called by an ERDA assistant administrator to consider whether biomass conversion was receiving adequate attention. Long-range energy supply from biomass in the broader sense may only be limited by the extent of efforts exerted in this area by government and industry in the future.

These are just examples of estimates being made by reputable and knowledgeable individuals, companies, and agencies. No doubt exists, however, that much of the waste and other biomass resources in Texas is widely dispersed and expensive to collect. For this reason MSW, other waste already collected, and some concentrated agricultural wastes hold the greatest near-term resource potential. Availability of capital is not seen as limiting expansion of waste conversion by the industry (EPA, 1976).

Regarding MSW, economies of scale may be a limiting factor to consider. The EPA states in several instances economics appear to dictate that MSW processing plants be built to accommodate nearly 500 tons per day of refuse. This scale requires a population of roughly 200,000 persons, or access to nearby agricultural or other wastes. U.S. News and World Report noted (May, 1976) there are over 50 urban centers in the U.S. that could support 1,000 ton-per-day plants and over 200 cities with populations capable of supporting plants of 250 to 1,000 tons per day. The EPA noted that a 600 mw(e) coal plant could dispose of 1,400 tons per day of refuse-derived solid fuel (RDF), while providing 10% of its fuel requirements. For every two tons of RDF burned, one ton of coal is saved. The Deely coal plant in San Antonio is being designed for this purpose.

Disposing of large amounts of solid wastes in a constructive manner solves other problems as well. The Texas Department of Health Resources has given the City of Houston one more year on its present landfill before it must be closed. While that agency does not yet have the authority to compel the use of resource recovery or waste reduction plants, the cost of another landfill may be incentive enough. Public pressure is also making landfilling a less acceptable alternative.

In a report to the Governor's Energy Advisory Council, Drs. Halligan and Huffman of Texas Tech stated (1974) that nine Texas cities or metropolitan areas were ideally suited for resource recovery plants. The areas included were: Austin; Beaumont-Port Arthur-Orange; Corpus Christi; Dallas; El Paso; Fort Worth; Houston; Lubbock; and San Antonio. Plants equipped to co-fire RDF with coal, like the Deely Plant, are the exception in Texas, but many alternatives for conversion are available. Fluidized bed combustion and pyrolysis are used to dispose of industrial wastes in a clean and acceptable manner, creating thermal energy or fuel as a by-product. Also, with relatively minor boiler changes, refuse derived fuel can be burned with oil quite successfully.

Agricultural wastes in many parts of Texas also offer a viable energy resource of particular significance on a localized basis. The wood and forestry industries have set the example in this respect. Together they now obtain about 37% of their energy needs for milling and pulping operations from wood scrap and bark. A recent survey (Stanford Research Institute, 1976) showed that 12.8 million tons of crop residues are generated yearly in Texas, over 9 million of which are either left in the field or disposed of at a cost. Where this residue exists in reasonable concentrations, particularly near rural communities, it could be a significant energy supplement to municipal solid waste. This is supported by a recent study completed for the TEAC (Vliet, et.al., 1977).

Additionally, the survey found that over 2 million tons of animal manure are generated yearly in Texas. This residue, however, is seen as more valuable than crop wastes as a fertilizer, and only slightly more than 675,000 tons generated at feedlots were unused or disposed of at a cost. This resource is therefore less significant as a potential fuel source on a statewide basis than agricultural or municipal solid waste. In selected areas, however, where the concentration is high (and also a problem) and ample sun is present for natural drying, manure conversion can be profitable.

Now consider these two resources together as an energy source for Texas. It must be conceded that wastes have a limited potential. In a study done for the Governor's Energy Advisory Council (Halligan and Huffman, 1974) the total potential energy from MSW and ASW in Texas was estimated to be 27 million barrels of oil equivalent annually. The realistic potential, however, for nine metropolitan areas and 2.4 million cattle gathered on feedlots in the High Plains was estimated to be 14 million barrels of oil equivalent annually. Assuming that manure continues to be more valuable as a fertilizer in some cases (in about the proportion reflected in present usage), a reasonable potential contribution would be between 10 and 12 million barrels of oil equivalent yearly. Texas has for years produced nearly 3 million barrels of oil daily. This amount is declining but it helps give a sense of proportion. Waste is valuable, there just isn't enough of it to make a major contribution. Another way to consider the potential of waste is to look at per capita waste generation and energy consumption. Including both MSW and ASW, about 6 lbs. of waste are generated daily for each Texan (30,000 Btu/person/day). But we each consume daily nearly 1.5 million Btu on the average. So the real potential contribution of waste for filling energy demand must be less than 2% statewide.

Looking toward the more distant future, energy crops appear promising to Texas. The two major exports of the state are now agricultural products and energy. How unrealistic is it to expect that in the future these might often be one and the same, or that energy exported might be derived from agricultural produce? The real potential of the technologies developing for disposal or conversion of wastes is linked with energy crops or "energy farming."

Probably the ultimate energy (and possibly food) source will be the oceans. It is physically impossible for the world's population to eat like Americans do now without resorting to the seas. Likewise, fossil and nuclear fission sources cannot sustain energy growth as we experience it now. In addition to land-based energy farms, ocean farming could be a significant contributor to our energy supply through bioconversion in the future.

Commercialization

The Texas Department of Health, Division of Solid Waste, is the lead state agency for municipal waste disposal. The Department of Water Resources retains responsibility for industrial and agricultural waste disposal where water pollution is a problem. Under an EPA grant made possible by the Resource Recovery and Conservation Act, the two agencies are beginning a systematic planning process to identify waste resource regions in Texas and to evaluate the potential of recovering materials or energy from wastes. Perhaps the major conclusion of an earlier study completed for TEAC (Vliet, et.al., 1977) is that the solar energy source showing the greatest potential for cities of 30,000 or less population, is biomass. This is particularly true for East and Southeast Texas. One of the major institutional barriers, as seen by the bioconversion industry, is the difficulty which arises in dealing with ambiguous organizations like "cities". A primary concern is lack of a local organization with negotiating authority as well as planning or operating authority for a waste conversion facility.

Another immediate need is for a demonstration of existing conversion technologies which involves local government, utility and/or industry participants. Again, empirical data, hands-on experience, is needed to increase user confidence, optimize system designs, and allow evaluation of realized economic benefits. The use of waste for generation of synthetic fuel gases or liquid fuels including alcohol is of particular interest. Although the construction of such facilities is very expensive, it is potentially profitable.

In the area of energy crops, a good deal of research and development remains to be done. Methods of harvesting and collection are of particular importance and compose a large part of total biomass resource costs. Investigation of the relative worth of various energy crops is also needed.

WIND

Although its potential statewide is considerably less significant than direct use of solar radiation, wind energy could be a substantial source of energy for subregions of Texas. Previous studies performed for the TEAC indicate that relatively high wind energy potential exists on the high plains areas of the Panhandle, and along the Gulf Coast. While published knowledge of wind characteristics is sparce or inaccurate, data indicate a level of magnitude which supports further research and development of wind energy conversion technologies on the part of Texas.

The generally level terrain characteristic of the two Texas areas of high wind potential also suggests that generation of electricity over large areas may be an appropriate application of wind technology here. In addition, task-specific applications of wind conversion systems show potential for replacement of fossil fuel use. Examples of this second class of applications include pumping of either water or oil, cathodic protection, or provision of electric or mechanical power at remote sites.

Over 45,000 irrigation wells in the high plains use natural gas for irrigation pumping. Roughly 125 trillion Btu of energy, or 125 million mcf of natural gas, are consumed for this purpose alone (Texas Department of Agriculture, 1974). It is reasonable to expect that 15 to 30 percent could be replaced by wind generated power, contributing 20 to 40 trillion Btu by 2000. Although total potential is considerably greater, market penetration is likely to be affected by receding water tables, a return to dryland farming, and/or reduction of farming generally in arid regions. Oil well pumping shows similar promise, with similar limitations.

The potential for electric energy generation with wind conversion systems is difficult to define due to the many technologies/resources which will compete with it in the future. Solar electric, biomass conversion, and coal, for example, compete with wind in this area. In addition, along the Gulf Coast the relative cost of power from geothermal or ocean thermal sources will be a determining factor. Also, should problems of nuclear safety and waste processing/disposal be resolved to the public's satisfaction, nuclear power could also compete for electric investment dollars.

Generation of electric power with wind energy could possibly develop along two lines: large-scale utility or industry owned plants and small-scale consumer owned plants. The potential of the first class of plants obviously depends on the attitude of Texas utility and large industry concerns. Potential use of either class depends also upon development of technologies in the area of both storage and the linkage of wind energy conversion systems to specific applications. In addition, while consumer attitude toward utilities may affect the potential market for small-scale systems, utility rate structures will also be an important factor. Assuming, however, that technical development and relative economic cost become favorable, wind generated electricity could reasonably provide 3 billion kwh of electric power annually, replacing roughly 30 trillion Btu of fossil fuels by 2000.

If this level of electric power is via large scale plants, the economic impact on Texas would not likely be significant. On the other hand, if small wind systems are used, it is extremely likely that it will be partially due to regional production capabilities, lower shipping costs, and availability of services. Mass production potential, a greater investor market, lower risk, and technology involved all combine to make such small-scale systems appear very attractive.

Commercialization

Both the potential markets and potential barriers for use of the wind as an energy source were discussed briefly above. As in the case of solar thermal and solar electric technologies some applications seem economically feasible or near feasible at present and mass production capabilities can still greatly reduce costs. In other areas, technical developments in systems or peripheral systems are still needed to improve commercial potential. And, as with most new technologies, social and institutional barriers exist. Generally those areas which can be expected to influence market development for wind machines can be discussed under three headings: resource availability, technical and commercial development, and utility interface.

As mentioned, two broad areas of the state appear to offer excellent wind conditions, but actual data now available is somewhat sparce. Those involved or potentially involved in wind energy development indicate that better, more reliable, empirical data is needed before investments are likely to be made on any large scale.

Resource availability could also be seen to include wind rights and capital availability. Availability of continuous access to winds on one's property, as in the case with solar radiation, are nowhere guaranteed by law at present. This could be an important factor, particularly in non-rural settings (where most of us live and consume energy) given the sizable capital investment required to use all the "free" wind energy. Other legal or social barriers which will have to be addressed include safety (primarily regarding blades) and environmental problems such as effect on migrating birds and interference with communications.

Also important is capital availability. Even if there are savings and provisions for tax relief, capital is still required by the potential user. In order for firms to develop the mass production and distribution capacity needed to bring costs down, additional capital is required. Once costs do drop, capital will be more readily available, of course; but, where does this circular barrier break?

Under the general category of commercial development are included the demonstration of appropriate applications and technical developments where such are still required. Demonstrations can be useful in giving hands-on experience to user groups as well as in producing empirical operating data to demonstrate commercial feasibility. In addition, demonstration of wind energy applications can be a beneficial experience for a Texas manufacturer trying to break into a developing marketplace.

The potential for technical developments in wind energy conversion is still great. Developments in blade design for horizontal--and particularly vertical--axis machines, augmenting subsystems or peripheral equipment, and other new or innovative concepts could well mean significant breakthroughs in commercial feasibility.

In the area of utility interface, several problems may surface as use of wind energy becomes more prominent. Two areas have been suggested already. First, how do utilities see themselves becoming involved as owners of wind facilities, and how would the variable nature of wind affect their load profiles? Second, how will utilities deal with the load variations potentially created by widespread use of small-scale systems by their customers? How will rate structures influence user decisions or economics? Will the utilities provide backup at average prices? Can utilities buy power from customers and at what rates? Solutions to utility interface problems, while national in scope, will likely be utility-specific.

CONSERVATION

In the United States and Texas, energy use has been increasing at an exponential rate. In 1975 Texas' use of energy amounted to 7,053.4 trillion (10^{12}) Btu or 3.97 trillion cubic feet of natural gas, 545 million barrels of petroleum products and 12.4 million tons of coal and lignite. Although conservation efforts have contributed to reduced energy use in the industrial sector, all other sectors have continued to increase their energy use after a slight decrease following the Arab embargo.

Proved reserves of oil and gas have been declining in Texas since 1965. The production of oil and gas peaked in 1972 and has since declined. Currently the reserve to production ratio for petroleum is 8.6 years and for natural gas is 10.1 years. (The reserve to production ratio is the number of years remaining in existing proved reserves prior to their depletion at current production rates. It is derived by dividing the present proved reserves by the present production rate.) As the production of oil and gas decreases and the consumption increases, the gap between supply and demand is being filled by increased foreign imports. In 1976 the United States imported over 42% of its crude oil needs. Coal, nuclear, and solar energy sources will require additional lead time before they can begin to replace oil and gas as major energy sources. Some environmental issues also need to be resolved prior to the widespread use of coal and nuclear sources in Texas. Energy conservation is the most immediate and economical solution to closing the gap between domestic supply and demand since one barrel of oil saved by conservation is less expensive and can be realized sooner than one gained by increasing production.

Energy growth and economic growth are not inseparable. Through the process of more efficient end use, energy growth is checked while economic growth can continue. Energy conservation does not mean doing without, it means better and more efficient use of what energy we have.

Industrial Energy Use

Energy conservation measures may be broadly categorized into two major groups. The first group consists of "quick fix" measures which require little or no capital. The second group includes "capital intensive" measures which require larger expenditures of capital and longer lead times.

Among the quick fix measures are such items as operation and maintenance improvement practices. These will include repair leaks in the energy flows, shutdown of idle equipment, closer monitoring to maintain efficient design operation, and regular maintenance to insure that equipment is at top design efficiency. Measures such as these are in the realm of proper use of current technology and installed equipment and will not necessarily require an extensive research effort.

Rather large energy savings can be realized through the application of quick fix measures. However, further incremental savings require greater investment of capital and more ingenious application of resources and technology. It is in this area that research programs by the federal government and industry have concentrated.

Among the most promising technology research areas are combustion efficiency improvements, process changes, cogeneration, waste heat recovery, waste product recovery and use, and instrumentation for control and monitoring.

Currently, the federal government and industry are expending a substantial amount of effort to develop methods of improving combustion efficiency. Much work has already been done and is continuing. The major goal to be realized now is to establish widespread use of these methods.

Process change is an area in which much research will be needed. In order to go beyond the limits of efficiency improvements with current technology we must find new and innovative methods of production and manufacture. Such innovation will require complete replacement of present methods in many cases. Necessarily, these changes will be industry or even plant specific. Under rising fuel prices the effort of industry to find new processes will be stimulated by economic conditions. Much capital will be expended in this effort but the energy savings realized will pay back the investments many fold.

Cogeneration is a major area in which savings can be realized. The technological problems in this case, however, may be dwarfed by the institutional, legal and regulatory problems. Each cogeneration facility also has a different set of contractual conditions. Much of the research that is needed deals with ways of overcoming these non-technical barriers. This research can be very extensive and expensive and may apply only to one particular project between a utility and an industry.

In the generation of electricity and in many industrial processes, large quantities of low temperature heat are rejected to the environment. Two problems are inherent in this situation. First, much energy is lost that might otherwise be used if a different method of generation and utilization were found. Secondly, the rejected heat has the potential for degradation of ecological systems in the area of discharge. Both the federal government and private industry are directing much effort to the area of waste heat.

Along the same lines, waste product recovery and use also hold potential for energy conservation. With careful research much of what is now considered waste can be put to use. Industry is involved presently in finding ways to accomplish waste product recovery. Their efforts will be stimulated by economics and the controlling conditions on a particular plant or process.

In the future there will be greater reliance on more instrumentation and automated controls. This area holds much potential and is being commercialized by the major suppliers of computer equipment.

Overall the industrial sector has greater incentives for conservation and greater awareness of its energy problems than the other sectors. The rising cost of energy has encouraged investment in measures which have attractive short-term paybacks and also in research for future measures. Necessarily this research requires substantial sums of money. With the exception of projects having potential for large matching federal funds it is not likely that State investment in large industrial research projects will have a significant impact.

Transportation Energy Use

Transportation accounts for about 22% of Texas energy use. As a process, it is the largest single use of energy nationally and in the state. The private automobile accounts for 62% of transportation energy use. As such, improvements in private vehicle travel will have the greatest immediate impact on energy conservation in this sector.

Until recently the American automobile has been large, heavy, powerful, and fuel consuming. High axle ratios to provide power, high compression engines which require more refined high octane fuels, and heavy bodies loaded with luxury power options have added penalties in fuel consumption. However, fuel economy can be improved by various changes in the present design of automobiles. There are three basic areas in which changes could be made--the engine, the power train, and vehicle weight. Of the three, vehicle weight offers the highest and most immediate payoffs.

In the immediate future the urban public transit systems have a limited capability for serving additional trips and thereby reducing automobile travel. The Office of Technology Assessment has concluded that automobile energy conservation strategies of various kinds are more effective than mass transit incentive strategies in reducing oil consumption. In a study by the Texas Transportation Institute it was found that in the long run, transit might serve as many as 15% of urban trips, reducing statewide transportation fuel consumption by about 1.8%. Table 3. gives a comparison of energy savings through implementation of various strategies.

Achieving major increases in the use of mass transit has long range implications beyond pure energy conservation. Mass transit has its greatest impact in urban areas with high population densities. In Sweden decisions to increase urban transit have been made on a variety of factors other than energy conservation such as transportation availability, congestion, and air pollution. Existing patterns of metropolitan growth are not conducive to major increases in the use of mass transit. Recent studies by the Council on Environmental Quality indicate that substantial savings in energy consumption could be achieved by fostering less scattered patterns of metropolitan settlement.

Strategy	Maximum Savings (% Transportation Energy, 1985)
1. One less urban trip per household	7.7
*2. 43% auto efficiency improvement	32.2
3. Increase work trip auto occupancy from 1.1 to 2.0	7.2
4. Triple urban transit usage	1.8

Table 3. Comparison of Texas Transportation Energy Savings

*Federal legislation (Energy Policy and Conservation Act, December 22, 1975) calls for a 43% improvement by 1980. Industry is making strides to meet this goal and has already achieved a 26.6% improvement from 13.9 mpg in 1974 to 18 mpg in 1976.

Other than improving vehicle efficiency, changing driver habits by carpooling or trip planning is a major strategy for reducing gasoline consumption. Such a strategy could be implemented through public awareness campaigns. Research in the transportation area, especially in mass transit, requires large investment. Unless large sums of Federal matching funds can be attracted, it is unlikely that the limited State funds can have a significant impact in the currently existing research effort in the area of transportation.

Residential/Commercial Energy Use

The residential/commercial sectors account for approximately 21% of the State's energy use. Of this the major use is for space conditioning. Unlike the rest of the country cooling is the biggest single load in this sector in Texas. Strategies to reduce the energy use for air cooling would have the greatest impact on residential/commercial energy use.

In the national research effort residential cooling receives less attention than heating. There is a direct correlation between the size of the building and the amount of research and design effort expended, most research being aimed at large structures. Unfortunately there is a reverse correlation between occupancy and size of building, since most people live in small buildings such as single family dwellings.

For the reasons described above the greatest potential for accomplishment through energy RD&D in the conservation category lies in the residential/commercial sectors.

Two potential approaches to the provision of desirable comfort levels in commercial and residential facilities are development of improved dehumidification systems and demonstration of the acceptability of higher temperatures under circumstances of air movement, distribution, and ventilation. These are concerns that are closely related to local conditions so that research efforts at the regional level can have their greatest impact.

Hot water heating is another area in which the development and demonstration of more efficient systems could produce early and significant results with near-term commercialization almost assured. While some hot water usage might be eliminated, much of the remainder might be provided through utilization of heat which is now wasted from air conditioning and refrigeration equipment.

Improved thermal storage systems would provide assistance in both space heating and cooling and water heating. At the same time such systems would aid in balancing the electric power load factors for increased energy supply efficiency.

Another major area of commercial concern which is of regional significance to Texas is the need for improved irrigation efficiencies which would reduce energy demand from the agricultural sector or divert such demand to renewable resources.

It is readily evident that the significant RD&D needs with conservation potential involve the application of technologies related to one or more of the alternative abundant energy sources specified for development under the Texas Energy Development Fund. Therefore there is high potential for the combining of projects which cut across technological categories as suggested in the administration plan for the fund (see Volume II).

INSTITUTIONAL CHANGES AND THE CAPITAL PROBLEM

The U. S. government has made strong commitments to objectives of reducing the growth rate, and even the actual level of crude oil imports as a method of protecting national security and reducing the drain on the balance of payments. The U.S. government has also made strong statements about equitable distribution of energy costs and policies to diminish the impacts of rising energy costs on low income residential consumers and other special interest groups.

Almost all changes in fuel consumption patterns and the development of new technologies to utilize developing resources require major outlays of capital. Some questions exist as to whether the private sector, unassisted, will provide capital at a rate sufficient to meet requirements to satisfy sectoral, equity and national security goals being expressed by governments.

Investment Decisions and Energy Production

Onshore oil and gas production lead times require from one to three years of capital commitments from drilling to delivery phases before returns on investment begin. Offshore lead times may be as long as five to ten years because of more complex drilling operations and federal leasing policies.

Nuclear power plant operation has in recent years required up to ten years from planning to licensing periods before the plant can begin earning a return on investment. Coal fired power plants will require scrubbers in the future and this requirement will lengthen the time between commitment and actual operation.

Coal mining operations in the West must be preceded by Federal leasing before strip mining operations can begin. The opening of new mines requires several years time between investment commitment and actual production of coal.

The pervasiveness of government regulation in each of these energy supply industries adds to the uncertainty about future outcomes from current investments. Capital investment commitments are large and lead times are great. The value of these investments are for long time periods a direct function of government energy policy and regulations.

Investment Decisions and Energy Consumption

Lead times for major consumption pattern changes are likewise great and few substitution possibilities exist without investment in capital equipment. About seven years is required to completely change the existing stock of automobiles. Highway systems built for the family automobile cannot be transformed into mass transit systems. Home furnaces manufactured to burn natural gas cannot be converted to oil or coal.

Boilers for producing steam to drive electric power generators can be converted from gas to oil but not to coal. Therefore, the substitution of coal and nuclear generators for gas and oil will take many years and large amounts of capital investment.

Government involvement in the consumption of energy, especially regulations on automobile production and requirements for phasing out oil and gas fired boilers, adds another source of uncertainty to investment decisions by individuals and corporations.

Regional Development Banks

Since governments are not likely to relinquish authority over major energy supply and demand activities, and since goals of reduced oil import levels and social equity will not be automatically achieved by private decisions, other government solutions may be required. Energy development banks could be created by government for the expressed purpose of stimulating investment in energy production and conservation activities.

Such banks could be regional to address regional-specific differences in resource base, climate and other factors. The banks would operate through existing banking institutions to make low cost loans for energy purposes. The banks could function by providing equity financing, low cost interest rates, or no-interest loans. The balance of such instruments could be determined by objectives of achieving stimulus in areas needing most attention in each region.

A bank approach to stimulating energy production and conservation purposes would place the decisions for investment near the source and would allow evalution on a case by case basis following standard banking practices. Such a system should provide for a minimum of "bad" loans and put decisions about which developments have the best pay-off into the hands of local investors and bankers.

SUMMARY OF RESEARCH NEEDS: A RATIONALE FOR PROJECT SOLICITATIONS

Since early commercialization of technologies being developed is of primary concern in the legislation creating the Texas Energy Development Fund, the State should focus on addressing the development gaps and the barriers to commercialization which have been described. The State should not attempt to compete with the programs of the federal government or duplicate other efforts. At this point, as many reasonable alternatives as possible should be evaluated. If the State program is successful in identifying new and innovative concepts of merit or demonstrating the feasibility of such systems as are excluded from federal commercialization efforts, then the federal government may be compelled to broaden the scope of its programs as well.

The State should not seek to enhance the economic viability of any technology because this quickly results in a misallocation of resources. State involvement should merely be aimed at encouraging and assisting the private sector transition to those contemporary technologies which are or will soon be economically justified or physically required. In some cases, of course, where risk capital is unavailable in the private sector, the State might provide support for research of regional or statewide significance which has not or would not be done by individuals or organizations under normal economic incentives.

On the basis of these considerations and the outlook on energy resources previously described the following discussion summarizes the research needs upon which the solicitation of Energy Development Fund projects is based.

SOLAR

Solar energy has been described as 1,000 solutions to 1,000 problems, and there are indeed a great many approaches to its use. The success of the solar industry will depend on finding appropriate matches between technology and energy needs. In addition, because of the great diversity of solar solutions, provision of consumer protection and development of a responsible, self-regulating industry will affect the eventual success of solar as an energy contributor. These two major objectives are addressed by the specific state RD&D projects described below.

Solar thermal systems for water heating or space heating have achieved a significant level of commercialization at this time and as such do not require subsidy. The incorporation of existing knowledge of energy conservation and passive and active solar systems into building design, however, lags behind development of solar hardware. Many builders are at a loss as to which of a multitude of alternatives available should be used, in what combination, and to what extent. And, omeowners are hard pressed to know what to demand or expect in new homes or lar installations specifically. And, relatively little empirical data exist substantiate the belief that solar heating is now economically feasible. her related problem is a lack of training and experience among those laborers alling systems, particularly with regard to retrofitting existing buildings. r projects 1., 2., and 6.) This has, in fact, created a reat deal of distress se New England states awarded federal grants for rapid installation of solar er systems. Texas installers will face many problems imposed by Texas conditions and building types.

The advent of solar, or solar-assisted, space cooling or refrigeration systems will certainly portend greater impact for Texas than space heating now does. Development of absorption cooling systems is being performed by several private firms, and it appears unlikely that high levels of efficiency will be achieved at the temperatures most economically provided by solar energy. The cooling problem would be reduced significantly, however, if effective systems of humidity control could be developed. By removing humidity (latent heat) and providing air circulation, comfort levels can be reached at temperatures as high as 85 F. Although such dehumidification systems have been understood conceptually for some time, no system is commercially available at present. (Solar project 4.)

Industry, including agriculture, is the largest energy consuming sector in Texas. As described in previous sections of this report, a large amount of fossil fuels is consumed for production of process steam or heat, a commodity easily provided by contemporary solar systems. Although conservation is clearly the first step required of industry, a large potential exists for solar derived process heat. Large scale demonstration would be most useful for a thorough evaluation of present feasibility. The agricultural community in certain geographic regions of Texas is presently threatened with extinction due to both rising energy costs and declining water supplies. New Mexico has done experimentation with the use of small solar greenhouses for heat and food production, but little effort has been expended on consideration of large and very large solar greenhouses. A greenhouse constructed in the Arab desert supplies food for nearly 20,000 people year-round and it is quite possible that such systems could provide a real alternative for Texas. (Solar project 3.)

The federal government and the electric utility industry are both expending millions of dollars for development of large-scaled solar thermal electric plants like the "power-tower." Likewise, the federal RD&D program and that of several major oil companies are concentrating on production of photovoltaic cells (solar cells). A recent comprehensive report from the Office of Technology Assessment, however, suggests that the federal program has overlooked the economic and technical attraction of small-to-moderate sized solar thermal electric systems. If developed, such systems, whether of the dispersed type or scaled-down versions of the centralized type, would have particular significance for large areas of Texas. (Solar project 5.)

In the area of consumer protection, standards for product design and criteria for product testing are being developed nationally. Although the solar industry is still in its infancy, responsible members are already expressing concern over the potential damage of misleading or fallacious advertising. Unscrupulous individuals wishing to take advantage of the general enthusiasm but naivete of the public could do irreparable damage to both their unfortunate customers and the industry as a whole. The state should provide support to the industry or a representative group to help it develop into a mature and self-policing professional industry. (Solar project 7.)

GEOTHERMAL

Geothermal energy is currently being commercially utilized in various locations around the world, but in comparison to the size of the potential resource its use is limited. Primary barriers to expanded use result from the lack of detailed resource knowledge, uncertain economics, lack of industrial familiarity, and regulatory barriers. Although technology for geothermal use is not readily available, the primary reason is thought to be lack of market demand rather than the complexity of technology. To bring geothermal resources in Texas into production, major research efforts must be accomplished in the areas of resource assessment and resource economics: does the resource exist and, if so, can it be economically produced? Above ground technology for the conversion of geothermal energy into electricity and for direct thermal applications either already exists or is sufficiently similar to other geothermal technology developments not to require extensive state funding.

Over the past three years a significant research program has been underway to investigate the potential of the geopressured resources of Texas and Louisiana. Funding from federal, and private university sources has supported resource assessment and other efforts related to this program. The University of Texas at Austin has taken the lead in much of this work. The U.S. Department of Energy, the major supporter of this work has indicated that as the program moves from a research program toward research utilization, direct state involvement and support will be increasingly important.

The other geothermal resources in Texas have received considerably less attention and as yet their potential is not known. Although these resources are similar to those being used elsewhere in the world, development is constrained by lack of resource knowledge and lack of user familiarity.

In the Gulf Coast resource knowledge is such that a resource of substantial importance to the state is believed to exist. Because of its potential significance to the state's economy and people, a systematic analysis of resource development options needs to be initiated so that potential technological, economical, environmental, and social impediments to various development options can be identified. Such analysis will provide the basis for identifying future technology and institutional research needs. (Geothermal project 1.)

Development of the state's hydrothermal resources is currently dependent upon the accomplishment of studies to determine the nature and extent of the resource. The status of hydrothermal resource knowledge is analogous to that of the geopressured resource four years ago. The initiation of a more detailed resource assessment program and planning of future research direction could allow for commercial development within the next decade. (Geothermal project 2.)

As mentioned earlier, lack of user familiarity can be a significant barrier to development of a new technology. At several locations in the state, especially in central Texas, naturally flowing hydrothermal resources exist and are currently being used for recreational and therapeutic purposes. An area in which the state could serve to reduce user hesitancy and increase subsequent commercial use would be to support a demonstration of the technical and environmental feasibility of using a known geothermal resource as an energy source to replace the use of fossil fuels. State support should be directed at a project which has broad application, high public visibility, and reasonable promise of favorable economics. (Geothermal project 3.)

LIGNITE

Because of its nature and present extent of usage, lignite distinguishes itself from the other resources enumerated in the Energy Development Act. Of primary significance, lignite is (1) the only one of these resources currently in extensive use, and (2) nonrenewable. Expressed another way, lignite offers the potential for large-scale contributions in the near-term, but no promise as a permanent solution. The need for state sponsorship of lignite research is not to demonstrate commercial feasibility for such already exists; nor is it to investigate long lead time technology. The emphasis on Energy Development Fund research should be to facilitate the near and medium-term use of lignite as a transition fuel between today's dependence on oil and gas and long-range dependence on renewable resources. The importance of lignite research stems from a single economic reality. Production of oil and gas is declining and substitute resources must be found rapidly. The other resources named by the Act are vital to long-range energy supply, but in the near-term only lignite and conservation are available.

Lignite is needed not only as a boiler fuel to produce steam for electricity and process heat, but in the medium-term also as a potential source of hydrocarbons for use as a feedstock by the petrochemical and other industries in the state. Research must therefore address methods for improving the efficiency of lignite production and use. In order for extensive conversion to lignite to benefit all citizens of the state, consideration must also be given to the environmental impacts which will result from lignite development.

Unfortunately, Texas lignite sometimes has been viewed at the federal level as a resource of local, but not national, significance. Recent federal regulatory actions and awareness of the size of lignite supply and demand have broadened the importance of Texas lignite, however. Therefore it is believed that state supported lignite research programs can reasonably anticipate support from federal and private sources. The availability of external funding can substantially assist the purpose of the Energy Development Act.

In order for lignite to be a major energy alternative, sufficient reserves must exist. Current estimates of lignite reserves vary from less than thirty years to more than a century. This variation has significance not only to the Texas economy but also to the need for and direction of lignite research. In order to develop reasonable state economic and lignite research policies, improved reserve data are very important. (Lignite project 1.)

Currently all lignite production in Texas is by surface mining. Reclamation of surface mined lands is already required under existing Texas law. The recently enacted federal reclamation law requires more attention to water quality and hydrology impacts, however, and may present problems to future mining operations. Because of the proximity of near-surface lignite deposits to fresh water aquifers it is anticipated that these new requirements may restrict mining of significant quantities of lignite. An analysis of the impact of lignite mining on aquifer quality and development of remedial technology are needed. (Lignite project 2.)

Texas consumes more fossil fuel energy than any other state in the nation. The state's economy and her people are both heavily dependent upon energy intensive industries which came to Texas when natural gas and oil were abundant. The conversion of many uses of these fuels to lignite is essential. Currently utilization of lignite is limited primarily to direct combustion in utility boilers.

Research into future lignite utilization needs must consider three normative requirements: finding a replacement for oil and gas in existing facilities, finding efficient methods for lignite utilization in future facilities, and finding methods of controlling adverse impacts to the environment from lignite utilization. The development of technologies such as gasification, improved combustion, and product utilization which can use lignite to satisfy these normative requirements is needed. In some instances, research into the physical and chemical properties of lignite also may be needed in order to better understand and design these lignite utilization technologies. (Lignite project 3.)

As can be seen from the development of other technologies from which broad societal impacts will occur, successful implementations of technology are dependent upon understanding the technology's impacts and controlling or eliminating those which are adverse. Effective control of the environmental impacts of lignite development is contingent upon understanding not only the impacts of individual pollutants and facilities but also upon understanding the aggregate impacts resulting from the development of an entire lignite industry. The identification of potential impacts allows researchers and policy makers to recognize the options for technology development and improves the usefulness of future research. (Lignite project 4.)

The timely accomplishment of needed lignite research perhaps can be best accomplished by the establishment of a permanent laboratory at which ongoing research programs could be conducted. A significant consideration in the establishment of such a facility is the provision found in the federal Surface Mining Control and Reclamation Act of 1977 which provides federal funding for the establishment and operation of university coal research laboratories. One such facility is to be located in the Gulf Coast coal province. Establishment of such a facility in Texas would greatly increase the State's overall lignite research capability. (Lignite project 5.)

BIOMASS

Biomass conversion refers to the use of organic material as an energy or fuel source. The conversion process may entail direct combustion, or the thermal or biological breakdown of the material into basic hydrocarbons such as methane, ethylene, or alcohols. The sources of organic matter available are very great. Those receiving the greatest amount of attention now are municipal and industrial solid waste. The EPA is concentrating its efforts on developing viable methods for utilizing these sources principally due to the severity of waste disposal problems as well as energy problems on the eastern seaboard, where population density is high and landfill costs exhorbitant. Only in a few instances do these conditions prevail in Texas, primarily in the large metropolitan centers. These cities are generally aware of their alternatives and have capable staffs as well as access to the EPA and State Department of Health. There are likely several small communities, however, that could actually receive a great portion of their power or fuel requirements from their own waste in conjunction with the wastes of nearby population centers or nearby agricultural products and residues.

The Department of Energy is now persuing the potential of agricultural residue conversion to fuels. Because of the concentration of agricultural operations in Texas, the State could provide a valuable service by helping draw federal demonstrations of agricultural waste conversion to Texas or by stimulating private investment in facilities for conversion of agricultural products or waste. (Biomass project 1.)

WIND

The use of wind energy in parts of Texas, particularly the Panhandle and the lower Gulf Coast, shows considerable potential. At present, however, wind energy conversion is only marginally economical for many applications. Often the investment decision will hinge on the wind energy available at a specific site. This is particularly crucial because of the relation of wind speed to wind power. (The power available from a given section of a wind stream is proportional to the cube of the wind speed, e.g., a 4 mph wind has eight times the power of a 2 mph wind.)

This suggests that it is extremely important to know the nature of this resource before it can be used. Presently, several entities--federal, state, university, and private--record wind data of one kind or another in varying forms. If these disparate sources could be identified and enrolled in a single statewide network, we would have a much more accurate picture of the wind potential in Texas. Consumers would have more accurate data upon which to base investment decisions, and manufacturers could realistically promise results. A thorough inventory of the wind resources could be a significant step toward commercialization and would directly benefit Texas. (Wind project 1.) This project might also interest the federal government as a pilot study, or as a data base upon which to test wind power estimation techniques.

Wind energy conversion systems (windmills for the most part) can perform a wide variety of functions. Federal research, development and demonstration (RD&D) programs have concentrated on the use of large and very large wind plants. A recent grant for $7 million was made to General Electric to design and manufacture a windmill blade 300 feet in diameter. The basis for this approach is the federal mandate to have an impact soon and have visibility. Large systems can be manufactured or purchased only by a very select few major concerns, however, and do not lend themselves to mass production techniques. Small-to-moderate sized wind systems could be easily mass-produced, be economically accessible to a greater market, and still contribute significantly to energy supply. In addition, many small systems could be more reliable than one large system in that the wind energy over a large network of small windmills might be more consistent than the wind at one specific site. Further, a network of small windmills would likely weather natural calamity better than one large windmill in a tornado. (Even if several are destroyed, the capital damage and power shortage is less.) In addition, many task-specific applications of wind power could prove economic. Examples include pumping of water or oil, anodic protection, or mechanical or electrical power at remote sites. The federal government has placed little emphasis on commercialization of this potential technology. Demonstration of small-scale wind power generation could prove worthwhile to both potential users and manufacturers. (Wind projects 2. and 4.)

In addition, a previous study completed for the Governor's Energy Advisory Council showed that a variable speed transmission or a variable stroke air compressor could greatly increase the efficiency of present windmills. Remembering the cubic relation of wind speed and wind power, it is important to be able to take advantage of even small increases in wind speed, or increases of short duration (i.e., gusting). Presently manufactured transmissions, for example, only allow inconvenient and incremental jumps in power conversion, or require that windmill blades feather to let the extra wind power "slip through." A well-designed and constructed variable speed transmission would allow power captured to vary directly with even small changes in wind speed and greatly improve the economics of any existing system. Although this is one example, other technical innovations are still possible in the design of wind energy conversion systems. Efficient and reliable blades, particularly for vertical axis systems, wind augmenting peripheral systems, and other application-specific subsystems can be developed which will increase the commercial value of existing wind systems. (Wind project 3).

CONSERVATION

A substantial amount of research, development and demonstration are being conducted by private industry, utilities, and the Federal government in the areas of industrial energy conservation, transportation conservation, and utility power transmission energy conservation and large scale storage. This is certainly appropriate given present economic incentives, the large scale of such programs, and the national significance of energy conservation in these areas. Conservation in the residential, commercial, and agricultural sectors, on the other hand, is so closely linked to climatic and geographic conditions that advances in energy conservation are extremely regional and should be addressed by the State. Except in the case where State funds could attract a large Federal or private demonstration for industrial transportation or utility projects, State emphasis on residential, commercial, and agricultural energy conservation technologies will have the greatest benefit.

Air-conditioning is a use of energy of particular importance in the southern part of the country. Nationwide cooling accounts for 3.3% of residential energy use, while in Texas cooling is 23.3% of residential energy use. Due to this imbalance, the problem of developing efficient air-conditioning systems takes on a regional nature and may not receive the necessary attention in a national RD&D program.

Along the Gulf Coast, conditioning air to a comfortable level entails the removal of humidity just as much as the lowering of its temperature. In order to condense water vapor and remove humidity it is necessary to lower the temperature of the air going through the air-conditioning equipment to a lower temperature than would be necessary to maintain comfort in less humid air. With less humidity in the air, however, it would not be necessary to run equipment at this lower temperature, thereby increasing efficiency and reducing energy consumption. A system for removing humidity without requiring such lowering of temperature would be of great value in reducing energy used for comfort cooling and would have special benefit to Texas and other Gulf Coast states. (Conservation project 1.)

At a temperature of 85 degrees in a gentle breeze most people can be as comfortable as in a 78 degree room of still air. Prior to the period of cheap energy, air movement was used extensively to maintain comfort. With present technology it is possible and desirable to combine air movement and conditioning to achieve a system which operates more efficiently and delivers the same level of comfort. (Conservation project 2.)

Hot water heating accounts for approximately 13% of residential and 3% of commercial energy use. Due to the low temperatures at which hot water is used (120 F - 140 F), heating of domestic water is a potential use of low-grade waste heat. Due to the high air-conditioning use in Texas, a great deal of low-grade heat is rejected to the atmosphere as a consequence. With the appropriate equipment this low-grade heat could be captured and reused to heat water, thereby reducing the need to expend high-grade energy such as natural gas or electricity. (Conservation project 3.)

Thermal storage is one method for reducing the daily summer electricity demand peak caused by air-conditioning use. By generating cooling capacity during off-peak hours and storing this capacity for use during peak demand times, a substantial reduction in the daily peak can be obtained. Such a project would have direct benefit to Texas since summer power demand peaks are higher in this region as compared to the rest of the country. (Conservation project 4.)

Irrigation accounts for well over half of the on-farm energy consumption in the state. Essentially all of the natural gas and much of the electricity consumed for food production is used for irrigation. In Texas a major portion of the crops produced are produced on irrigated land.

As the price of natural gas increases, many farmers are not able to produce a profit and, therefore, go out of business. If this trend continues, it can lead to high food prices and serious shortages. New and more efficient methods of irrigation which reduce operating costs and energy consumption may mean the difference between a farm making a profit or going out of business. (Conservation project 5.)

SPECIAL PROJECTS

The Texas economy is more heavily dependent upon the production, refining, and consumption of crude oil and natural gas products than any other state in the nation. As the production of oil and gas declines in the long-term, Texas must not only switch to alternate energy sources for consumption but must find an alternate industrial base to maintain the State's economic growth and strength.

A major shift to alternate energy consumption and alternate industrial development will require major quantities of capital investment, amounting to billions of dollars. Since lead times for such development are long and the risks for individual investors are high, existing private capital sources may not be adequate to meet the task. A major study is needed to determine the feasibility of establishing a regional development bank for the purpose of accumulating capital to be channeled into selected energy and energy-related development projects at risk levels lower than investors now face. The primary purpose of such a bank would be to make capital available for specified purposes consistent with activities which will support regional development.

The study would address such issues as (1) legal and institutional requirements for the operation of a regional bank potentially serving more than a state, (2) relationship to existing banking institutions, (3) specification of investment areas eligible for funding from the bank, (4) the states to be involved in the definition of the "region", and (5) alternative methods of bank financing. Econometric modeling work would be required in order to investigate which investment categories would have the most influence on regional economic development. (Special project 1.)

A second study would provide detailed information related to current government RD&D investments as well as early information for a regional development bank, should one be established. This study would estimate current costs of doing specific jobs with alternate energy sources or combinations thereof. Data currently exist on trial bases with which to compare the relative economic costs of doing specific jobs. The scope of the project should include specific applications in agriculture, industry, electric power generation, home heating and air-conditioning, and transportation systems, identifying specific parts of the process most subject to cost reductions as development reaches commercial levels. (Special project 2.)

These two studies would provide much needed information about the most effective means of operating future development fund monies and banking institutions large enough to make a significant impact on regional development. Without such information we are dependent upon guesswork in arriving at specific RD&D funding levels and in identifying which factors will be the most important in determining future regional growth.

Since all energy development projects potentially result in significant impacts in the areas in which they are located, it is important to develop the capability of assessing such impacts so that potential constraints and mitigating actions can be identified in time to prevent unnecessary irreversible consequences which are not acceptable. (Special project 3.)