BNL-17280

CONF-721042--1

THE UNITED STATES ENERGY CRISIS: SUPPLY AND DEMAND*

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Presented at:

Science Teachers Association of New York State
Annual Conference
Concord Hotel, Kiamesha Lake, New York
October 23, 1972

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* This work was supported by the U.S. Atomic Energy Commission.

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THE APPROACHING STORM

Energy is that commodity which heats our homes, runs our factories, and propels our transport.

The energy difficulties that we face stem from the fact that we are consuming energy at a staggering rate which continues to increase with no limit in sight. As a result our conventional fuels of today are being depleted rapidly, our atmosphere is choked with combustion products, and we are laying waste to our landscape, to produce, process, distribute, and consume these fuels. When we take a close look at the whole picture it is obvious that we cannot continue in the present pattern for very long. Some major changes must take place.

We are faced with few alternatives, each of which involves various trade-offs. Dr. Robertson and I will be discussing these today.

Instructional Opportunities: I believe there is great need for the public to be well-informed and accurately informed on the matters we will be discussing today. I also believe that one of the best opportunities for educating the general public is via high school teachers. You have the background to study and grasp the problems, and you have the professional ability to pass this information on to your students and to the community in a manner that they can understand.

There appear to be many interesting instructional opportunities that you might be able to put to work in your class room:

1. The energy problems have both scientific and social components.

Regardless of whether you teach physics, biology, social science, earth science, etc, you will find many interesting questions to examine.

2. The problems are of current interest. Hundreds of news stories, magazine articles, and technical reports are appearing weekly. There is abundant opportunity for students to collect information.
3. Most localities have some kind of dispute involving energy systems--a new oil pipeline, high transmission line, or nuclear power plant--and your classes can quickly become absorbed in the local debate.
4. There is ample opportunity for special student projects. I have attached a list of a few ideas (Appendix A), some of which were tried in various classes that I have taught.

The Arising Crisis: Throughout most of history, mankind derived the energy he needed from simple, natural sources; e.g., the muscle power of humans and domesticated animals, fuel from wood and animal fat, and the force of the winds. Individuals who were fortunate enough to enjoy a few luxuries did so at the expense of their fellow man, by exploiting the efforts of servants or slaves.

Only a few generations ago, mankind began to use appreciable quantities of the fossil-fuels--first coal, later petroleum and most recently natural gas. The large-scale exploitation of these fuels coincided with the global population explosion, and the industrial revolution. The use of these fuels bred new uses, technology flourished, and the consumption of fuel increased at an ever-increasing rate. The doubling time for fuel consumption is about 22 years. This means that over the span of our lifetimes each of us will witness an eight-fold increase in the use of energy!

You don't have to be a mathematical genius to see that this growth rate cannot continue. The earth has finite resources. Someday they will all be gone. When consumption doubles every 22 years, that "someday" is not far away, at least for certain resources.

Our Increasing Dependence on Energy: The changes in our patterns of living, the processes of urbanization and suburbanization have made each one of us more critically dependent on a regular uninterrupted supply of energy:

1. Our society depends on intensive use of energy for its productivity. It is a key ingredient to our capacity to earn wages.
2. Our society depends on energy to move the necessities of life to the densely settled areas. The whole web of urban existence would collapse if energy supply were suddenly cut-off. In a large city the loss of electricity is instantly a serious matter. If prolonged for more than a few hours it becomes a civil disaster.
3. The growth pattern of suburbia has made the suburban family totally dependent on the automobile, and hence, on the fuel to propel it.

Energy Conservation: We are all aware that some uses of energy are wasteful, frivolous, inefficient, extravagant, etc. One reason that this is true, is that energy has always been a very inexpensive commodity in the U.S. Many people point out that the price of energy has been artificially low because we do not include many important costs in the price we pay, e.g., the costs of damage from air pollution is not included in the price

we pay for a gallon of fuel oil for our home furnace. If these external costs were included, the price of fuel would increase substantially. Actually the costs of some of the environmental clean-up efforts will eventually be included in the price you pay for energy.

Environmental clean-up costs and fuel shortages will both force prices upward. Rising prices will force us to use energy more wisely and more efficiently. However, it might not be wise for us to wait for rising prices to force us to be more frugal with our energy resources. The power required to operate various household devices is given in Appendix B. Because of the rapid growth of uses, the restraining forces of the economic market-place might not respond fast enough to avert a serious crisis of energy shortage. I do not mean to imply that we will get up some morning and find that energy "cupboard is bare," although some localized shortages will develop suddenly from time to time. The most serious aspect of the problem is a steady and worsening squeeze for cheap resources, which force energy prices steadily upward beyond tolerable limits. Such a crisis could become an economic and social disaster.

We need to develop a national energy policy to guide our actions in the years immediately ahead. To better understand the complexities of the problem we must look at some data. Let us begin with the U.S. energy budget.

UNITED STATES ENERGY BALANCE

Last year--1971--Americans consumed an amount of energy equivalent to 69×10^{15} Btu. ⁽¹⁾ If you are like I am, your mind does not work too well in terms of British thermal units (Btu's) particularly in powers of

10^{15} . Even if I express this huge amount of energy in terms of more familiar units, it is still hard to grasp, e.g., the 1971 consumption is equivalent to 2.6 billion tons coal--this would make a pile big enough to cover Manhattan Island to a depth of 193 feet and 9 inches; or 69×10^{15} Btu is equivalent to 12.3 billion barrels of oil--which would fill a tank a mile in diameter and 0.6 miles high.

The sources of energy for the U.S. are shown in Table I. To be consistent with tradition, I reluctantly cite most data in terms of Btu's. (See Appendix C for conversion factors between various units.) Often the quantity 10^{18} Btu is referred to as Q. Thus our total 1971 consumption was 69 milli-Q. The world consumption was only three times larger.⁽²⁾ In other words, at the present time we consume almost exactly 1/3 of the world's energy, even though we have only 5.6% of the world's population. The quantities of energy which I have cited do not include the muscle power of human beings and work animals. Of course, many countries of the world depend heavily on such primitive sources.

There is a strong correlation between energy usage and economic affluence. Workman who command more energy produce more goods and thus receive higher pay. In turn, they can afford to buy more energy for their family comfort and leisure activities. This is illustrated in Fig. 1 which shows the relationship between per capita national income and per capita energy usage.⁽²⁾ The enhancement of the economic status of the world's masses, implies an enormously increased energy usage.

As can be seen in Table I, the bulk of our energy was supplied by natural gas and petroleum. Together they supplied more than 77% of our energy. Natural gas and natural gas liquids supplied 36.4% of the total--almost as much as crude oil.

Nuclear power supplied less than 0.6% of the 1971 gross energy input. For comparison I have included an estimate of the energy derived from wood and wood products burned as fuel. As you can see, wood provided us with about twice as much energy as was obtained from nuclear fission. However, the small nuclear contribution is growing at a very large rate--a 68% increase from 1970 to 1971--and its contribution will almost double during 1972. In some areas of the country the nuclear share is already quite significant, e.g. in southern New England about 35% of the electricity was generated in nuclear plants. Later this morning Dr. Robertson and I will talk in more detail about nuclear power plants and their public health implications.

The Need to Import: Unfortunately the U.S. is no longer self-sufficient in energy supply. In 1971 we had to import slightly more than 10% of our total energy. Most of this was in the form of petroleum from Venezuela and Canada. The import data are given in Table II. For the past several years this has been increasing. The National Petroleum Council estimates that by 1985, almost 30% of the energy we consume will be imported. Their predictions are illustrated in Fig. 2.⁽³⁾

Ten years ago we were a net exporter of energy. This change in status--our increasing dependence on imported oil has rather ominous implications in regard to foreign policy and international trade balance.

Our Domestic Energy Resources: One of the reasons for our need to import oil is that our domestic production of petroleum and natural gas can no longer keep pace with demand. Dr. M. King Hubbert of the U.S. Geological Survey has discussed the world energy resources in a Scientific American

article.⁽⁴⁾ He argues that the complete production cycle of crude oil and natural gas will pass through a cycle as shown in Fig. 3.⁽⁵⁾ According to Hubbert's estimates we are close to the peak of domestic crude oil production--probably already past the half-way point.

Table III compares the estimated remaining recoverable resources with the 1971 production and the cumulative production through 1971. The crude oil resource estimate by the American Petroleum Institute is more optimistic than Hubbert. It is my personal inclination to use Hubbert's estimate.

Several things are apparent from Table III. Both petroleum and natural gas will not last much longer. In 25 or 30 years, they will be gone for the most part. We have large resources of coal and uranium--enough to meet the needs for several centuries. However, if we are to make much greater use of these resources we face several difficult problems.

If coal is selected as the replacement for oil and natural gas, coal production must be increased tenfold or twentyfold by the end of the century. This would exact a frightful environmental toll. Also means must be found to expand production capacity--at great capital costs--and expand the working force. Most of the coal east of the Mississippi has high sulfur content. We have no practical technology today to remove sulfur from the combustion products. Coal can be gasified to produce a substitute for natural gas. The cost is high--several times the present cost of natural gas--but, no doubt, twenty years from now a large fraction of our gas will come from coal. Several pilot plants are testing various methods of coal gasification. In this case, the sulfur can be removed.

The growth of nuclear energy will be limited by the capacity of the nuclear industry to expand. It is estimated that nuclear power can satisfy about 1/3 of our energy needs by the year 2000 AD. It should be noted that nuclear plants produce only electricity which is not suited for most transportation needs. Methods must be found to produce synthetic liquid fuels from nuclear power plants. At Brookhaven we are working on one such possibility--the production of hydrogen fuels from water. The problems which must be solved are primarily economic. We believe that safety problems in handling large quantities of hydrogen are essentially solved already.

Alternative Future Sources: Two other energy resources hold interesting promise--solar energy and fusion. Both of these need intensive research effort before they can be put to practical use. Study panels,⁽⁶⁾ which have examined the situation very thoroughly, conclude that the federal government should invest large sums of research money in the effort to develop these resources, starting at once.

The U.S. has large deposits of oil shale which can yield a form of crude oil. Difficulties in exploiting this resource are similar to coal--environmental impact and costs.

ELECTRICITY

About 25% of our gross input energy is used to generate electricity. Only about 1/3 of the input can be converted to electricity, the remaining 2/3 is waste heat--thermal pollution. The demand for electricity is increasing faster, than for other forms of energy. About every ten years the demand doubles (Fig. 4). Part of the reason for this is that many consumers are converting from other fuels to electricity, e.g., home heating and factories.

The Steam-Electric Generating Plant: Most electricity used in the U.S. is produced in steam-electric generating plants. The principle of operation is shown in Fig. 5. Steam is produced from a source of heat--from burning coal, or oil, or from a nuclear reactor. The steam drives a turbine-generator to produce electricity. The steam at the exhaust end of the turbine must be condensed by using large quantities of cooling water. About 2/3 of the heat from the fuel is discharged into the cooling water.

The heat balance for a 1000 MWe plant is shown in Fig. 6. The best coal-fired plants have a net efficiency of about 38.6% whereas the typical nuclear plants are about 33%. The nuclear plant discharges about 50% more waste heat to cooling water.

The local impact of waste discharge can be reduced by installing a cooling tower on the condenser cooling discharge. These are not without disadvantage because they are big and ugly (Fig. 7), and their operation causes some local effects such as fogging and icing. Also, they are costly to build and operate--thus, they mean more expensive electricity.

ENVIRONMENTAL EFFECTS

The production and use of energy has many undesirable environmental effects. These include destruction of land from mining, water pollution from oil spills, air pollution, and noxious waste products. I will limit my discussion to air pollution.

Air Pollution from Transport: By far the worst polluter of all is the automobile. The problem is increasing because the number of vehicles is increasing (see Fig. 7), and the total amount of fuel being consumed is increasing (see Fig. 8).⁽⁷⁾ New EPA emissions standards are designed

to reduce air pollution from vehicles. It is too early to predict how successful the regulations will be. Unfortunately, the anti-emission devices will reduce mileage. The real solution to this problem is to make cars smaller and reduce the use of automobiles.

The total quantities of air pollutants from transport is summarized in Table IV.⁽⁸⁾ Carbon dioxide is not noxious but there is concern about long-term climatological effects as the CO₂ content of the atmosphere increases. Carbon monoxide, CO, is a serious problem in urban areas and the nitrogen oxides, NO_x, produce photochemical smogs which are very injurious to the health.

Home Heating: Furnaces in homes and buildings contribute to air pollution. Usually these units are not adequately designed and maintained to minimize emissions (see Table V).⁽⁸⁾

Air Pollution from Industry and Steam Electric Generating Plants: The chimneys of our factories and power plants emit large quantities of pollutants. These are summarized in Table VI.⁽⁸⁾ The oxides of sulfur and nitrogen constitute the worst problems.

AIR POLLUTION: EMISSION-DOSE RELATIONSHIP

There is still much to be learned about the relationship between pollutants that are discharged into the air, and the dose that people receive. The movement of pollutants through the atmosphere depend on weather conditions, height of discharge, and many complex chemical reactions. At this time, it is impossible to write down a simple formula which will describe the concentration of a pollutant in terms of the various sources of emission.

Dr. Robertson will discuss the health effects of air pollutants.

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Your Congressman, the EPA, the FPC, the Bureau of Mines, the AEC, and local utilities will provide you with much information, if asked.

TABLE I

1971 U.S. ENERGY CONSUMPTION^(a)

<u>Energy source</u>	<u>Consumption (10¹⁵ Btu)</u>	<u>Percent</u>
Coal	12.560	18.2
Petroleum (Crude oil)	27.940	40.5
Natural Gas (Liquids)	2.552	3.7
Natural Gas (Dry)	22.734	32.9
Hydropower ^(b)	2.833	4.1
Nuclear ^(c)	0.391	0.57
Wood ^(d)	<u>(~0.8)</u>	--
TOTAL	69.010	

(a) Data taken from Ref. 1.

(b) Theoretical input computed at 10,494 Btu/kWh.

(c) Nuclear fission heat input computed at 10,660 Btu/kWh.

(d) Estimate of energy derived from wood used as fuel.

TABLE II

1971 U.S. SOURCES OF ENERGY^a
(in units of 10^{15} Btu)

<u>Energy source</u>	<u>Domestic production</u>	<u>Import</u>	<u>Export</u>
COAL	14.154	0.002	1.645
PETROLEUM (CRUDE AND REFINED	19.558	8.291	0.474
NATURAL GAS (WET)	24.871	0.954	0.083
HYDROPOWER ^b	2.796	0.074	0.037
NUCLEAR	0.391	0	?
TOTAL ^c	61.770	9.321	2.239
NET IMPORT		7.082	

PERCENT OF ENERGY IMPORTED:^d 10.3%

a) Data from Ref. 1.

b) Data from FPC. Computed at rate of 10,494 Btu/kWh.

c) Totals will disagree with Table I because stockpile net withdrawals are not included.

d) Based on 69.010×10^{15} Btu, 1971 consumption.

TABLE III

Estimated Ultimate Recoverable Energy
Resources of the United States

The 1971 domestic production is compared with the cumulative production through 1971 and the estimated remaining recoverable resources.

<u>Commodity</u>	<u>1971 Domestic production (10¹⁵ Btu)</u>	<u>Cumulative production through 1971 (10¹⁵ Btu)</u>	<u>Estimated remaining recoverable resources</u>
COAL	14	1069	32,200
PETROLEUM	20	540	555
NATURAL GAS (WET)	25	480	1,094
OIL SHALE	Neg.	Neg.	1,066
URANIUM (<15/lb)	--	--	162,000

TABLE IV

Emissions of Air Pollutants from Transportation

<u>Fuel</u>	<u>CO₂</u>	<u>CO</u>	<u>SO₂</u>	<u>NO_x</u>	<u>Particulates</u>	<u>Hydrocarbons</u>	<u>Aldehydes</u>
(BILLION POUNDS PER YEAR)							
YEAR 1969 (ACTUAL)							
Gasoline	1570	180.2	0.422	15.4	0.75	31.6	?
Diesel Fuel	231	2.20	0.264	3.51	0.128	0.361	0.030
Jet Fuel	311	2.24	0.171	0.431	0.688	1.46	0.044
YEAR 1977 (ESTIMATED)							
Gasoline	1750	163.3	0.47	14.33	0.834	21.13	?
Diesel Fuel	504	4.80	0.575	7.65	0.279	0.788	0.065
Jet Fuel	745	5.35	0.41	1.03	1.645	3.50	0.105

TABLE V

Emissions of Air Pollutants from Home and Commercial Heating

<u>FUEL</u>	<u>CO₂</u>	<u>CO</u>	<u>SO₂</u>	<u>NO_x</u>	<u>Partic- ulates</u>	<u>Hydro- carbons</u>	<u>Alde- hydes</u>
(BILLION POUNDS PER YEAR)							
YEAR 1969 (ACTUAL)							
Gas	873	0.132	0.004	0.426	0.127	0.053	0.067
Oil	961	0.116	3.46	1.00	0.498	0.121	0.079
Coal	116	0.211	0.80	0.125	0.084	0.062	0.0001
YEAR 1977 (ESTIMATED)							
Gas	878	0.139	0.004	0.445	0.132	0.055	0.070
Oil	972	0.120	3.51	0.998	0.501	0.122	0.080

TABLE VI

Emissions of Air Pollutants from
Fossil-fueled Steam-Electric Plants

<u>FUEL</u>	<u>CO₂</u>	<u>CO</u>	<u>SO₂</u>	<u>NO_x</u>	<u>Particulates</u>	<u>Hydrocarbons</u>	<u>Aldehydes</u>
(BILLION POUNDS PER YEAR)							
YEAR 1969 (ACTUAL)							
Gas	439	0.001	0.002	1.36	0.052	0.139	0.010
Oil	272	0.0003	3.85	1.12	0.086	0.021	0.011
Coal	1660	0.297	31.8	6.02	7.83	0.090	0.001
YEAR 1977 (ESTIMATED)							
Gas	466	0.002	0.002	1.17	0.055	0.148	0.011
Oil	529	0.001	2.46	1.68	0.168	0.040	0.022
Coal	2140	0.383	11.9	7.32	6.81	0.115	0.002

Fig. 1

Fig. 2 U.S. ENERGY BALANCE - INITIAL APPRAISAL

from: U.S. Energy Outlook, An Initial Appraisal, 1971-1985, an interim report of the National Petroleum Council, Volume One, July 1971

Fig. 3 Total Production Cycle for North American Crude Oil.
(Curve taken from M. K. Hubbert, ref. 5)

Fig. 4 GROWTH OF PER CAPITA
Electricity Consumption
United States

Fig. 5

HEAT REJECTED BY TYPICAL PLANTS
(1000 MWe NET OUTPUT)

FOSSIL
 $\epsilon = 38.6 \%$

NUCLEAR
 $\epsilon = 33 \%$

Fig. 6

FIGURE 7

Fig. 8

Fig. 9

APPENDIX A
POSSIBLE STUDY TOPICS

1. How utilities are regulated.
2. AEC licensing procedures.
3. The New York City Power Crisis.
4. Power pool arrangements.
5. Environmental problems with high voltage transmission lines.
6. Health hazards from air pollution.
7. Health hazards from radiation.
8. Useful applications of waste heat.
9. Cooling towers.
10. Environmental reports of various utilities.
11. Ecological effects of thermal pollution.
12. Fuel resources of the United States.
13. Breeder reactors.
14. Problems of site selection for power plants.
15. Our national gas supply.
16. Social and economic consequences of energy rationing.
17. Can electricity be substituted for gasoline in transportation?
18. Political factors in energy supply.
19. Tax problems.
20. Rate structures in sale of electricity.
21. Improved techniques of coal combustion.
22. Tidal power.
23. Geothermal power.
24. Solar power.
25. Objections to nuclear power.
26. Power supplies for the future (MHD, fuel cells, fusion reactors).
27. Politics of a national energy policy.
28. Hydroelectric possibilities.
29. Pumped storage.
30. The price of safety.
31. Off-shore oil drilling.
32. The Alaskan pipeline.
33. Desalination of water.

APPENDIX B
APPROXIMATE WATTAGE RATING AND ESTIMATED ANNUAL KWHR
CONSUMPTION OF ELECTRICAL APPLIANCES - ASSUMING NORMAL USE

<u>Appliance</u>	<u>1969 Est. Kwhrs Consumed Annually</u>	<u>1969 Av. Wattage</u>
Heat Pump	16,003	11,848
Water Heater (Quick Recovery)	4,811	4,474
Water Heater (Standard)	4,219	2,475
Refrigerator-Freezer (Frostless 14 cuft)	1,829	615
Food Freezer (Frostless 15 cuft)	1,761	440
Air Conditioner (window)	1,389	1,566
Refrigerator (Frostless 12 cuft)	1,217	321
Food Freezer (15 cuft)	1,195	341
Range	1,175	12,207
Refrigerator-Freezer (14 cuft)	1,137	326
Clothes Dryer	993	4,856
Refrigerator (12 cuft)	728	241
Television (Color)	502	332
Oil Burner or Stoker	410	266
Fan (Furnace)	394	292
Dehumidifier	377	257
Dishwasher	363	1,201
Television (B&W)	362	237
Fan (Attic)	291	370
Water Pump	231	460
Roaster	205	1,333
Frying Pan	186	1,196
Heater (Radiant)	176	1,322
Fan (Window)	170	200
Humidifier	163	117
Iron (hand)	144	1,088
Bed Covering	147	177
Radio-Phonograph	109	109
Coffee Maker	106	894
Washing Machine (Automatic)	103	512
Broiler	100	1,436
Hot Plate	90	1,257
Radio	86	71
Deep Fat Fryer	83	1,448
Washing Machine (Non-automatic)	76	286
Vacuum Cleaner	46	630
Fan (Circulating)	43	88
Toaster	39	1,146
Grill (Sandwich)	33	1,161
Food Waste Disposer	30	445
Waffle Iron	22	1,116
Shaver	18	14
Clock	17	2
Sun Lamp	16	279
Floor Polisher	15	305
Food Blender	15	386
Cooker (Egg)	14	516
Hair Dryer	14	381
Food Mixer	13	127
Heat Lamp (Infrared)	13	250
Sewing Machine	11	75
Heating Pad	10	65
Carving Knife	8	92
Tooth Brush	5	7
Vibrator	2	40

Source: Elec. Council New England, Statistical Bulletin, 1968. Figures based on National Averages prepared by The Edison Electric Institute

APPENDIX C

CONVERSION FACTORS AND ENERGY EQUIVALENTS

Conversion Factors

1 Kw-hr (Kwh)	= 3412.8 Btu
1 Mw-yr	= 2.992×10^{10} Btu
1 HP-hr	= 2545 Btu = 1.98×10^6 ft-lb = 2.685×10^6 Joules
1 Watt-hr	= 3600 Joules
1 HP	= 0.7455 Kw = 1 HP = 550 ft-lb/sec

Energy Equivalents

The energy content of most fuels can vary depending on their source.

The following energy equivalents have been used in this report.

COAL

Anthracite	25.4×10^6 Btu/ton
Bituminous	26.2×10^6 Btu/ton
Sub-bituminous	19.0×10^6 Btu/ton
Lignite	13.4×10^6 Btu/ton

The average heating value of bituminous coal and lignite exported and used in electricity generation and in industrial sectors in 1969 was 24.7×10^6 Btu/ton (from U.S. Dept. of the Interior, Bureau of Mines, "Mineral Industry Survey", Weekly Coal Report No. 2839, Feb 11, 1972).

PETROLEUM

Crude Petroleum	5.60×10^6 Btu/42 gal barrel
Residual Fuel Oil	6.29×10^6 " " " "
Distillate Fuel Oil	5.83×10^6 " " " "
Gasoline (including aviation)	5.25×10^6 " " " "
Jet Fuel (kerosine-type)	5.67×10^6 " " " "
Jet Fuel (naphtha-type)	5.36×10^6 " " " "
Kerosine	5.67×10^6 " " " "
Petroleum Coke	6.02×10^6 " " " "
Asphalt and Road Oil	6.64×10^6 " " " "
NATURAL GAS (DRY):	1031 Btu/ft ³ at STP
NATURAL GAS (WET)	1103 " " " "
NATURAL GAS LIQUIDS (AVG.)	4.1×10^6 Btu/42 gal barrel
FISSIONABLE MATERIAL	74.0×10^6 Btu/g U-235 fissioned
(based on 192 MeV fission)	

APPENDIX D

Table I: Scheduled Operational Dates and Capacities of Nuclear Power Plants under Construction⁽²⁾. 1970 is shown for reference.

Year	Number of Plants	Total Capacity (Millions of Kilowatts)	Average Capacity (Megawatts)
(1970)	(4)	(2.7)	(664.0)
1971	12	8.9	741.5
1972	19	16.1	849.5
1973	16	14.9	934.1
1974	10	9.1	907.0

Number and Total Capacity of Nuclear Plants Ordered in Recent Years in the U. S.⁽⁵⁾.

Year	Number of Plants Ordered	Total Capacity (Millions of Kilowatts)
1966	20	16.3
1967	31	25.9
1968	16	14.8
1969	7	7.3
1970	14	14.4
1971 (Jan-Sept)	22 ⁽⁶⁾	22.5

Projected Nuclear Share of Total Primary Energy and of Electrical Output, United States 1970-1985⁽³⁾.

Year	Nuclear Share Primary Energy*	Nuclear Share Electrical Output
1970	0.3%	1.6%
1975	4.0	17.6
1980	9.3	39.1
1985	17.2	48.0

*Primary nuclear energy will be converted to electricity at an average efficiency of approximately 35%.

TABLE II: Typical Characteristics and Operating Parameters of Commercial Power Reactors.^a The properties listed are for a 1000 MWe capacity.

<u>PROPERTY</u>	<u>BWR</u>	<u>PWR</u>	<u>HTGR</u> ^b
<u>FUEL</u>			
Compound	UO ₂	UO ₂	UC ₂ -ThC ₂
U ²³⁵ Enrichment	~2%	~3.2%	(Fully Enriched)
Pellet Size: height x diameter (in.)	0.58x 0.48	0.60x 0.37	(See text)
Length of Fuel Pin (ft.)	12	12	(See text)
Spacing Between Fuel Pins (in.)	0.74	0.56	(See text)
Number of Pins Per Element	49	204	(See text)
Total Number of Elements	764	193	3841
Total Fuel Weight (Tons)	186.1	108.3	2.3(U ²³⁵)
Core Size: heightxdiameter (ft.)	12x15.6	12x11.1	15.6x31.1
Conversion Ratio	~0.5	~0.5	~0.75
<u>THERMODYNAMIC</u>			
Coolant Inlet Temp (°F)	376	545	758
Coolant Exit Temp (°F)	546	610	1449
Reactor Vessel Pressure (psia)	1050	2235	700
Net Plant Efficiency	32.8	32.5	40.7

^a Data were obtained from ref. 5.

^b The HTGR data correspond to a "scaled-up" Fort Saint Vrain reactor (ref. 6).

TABLE III. BWR-Type Commercial Nuclear Power Stations in the United States (ref. 7).

Only those plants which are operating or expected to be in operation before the end of 1972 are listed. Experimental and "demonstration" plants which have fulfilled their function and have been shutdown are not listed.

<u>Name</u>	<u>Location</u>	<u>Electric Power (MWe)</u>	<u>Thermal Power (MWt)</u>	<u>Year of Start-Up</u>
Dresden #1	Morris, Ill.	200	700	1959
Big Rock Point	Big Rock Point, Mich.	70.3	240	1962
Humbolt Bay #3	Eureka, Calif.	68.5	240	1963
LaCrosse	Genoa, Wis.	50	165	1967
Oyster Creek #1	Toms River, N.J.	650	1930	1969
Nine Mile Point	Scriba, N.Y.	625	1850	1969
Dresden #2	Morris, Ill.	809	2527	1970
Millstone #1	Waterford, Conn.	652	2011	1970
Monticello	Monticello, Minn.	545	1670	1970
Dresden #3	Morris, Ill.	809	2527	1971
Browns Ferry #1	Decatur, Ala.	1065	3293	1972
Quad Cities #1	Cordova, Ill.	809	2511	1972
Vermont Yankee	Vernon, Vt.	514	1593	1972
Quad Cities #2	Cordova, Ill.	809	2511	1972
Pilgrim	Plymouth, Mass.	655	1998	1972
Cooper	Brownville, Neb.	778	2381	1972
Peach Bottom #2	Peach Bottom, Pa.	1065	3294	1972
Edwin I. Hatch #1	Baxley, Ga.	786	2436	1972

TABLE IV. PWR-Type Commercial Nuclear Power Stations in the United States (ref. 7).

Only those plants which are operating or expected to be in operation before the end of 1972 are listed. Experimental and "demonstration" plants which have fulfilled their function and been shutdown are not listed.

<u>Name^a</u>	<u>Location^b</u>	<u>Electric Power (MWe)</u>	<u>Thermal Power (MMt)</u>	<u>Year of Start-Up</u>
Shippingport	Shippingport, Pa.	90	505	1957
Yankee	Rowe, Mass.	175	600	1960
Indian Point #1	Buchanan, N.Y.	265	615	1962
San Onofre #1	San Clemente, Calif.	430	1347	1967
Connecticut Yankee	Haddam Neck, Conn.	575	1825	1967
Robert Emmett Genna #1	Ontario, N.Y.	420	1300	1969
H. B. Robinson #2	Hartsville, S.C.	700	2200	1970
Point Beach #1	Two Creeks, Wis.	297	1518	1970
Palisades #1	South Haven, Mich.	700	2212	1972
Oconee #1	Seneca, S.C.	841	2452	1972
Indian Point #2	Buchanan, N.Y.	873	2758	1972
Surry #1	Gravel Neck, Va.	780	2441	1972
Turkey Point #3	Turkey Point, Fla.	693	2200	1972
Point Beach #2	Two Creeks, Wis.	497	1518	1972
Zion #1	Zion, Ill.	1050	3250	1972
Oconee #2	Seneca, S.C.	886	2568	1972
Three Mile Island #1	Goldsboro, Pa.	831	2452	1972
Ft. Calhoun #1	Ft. Calhoun, Neb.	457	1420	1972
Surry #2	Gravel Neck, Va.	780	2441	1972
Salem #1	Salem, N.J.	1050	3250	1972

TABLE IV (continued)

<u>Name^a</u>	<u>Location^b</u>	<u>Electric Power (MWe)</u>	<u>Thermal Power (MWt)</u>	<u>Year of Start-Up</u>
Turkey Point #4	Turkey Point, Fla.	693	2200	1972
Parie Island #1	Red Wing, Minn.	530	1650	1972
Maine Yankee	Wiscasset, Me.	790	2440	1972
Kewaunee	Carlton, Wis.	540	1650	1972
Crystal River #3	Red Level, Fla.	858	2452	1972
Rancho Seco #1	Clay Station, Calif.	804	2452	1972
Calvert Cliffs #1	Lusby, Md.	845	2570	1972
Donald C. Cook #1	Bridgman, Mich.	1054	3250	1972
Beaver Valley #1	Midland, Pa.	847	2660	1972
Arkansas #1	London, Ark.	820	2452	1972

^a Only the identifying words in the formal name have been given. Most are called,

"Nuclear Power Station, Unit No. 1", or equivalent. Often fossil fuel units are located at the same site and are assigned unit numbers, e.g. Turkey Point Station, Units 1 and 2 are fossil whereas 3 and 4 are nuclear.

^b Since most plants are sited in remote areas, the location is sometimes given as the nearest population center or in terms of some prominent geographical feature. Locations cited here are those listed in the AEC licensing dockets.

TABLE V. Miscellaneous Commerical Nuclear Power Stations in the United States. The table includes only those operating or scheduled to begin operating in 1972, and omits several small demonstration plants which have served their function and been shut-down and dismantled.

<u>Name^a</u>	<u>Location^b</u>	<u>Type</u>	<u>Electric Power MWe</u>	<u>Thermal Power MWt</u>	<u>Year of Start-Up</u>
Enrico Fermi #1	Lagoon Beach, Mich.	Sodium Cooled Fast	60.9	200	1963
N Reactor	Richland, Wash.	Graphite dual purpose	790	4000	1963
Peach Bottom #1	Peach Bottom, Pa.	HTGR	40	115	1966
Fort St. Vrain	Platteville, Col.	HTGR	330	842	1972

^a Only the identifying words in the formal name have been given. Most are called, "Nuclear Power Station, Unit No. 1", or equivalent. Often fossil fuel units are located at the same site and are assigned unit numbers, e.g. Turkey Point Station, Units 1 and 2 are fossil whereas 3 and 4 are nuclear.

^b Since most plants are sited in remote areas, the location is sometimes given as the nearest population center or in terms of some prominent geographical feature. Locations cited here are those listed in the AEC licensing dockets.

TABLE VI

ESTIMATE OF U.S. POPULATION RADIATION DOSE

(Source: EPA)

	<u>Doses in Million Man-Rems Per Year</u>			
	<u>1970</u>		<u>2000</u>	
Natural Background	26.6	(63.0%)	41.7	(62.7%)
Medical X-Rays	14.8	(35.1%)	23.1	(34.7%)
Weapons Tests	0.8	(2.0%)	1.6	(2.4%)
Nuclear Power	0.004	(0.01%)	0.14	(0.2%)
TOTALS	42.2		66.5	
U. S. Population (Millions)	205		321	
World Nuclear Capacity (GWe)	20		2000	

TABLE VII

Estimated Radiation Dose from Proposed Shoreham Nuclear Power Plant*

<u>LOCATION</u>	<u>DOSE</u>
"FENCE-POST" (at Site Boundary)	5 mrem/year [†]
Average Population Exposure within 50-mile radius of plant	0.005 mrem/year
Average U.S. Population Exposure 1970 from 17 operating nuclear power plants	less than 0.001 mrem/year
Average U.S. Population Exposure in year 2000 from ~ 200 operating nuclear power plants and fuel processing plants	less than 0.1 mrem/year

*Based on Public Health Service surveys at Dresden I Nuclear Power Station.

[†]Public commitment by Long Island Lighting Co. that "fence-post" dose will be maintained at 1% or less of A.E.C. guidelines.

Fig.2: Schematic of a Pressurized Water Reactor (PWR)

Fig. 1: Schematic of a Boiling
Water Reactor (BWR)

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FEDERAL REPOSITORY

Fig. 3: Schematic of proposed
Bedded Salt Repository for
Storage of Radioactive Wastes

Thorium Breeding Cycle

Uranium-238 Breeding Cycle