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A Systems Study of Our Energy Problems

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Abstract

The diminishing supply of petroleum and natural gas has induced many concerned citizens as well as many interest groups to study energy problems. Based on different sources of information and various degrees of economical consideration, conflicting conclusions have been reached. To help resolve this situation, a systems study was conducted. The available statistics on the supply and demand of energy were examined. The resources of nuclear energy, fossil fuel, and renewable energy sources were analyzed. Considerations were weighted equally on energy content, resource availability, existing technology, and consumer economics as well as on the impact of ecology and sociology. The objective is to develop a long-range solution that will enhance the quality of life by minimizing waste in our present life style. The optimum approach is to make the best use of our free enterprise system in which technology and economics are the only governing factors. In the meantime, effective government regulations can be readily applied fairly and decisively when the balance of ecology and sociology is threatened.

1. INTRODUCTION

The diagnosis of the Nation's energy problem is quite simple: demand for energy is increasing, while supplies of conventional energy are diminishing(1). In order to find a workable solution, studies of many alternative resources are being made. Although the specialists of various energy fields have addressed themselves to the importance of their respective disciplines(2) as to the availability of possible energy resources, consideration has to be given to ecology, sociology, technology, and economics in a comprehensive, objective, and systematic manner. This study reviews the statistics of available energy resources, analyzes the energy situation, and recommends possible solutions.

2. STATISTICS

Historical evidence indicates that the progress of mankind is directly related to energy consumption(3) (Table 1). A person in today's industrial environment consumes approximately 20 times the amount of energy as a person in the agricultural environment of the first century, yet as the result of the drastically different distribution of energy consumption throughout the world as shown in Table 2, can we, the residents in industrialized North America, claim that we are twice as civilized as those in Western Europe or Japan because we consume twice as much energy?

Examination of the energy demand in the U.S.(4) (Table 3) reveals that automobile transporation alone constitutes 13% of the total energy consumption of our country. Based on the yearly consumption of 82 quadrillion Btu of energy in 1976, each American used an average of 50 million Btu of energy for his automobile alone. Table 4[5] shows that oil has been used as the major source of automotive energy for the last five years, in spite of the fact that the price for imported oil has increased from $3.50/bbl in 1973 to $13.50/bbl in 1976. Moreover, imported oil accounted for 50% of the total amount of oil consumed in 1976 at a cost of 36 billion dollars (or $1,000/sec). Inflation and recession may become the facts of life if our economic resources cannot be used for something more constructive than the importation of oil for the operation of automobiles.

An easy solution would be to explore for more domestic oil, but even unproven reserves are limited. The proven reserves of U.S. and world oil shown in Table 5,[6-8] are known quantities that can be used to make plans for the future. Based on the production rate of 1974, the U.S. has only about a ten-year supply of oil. The world has about a 30-year supply. The natural gas situation is not any better. The unproven reserves, which appear attractive, are unrealistic for making long-range plans, because they are speculative and even if true would be very costly to develop. The proven coal reserves, on the other hand, are encouraging. Based on the rate of current energy consumption, the U.S. coal reserve should last more than 100 years even if all our energy demands are to be supplied by coal. With additional shale oil and tar sand, there are still fossil fuels available, but the question is: Does human civilization need to depend on these energy resources alone?

3. ANALYSIS

The systems study, which has been conducted to analyze our energy problem, takes into consideration the sources of energy, factors in reality, and a planning philosophy (Table 6). The planning philosophy is the basic principle that is generally applicable to most situations involving interactions among people as well as interrelations between people and events. The first and foremost consideration is the ethics in a decision-making process. This may be simply expressed as the practice of the Golden Rule in human relations. It is followed, in the order of importance for strategic planning, by the timing of an action, the availability of material resources, the potential of human resources, and, finally, the possible methods of accomplishing a given objective. The restraint, factors in reality, which is second in importance to the planning philosophy, may be considered as the boundary conditions to a set of mathematical equations that govern a physical phenomenon. For energy problems, the factors are: resource availability (RAV), energy content (ECT), existing technology (XTE), consumer economics (CEC), impact on ecology (ECL), and sociology (SOC). Analysis of the nergy problem can then be initiated with the current situations of all potential energy sources, namely: nuclear energy, fossil fuel, and renewable resource.

3.1 NUCLEAR ENERGY

Nuclear energy can be harnessed in one of two ways: fission or fusion (Table 7).

3.1.1 Fission

The cracking process of uranium has been used in light-water reactors (LWR) to produce electricity. One gram of uranium-235 can release 25,000 kWh of energy. It is economically attractive and technologically sound. The proven reserve of uranium ore, U_3O_8 (yellow cake), in the U.S. is capable of supplying 150 light-water reactors -- a 1000 MW nuclear power plant requires 5300 tons of yellow cake -- for their life time, which is about 30 to 50 years. The unproven reserve may be as high as four times that of the proven reserve. The Nation has about 50 light-water reactors, which generated about 10% of the country's electrical needs in 1976.[9] Over 100 more plants will be ready by 1990; however, it is necessary to emphasize that the technologies for treating solid waste and waste heat have yet to be improved.

The use of uranium-238 for liquid metal fast breeder reactors (LMFBR) is another fission process that produces more plutonium than it consumes.[10] Currently, only the Fast Flux Test Reactor Facility in Hanford, Washington, is scheduled to go into operation by 1980. While the economic incentive is great, its potential impact on both ecology and sociology makes it necessary that the LMFBR be closely regulated against nuclear proliferation.

3.1.2 Fusion

The melting process through which the energy of the sun is made available to us can be used to provide fusion energy from the isotopes of hydrogen (deuterium), helium, or lithium.[11] One gram of deuterium can release 100,000 kWh of energy. Moreover, deuterium is available in water at a ratio of 1/6500. Its impact on ecology and sociology is relatively slight, because it does not contain radioactive materials; however, the technology for creating a fusion environment of several million degrees in temperature for a sufficient length of time is still in the research stage. Two approaches are currently being developed. One involves magnetic confinement and the other inertial confinement. In magnetic confinement, the plasm of deuterium and tritium is confined and heated in a magnetic chamber. The Tokamac Fusion Test Reactor in Princeton, New Jersey, is of this type and will be operational in 1981. In inertial confinement, laser, electron-beam, or ion-beam sources are used to implode pellets of deuterium and tritium. The major research effort is to provide a high energy gain laser facility as a triggering mechanism by the 1980's.

3.2 FOSSIL FUEL

It has taken millions of years for fossil fuels to form, but it has only been in the last 200 years or so that they have been used in large quantities as energy sources. Three types of fossil fuels are analysed in this study (Table 8).

3.2.1 Petroleum and Natural Gas

Petroleum and natural gas have been the most economically accessible of the fossil fuels for the last 30 years. Their energy content is about 0.01 kWh/gm. Within present technological and economical limits, they have had no significant impact on ecology in bringing comfort and convenience to our everyday life. The only problem is that the proven reserve cannot last for more than ten years at the current consumption rate.[12] It is very clear that some of these resources have been wasted by automobiles (10 quads in 1976) and space heating (15 quads in 1976). Conservation is most urgently needed in these areas. Effective use of public transportation could reduce automobile usage, lower the rate of fuel consumption, and provide a cleaner environment. Better insulation for residential and commercial buildings would also conserve the energy used for space heating and air conditioning.

3.2.2 Coal

Coal has been used as an energy source for more than 100 years, but its low energy content of approximately 0.005 kWh/gm, the difficulty of transporting it from producers to consumers, and its adverse effect on environment when burned have encouraged the use of petroleum and natural gas as primary energy sources for the last 30 years. Currently, coal supplies only about 20% of our total energy needs. In spite of its defects as an energy source, its proven reserve is encouraging. It can be counted upon for the next century, even if it is used to supply 100% of our energy needs.[3]

Coal consists of four different grades: anthracite, bituminous, subbituminous, and lignite (Table 9).[13] Because lignite and subbituminous coals are relatively low in quality, anthracite has been the major source of supply, and it is diminishing. An immediate substitute source is bituminous coal of which there is 36 billion metric tons in surface mine reserves: 30% in

Illinois, 10% in Kentucky, 8% in Missouri, and 4% in Indiana (Table 10).[14] An ultimate analysis of Illinois coal is given in Table 11.

If coal is to be used more intensively, it is clear that some precautions will have to be taken 1) to produce it economically and ecologically, 2) to convert existing petroleum and natural gas facilities to coal with adequate protection of the environment, 3) to convert coal from solid to either liquid or gas forms that can replace petroleum or natural gas fuels economically, and 4) to develop facilities that can burn low quality coal with no adverse impact to the environment.

An effective transition from petroleum and gas to coal requires new programs, such as restoration of mined lands, development of hydrodynamic mining technology, design of pollution free coal burning facilities, economizing coal gasification and coal liquefaction processes, and demonstration of magnetohydrodynamic power generation through coal burning plasma jets.

3.2.3 Other Fossil Fuels

Large quantities of subbituminous coal, lignite, shale oil, and tar sand form known reserves that can be used as energy sources; however, in addition to their ecological drawbacks, it is not yet possible to evaluate their economical advantages, because the required technology for their exploitation has not been developed.

3.3 RENEWABLE RESOURCE

The many renewable resources shown in Table 12 can be harnessed for energy without adversely affecting either the ecology or sociology. Unfortunately, they are generally too diffused to be efficient.

3.3.1 Hydroelectric Power

Water, which is evaporated from the ocean by solar energy, condensed to clouds at higher altitudes, moved to land by wind, and formed into rain, has been available as an energy source since the origin of the world's atmosphere. Hydroelectric power is today's most efficient product of solar, wind, and ocean energies. Of the total water-flow rate in the United States, 13% is being used for generating electricity. This constituted about 4% of the total energy supply in 1976. Flood control, agricultural irrigation, and energy demand will necessitate the continued construction of water reservoirs in the future, but it will be necessary to develop the best technology to minimize their impact on ecology and to maximize their return on investment.

3.3.2 Biomass Fuels

Wood, vegetation, and animal waste can be used as energy resources.[15] They are economically competitive in rural areas where the transportation cost of biomass fuels is very low. The energy content of wood is approximately 0.002 kWh/gm. Biomass fuels can provide a substantial resource if they can be converted to liquid or gas forms for storage and transportation.

3.3.3 Solar Energy

Approximately 40% of this country's energy demand is for residential and commercial uses. A large portion is being used for space heating, water heating, and air conditioning. It is technologically possible to use solar energy for these purposes without adversely affecting either the ecology or sociology, but the question of consumer economics should be given serious consideration (Table 13). The radiant energy of the sun is 4850 kJ/m^2-hr (428 Btu/ft^2-hr).[16] Based on the assumption that 65% of this radiant energy passes through the atmosphere continuously, that 22% reaches the collector panel as a result of noctural variations, and that the collector is 55% efficient, a collector panel can absorb 3.2×10^6 kJ/m^2-yr (300,000 Btu/ft^2-yr) of energy. Each square foot of solar collector can supply the same amount of energy as 2.5 gallons of gasoline every year. The economics of solar energy is related to the factors of initial cost, interest rate, and durability. Based on the price of gasoline at $1.00/gal and an interest rate of 9%, a solar heating system of \$10.00/ft^2 has to perform effectively for ten years in order to be competitive.

Solar energy for air conditioning can be produced by using the principle of absorption refrigeration[17], but the economics of doing so are much worse than those for solar heating. Further development is needed in two areas. One is to design and manufacture economically the high efficiency collectors that will provide the required temperature to evaporate a refrigerant. The other is to find new refrigerants that can be operated efficiently within the limits of the low-cost, flat-plate collectors.

Solar cells can convert sun light into electricity through a photovoltaic process. The success of the technology has been demonstrated in the space program.[18] The cost in 1976 was about \$15 per peak watt as compared to the commercial rate of electricity, which was about 10 cents at that time. To make solar cells economically competitive, it will be necessary to develop new cell materials, different configurations, and improve the manufacturing processes.

3.3.4 Wind Power

Wind was harnessed for sailing ships prior to recorded history, and even today the use of wind mills for power generation is a common practice in many rural areas. Even if the efficiency of wind power can be significantly improved, the availability of wind at a specific time and place makes it a very restricted energy source unless the problem of energy storage can be solved successfully.

3.3.5 Geothermal Energy

The thermal energy that exists in the outer 10 km of the earth's crust is approximately equivalent to 5×10^{18} kWh, but it is too diffuse to be used effectively as an energy source on a world-wide basis. Intensively active geothermal reservoirs are known to be present along the coastal regions of the Pacific and the Indian Oceans.[19] These huge resources can be developed for regional use economically, if the technical problems of corrosion and scaling can be resolved.

3.3.6 Ocean Energy

Two oceanic energy sources can be used for power generation: waves plus tide and thermocline.

Waves plus Tide: Marine water carried to shore by waves during high tides can be stored in reservoirs for power generation through hydroelectric power plants, but the technic is limited. Even if the technical problem of corrosion can be solved, only a few locations in the world can make this an economical energy source.

Thermocline: The temperature of marine water at and near the surface (up to 50 m deep) in the tropical region is about 25°C, whereas the temperature at a depth of 1000 m or more is only 5°C.[20] Owing to the large quantity of ocean water, this small temperature difference can provide significant amounts of power.[21] Moreover, power generated in the oceanic regions can be used for converting water to hydrogen fuel, which can be stored or transported as petroleum or natural gas fuels.[22]

4. CONCLUSION

In early civilizations, an energy source was the one that was most available, therefore, wood was a popular fuel. As industry began to develop, technology began to demand a fuel with a higher energy content. Coal then became the most useful fuel. Because highly industrialized society is governed by the laws of economics, its technology must be developed only in the direction of the highest economic return. Petroleum and natural gas have therefore satisifed this requirement for the industrial nations of the world for the last 30 years; however, the distribution of economic wealth among the haves and the have-nots has increased social concerns. The excessive and uncontrolled use of energy by the affluent societies has brought about the deterioration of the environment and threatens to deplete the resources of fossil fuels. Today, for the first time in his history, man faces a depletion crisis of the more available fuels. Should the laws of economics continue to be the sole factor to govern developed countries, it will be no surprise if they march directly into the nuclear era. The Fast Breeder Reactor is capable of providing the greatest economic return because it produces more nuclear fuel than it consumes. It is thus absolutely necessary that it be critically examined comprehensively and objectively by the responsible members of society. Can we continue to ignore ecology and sociology at the expense of economic growth? What price are we willing to pay in the future for ourselves and our children for some luxuries of doubtful value today? Considering the composite situation of energy content, resource availability, existing technology, and consumer economics as well as sociological and ecological affects, it appears that a logical solution of the energy problem can be derived in the following manner.

4.1 LONG-RANGE SOLUTION

It is unrealistic to expect that the momentum of "progress" can be turned 180 degrees, but its forward march can be guided slowly along a less dangerous path in a more advanced era of nuclear fusion with a long-range solution. Deuterium, which has a very high energy content (100,000 kWh/gm), is abundantly available in water (1/6500). To supply the increasing demand for energy in the future, it is necessary to accelerate research in nuclear fusion to provide an abundant energy supply with no radioactive waste. The time needed to acquire the necessary technology has to be used efficiently for developing an ethical way for man to live harmoniously with a balanced ecology and sociology.

4.2 SHORT-RANGE SOLUTION

The maintenance of the present quality of life before nuclear fusion can be harnessed may become a very serious challenge, if the resources of petroleum and natural gas are depleted to a critical stage. The abundant reserve of coal has to be made as convenient as petroleum and natural gas without adversely affecting the environment. Development of technology in coal liquefaction and coal gasification is necessary, but one must consider carefully both the economic requirement of the consumers and the delicate balance of the ecological system.

4.3 IMMEDIATE NEED

If we consider ourselves to be responsible members in the world community, there are two questions we need to ask: "Are we, the leaders of democracy, good custodians to whom the beauty and wealth of the earth are entrusted?", and "Have we, the people with the best knowledge in science and technology, used our talents to promote the best interests of mankind?" We have been led to believe that we are the most advanced nation on earth, because we consume at least twice as much energy per capita than any other nation. Facing the world-wide energy crisis today, it is necessary that we take the leadership to conserve energy, immediately. Several approaches can be pursued:

(1) Use of mass transit instead of automobiles whenever possible is a necessary requirement to prevent our Nation from importing oil, a practice that escalates our trade deficit, which is the most potent factor in causing inflation and unemployment.

(2) Insulation of our residential and commercial buildings can produce substantial savings in the energy required for space heating and air conditioning.

(3) Development of renewable energy resources is a postive approach in dealing with immediate problems, but consumer protection is necessary to prevent the cooperating public from being economically exploited.

(4) A contingency plan of Government enforced conservation has to be made ready for implemen-

tation in case the voluntary program fails to meet the objective. One possible plan is to impose a high tax on imported oil. The objective is to make domestically available energy sources economically competitive in the free market system, while the Nation's oil consumption is substantially reduced through voluntary conservation. The problem of inflation can be controlled by reducing trade deficits from importing foreign oil. The increased tax revenue has to be used to combat unemployment through Government sponsored programs, such as mass transit, renewable resources development, and fusion research.

It is concluded that our Nation posesses all the necessary ingredients required by a sound planning philosophy to achieve energy sufficiency for ourselves as well as for generations to come. We have more than a sufficient amount of material resources at our disposal. We have a higher than necessary potential in human resources. There are many possible methods for achieving a national objective, but the "timing of action" keeps us agonizing in our current predicament. The reason for such poor timing on a national scale is the neglect of the "ethics in decision-making" by some special interest groups who have teamed up with a small number of selfish politicans. In order to deliver ourselves from our own bondage, it is the responsibility of every concerned citizen to examine himself conscientiously and vigorously to identify the unethical elements of society even though they may be rich, famous, or powerful.

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BIOGRAPHY

Dr. Shen C. Lee is a Professor in Mechanical and Aerospace Engineering. His research activities have been in the areas of hydrodynamics and thermodynamics for aerospace propulsion systems, environmental quality control and energy conversion since 1958.

TABLES

TABLE 1, ENERGY CONSUMPTION-HISTORICAL INFORMATION

TIME / ENERGY	PRIMITIVE MAN 5,000 BC	EARLY CIVILIZATION 3,000 BC	AGRICULTURAL MAN 1 AD	EARLY INDUSTRIAL MAN 1785 AD	MODERN MAN 1977 AD
CALORIES / DAY-MAN	3,000	8,000	12,000	75,000	250,000
TONS OF COAL / YR-MAN	0.14	0.35	0.55	3.7	11.0

TABLE 2, ENERGY CONSUMPTION-GEOGRAPHICAL INFORMATION

LOCATION / ENERGY	AISA	LATIN AM.	W. EUROPE	N. AM.
TONS OF COAL / YR-MAN	0.5	1.0	5.0	10.0

TABLE 3, ENERGY DEMAND IN U.S.

ENERGY DEMAND	%	QUAD (1974)	QUAD (1976)	REMARK
TRANSPORTATION	(25.2)	(18.9)	(20.7)	* Auto alone used 80 billion gallons of gasoline in 1976
* Auto	13	9.8	10.7	
Truck	5	3.8	4.1	
Bus	0.2	0.1	0.2	
Train	1	0.7	0.8	
Airplane	2	1.4	1.6	
Others	4	3.0	3.3	
INDUSTRY	(41.2)	(30.9)	(33.8)	
Process Steam	17	12.8	13.9	
Direct Heat	11	8.2	9.0	
Electric Drive	8	6.0	6.6	
Electrolytic Proc.	1.2	0.9	1.0	
RESIDENTIAL USE	(19.2)	(14.4)	(15.7)	* Space heating for both Residential and Commercial uses consumed an equivalent of 120 billion gallons of gasoline in 1976
* Space Heating	11.4	8.6	9.4	
Water Heating	3	2.2	2.5	
Air Conditioning	1	0.7	0.8	
Refrigeration	1.2	0.9	1.0	
Cooking	1.2	0.9	1.0	
Lighting & Others	1.4	1.0	1.2	
COMMERCIAL USE	(14.4)	(10.8)	(11.8)	
* Space Heating	7	5.3	5.7	
Water Heating	1	0.7	0.8	
Air Conditioning	1.8	1.4	1.5	
Refrigeration	1	0.7	0.8	
Lighting & Others	3.6	2.7	3.0	
TOTAL	100%	75	82	

TABLE 4, ENERGY SUPPLY IN U.S.

ENERGY SOURCE (%) \ YEAR	1885	1910	1950	1973	1974	1976
WOOD	90	10	--	—	--	--
COAL	10	80	50	18	20	21
OIL		10	35	46	45	46*
GAS			15	31	29	25
HYDRO				4	4	4
NUCLEAR				1	2	3

* In 1976, 50% (35% in 1973) of the U.S. oil supply was imported at $13.50/Barrel ($3.50/Barrel in 1973). The cost was 36 billion dollars per year ($1,000.00/sec.).

TABLE 5, FOSSIL FUEL RESERVE

FOSSIL FUEL \ RESERVE		PRODUCTION RATE (1974)	PROVEN RESERVE	UNPROVEN RESERVE
OIL	U.S.	3.2	35	98
(Billion Barrels)	World	20.4	560	1,140
NATURAL GAS	U.S.	4.6	52	110
(Billion Barrels)	World	9.6	450	1,550
GOAL	U.S.	0.6	390	1,442
(Billion Metric Tons)	World	7.0	1,140	8,230
SHALE OIL	U.S.	--	280	3,530
(Billion Metric Tons)	World	--	415	47,000
TAR SAND	U.S.	--	4	--
(Billion Metric Tons)	World		140	

TABLE 6, SYSTEMS STUDY OF ENERGY PROBLEMS

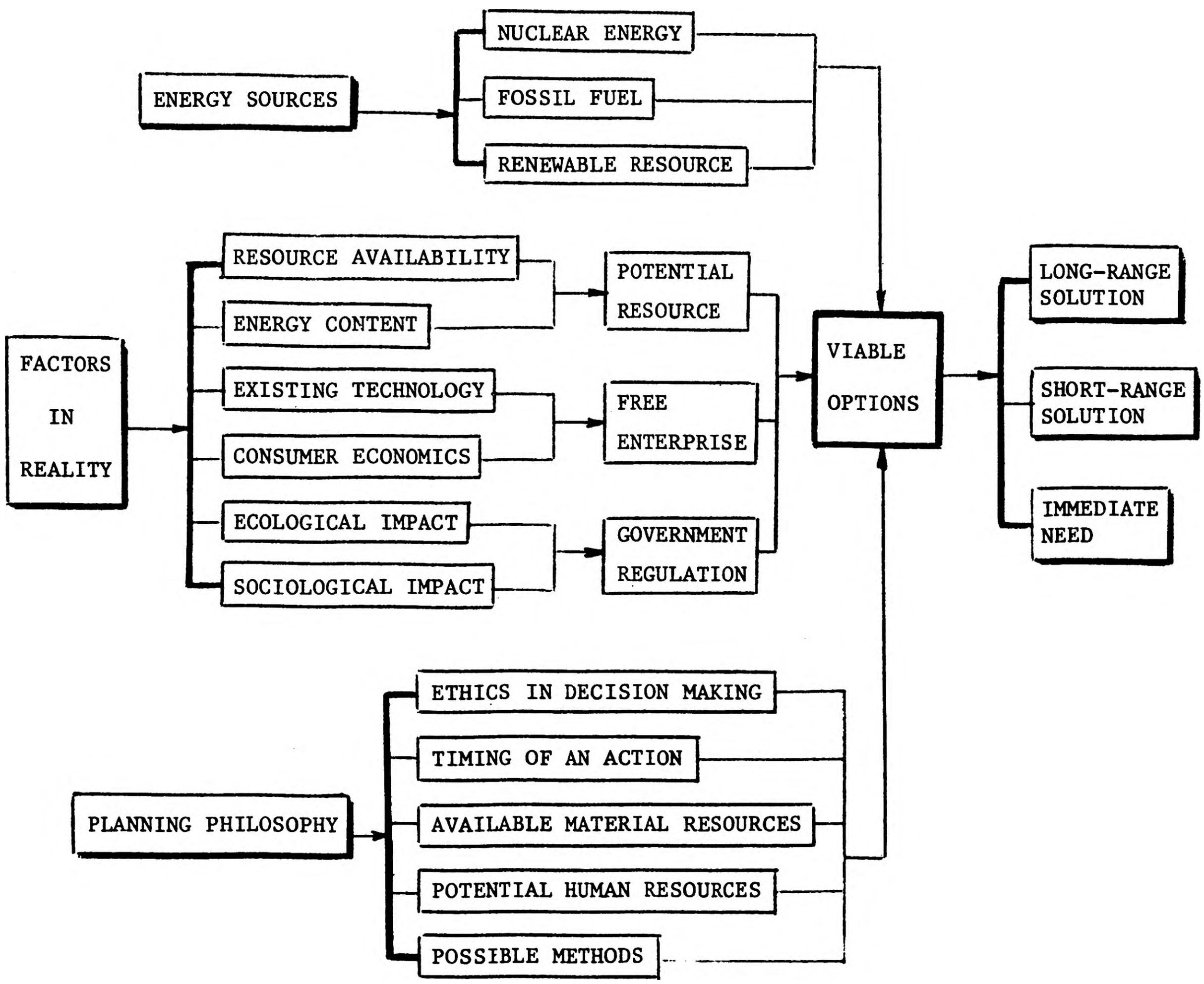

TABLE 7, NUCLEAR ENERGY

NUCLEAR ENERGY / FACTOR	FISSION		FUSION	
	LIGHT-WATER REACTOR	FAST BREEDER REACTOR	MAGNETIC CONFINEMENT	INERTIAL CONFINEMENT
RAV	(URANIUM) 150 plants for 30 yrs	(PLUTONIUM) produce more than consumed	(DEUTERIUM & TRITIUM) $\frac{H_3}{H_2O} = \frac{1}{6500}$	
ECT	25,000 kW-hr/gm		100,000 kW-hr/gm	
CEC	HIGH ECONOMIC RETURN			
XTE	READY	CAN BE READY	To Achieve Fusion Environment	To Develop High Gain Laser
ECL	Solid Waste Radioactive Fall-out Waste Heat		Waste Heat	
SOC	Questional Acceptance	Potential Nuclear Proliferation	No foreseeable problem for acceptance	

TABLE 8, FOSSIL FUEL

FOSSIL FUEL / FACTOR	PETROLEUM & NATURAL GAS	COAL	SHALE OIL & TAR SAND
RAV	10 yrs	100 yrs	100 yrs
ECT	0.01 kW-hr/gm	0.005 kW-hr/gm	0.005 kW-hr/gm
CEC	High Demand Low Supply (Economical in 1977 only thru regulations)	CAN BE COMPETITIVE IN FREE MARKET	QUESTIONABLE
XTE	WELL DEVELOPED	CAN BE IMPROVED	NOT AVAILABLE
ECL	MANAGEABLE	AIR POLLUTION SOLID WASTE LAND RESTORATION	---
SOC	High-standard of living	Essential Qualities of Life	---

TABLE 9, COAL RESERVE IN U.S.

RESERVE \ COAL	ANTHRACITE	BITUMINOUS	SUB-BITUMINOUS	LIGNITE
HEATING VALUE (Btu/lbm)	15,000~16,000	14,000~16,000	13,000~14,000	11,500~13,000
CARBON CONTENT (%)	90~94	80~90	75~80	60~75
DEEP-MINE RES. (Billion Metric Tons)	6.6	173	87.8	---
SURFACE-MINE RES. (Billion Metric Tons)	.08	36	61.2	25.4
TOTAL (Billion Metric Tons)	6.7	209	149	25.4
PERCENTAGE (%)	1	54	38	7

TABLE 10, SURFACE-MINE RESERVE, BITUMINOUS COAL

DISTRIBUTION \ STATE	ILLINOIS	KENTUCKY	MISSOURI	INDIANA	OTHERS
Billion Metric Tons	10.8	3.6	2.9	1.4	17.3
Percentage	30%	10%	8%	4%	48%

TABLE 11, ULTIMATE ANALYSIS OF ILLINOIS COAL

COMPONENT	S	H_2	C	N_2	O_2	ASH
PERCENTAGE	1%	5.5%	66%	1.5%	17%	9%

TABLE 12, RENEWABLE ENERGY RESOURCE

RENEWABLE RESOURCE / FACTOR	HYDRO-ELECTRIC	BIO-MASS	SOLAR	WIND	GEO-THERMAL	OCEAN
RVA	13% of U.S. water flows are used for electric power	Abundant Supply				
ECT		.002 kW-hr/gm	Too Diffused To Be Efficient			
CEC	High Return	Good If transportation cost is low	See Table 13	Economical Advantage in Certain Regions		High Potential
XTC	Available	Can Be Improved If There Is Economic Incentive				
ECL	Need Water Reservoirs	No Adverse Impact on Ecology				
SOC	Acceptable	Can Be Made Acceptable				

TABLE 13, CONSUMER ECONOMICS

(Solar Energy For Space Heating)

MAXIMUM AVAILABLE ENERGY FROM THE SUN, 428 $\frac{Btu}{ft^2\text{-}hr}$			
Estimated Effectiveness	Maximum	Average	Minimum
Transmissivity Thru Atmosphere	80%	65%	50%
Usefull Day-Light Hours	30%	22.5%	15%
Collector Efficiency	70%	55%	40%
Recoverable Solar Energy	17%	8%	3%
in [Btu/ft^2-hr]	72	34	13
in [10^5 Btu/ft^2-yr]	6.3	3	1.1
*Each Year, Per Ft^2 of Solar Collector is Equivalent to [Gallons of Gasoline]	5	2.4	0.9
[Ft^3 of Natural Gas]	630	300	112

* Consider a solar collector, that costs \$10.00/ft^2 to be installed at an interest rate of 9% yearly, lasts for 10 years without any repair. The yearly cost is \$10.(1+0.09)^{10}/10 = \$2.36/ft^2-yr.