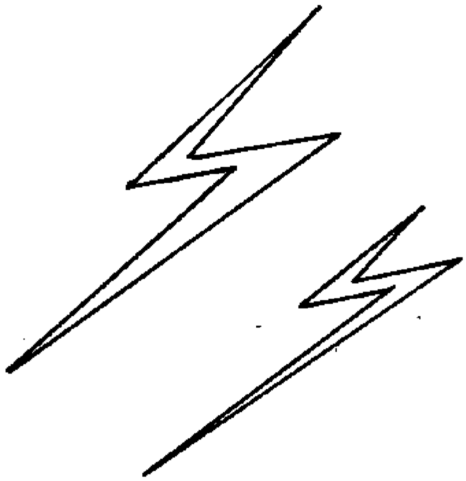
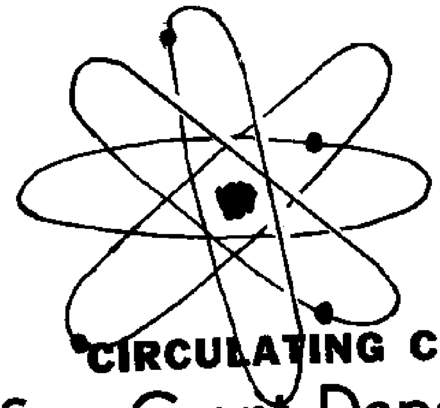
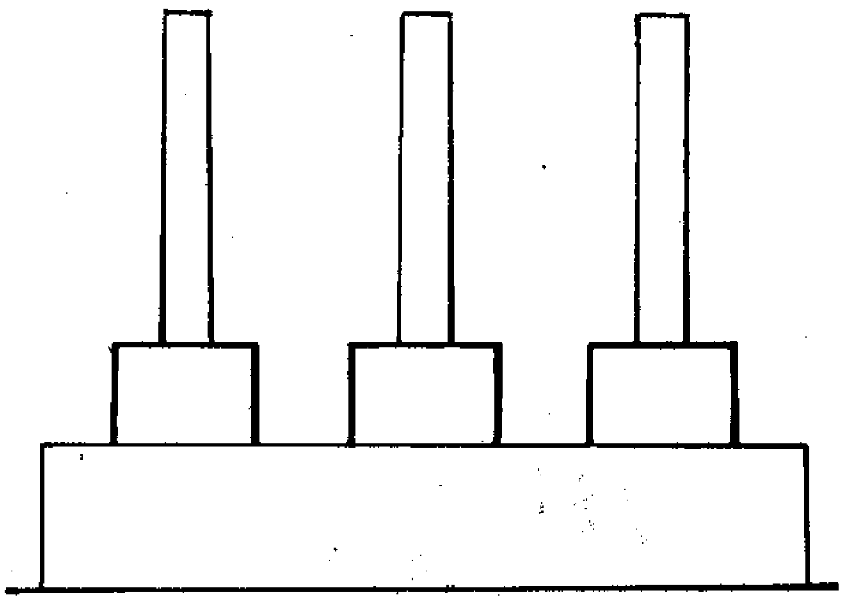




PROCEDINGS OF THE MEETING
MAY, 1972
STATE UNIVERSITY OF NEW YORK
OSWEGO, NEW YORK

POWER PLANT SITING



A NEW YORK SEA GRANT ADVISORY SERVICE PUBLICATION

PROCEEDINGS

OF A

CONFERENCE ON

POWER PLANT SITING

Sponsored by the
New York State Sea Grant Program

May 10, 1972
State University of New York
Oswego, New York

Sea Grant is a new way of helping coastal users and coastal communities. Through research, it discovers new ways of using or protecting the sea's resources. Campuses of State University of New York and Cornell University are training competent workers in marine careers. An Advisory Service working with Cooperative Extension has been established to help bring needed information about the sea to fishermen, consumers, community groups and industry.

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OPENING REMARKS

By Bruce Wilkins, Assistant Professor, Department of Natural Resources, Cornell University and Program Leader, Sea Grant Advisory Service

Objectives of Meeting

Power plant siting is the subject of a major research thrust within New York's Sea Grant Program. We chose this topic for discussion at the first New York meeting sponsored by Sea Grant because Cooperative Extension agents and decision-makers have expressed interest in learning about the subject. The problems involved in locating power generating stations are numerous and complex and they cannot all be dealt with today, of course. However, through the joint efforts of the speakers, Sea Grant and Cooperative Extension, problems basic to power plant siting may be better understood.

Description of Sea Grant

Sea Grant is an organized attempt on the part of state and federal government to do for the resources of the oceans and the Great Lakes what the Land Grant System has done for the resources of the land. This effort has come to New York State only recently, beginning in November 1971.

The Advisory Service component of Sea Grant is the group that organized this meeting, in cooperation with Oswego County Cooperative Extension Service and the State University at Oswego. The Advisory Services' role is to take research findings to potential user audiences, people who can use research findings to aid them in their daily lives. In its first year, the Sea Grant Program concentrated on a number of different areas viewed as important to the coastal regions, both the marine and Great Lakes areas: activities pertaining to wetlands, recreation industry, commercial fishing and aquaculture. Another major area of interest and concern to both research and Advisory Service components of Sea Grant is power plant siting. We'd like to develop a program in which you and others can gain a better understanding of the complex questions involved, not in reference to particular sites, but understanding the general factors influencing this question today.

THE STATUS OF NEW POWER PLANT PROPOSALS IN NEW YORK

Address by Mr. Ronald Stewart, Senior Research Associate
Atmospheric Sciences Research Center
State University of New York at Albany

I. Power Plants in New York State, Present and Projected Population and Power Demand

If we demanded the same amount of electrical power today as demanded by persons when we were born, we likely would not be at this meeting. But when you and I demand eight times as much electricity as we did some 40 years ago, then we have an entirely different problem. For while the population has doubled in the past 35-40 years, the demand for power has increased more than eightfold. Hence, demand, not necessity, is the pivotal factor spurring development of greater energy generating power.

Information Sources

There are various sources of information on electricity demands, power plants and related topics. For instance, literature is published by power companies specifically to inform the public. Some of the data used in this speech is from such sources.

Reports (three volumes) on thermal pollution are available from the Congressional Hearings for the Subcommittee on Air and Water Pollution. These cover both sides of each issue, and include a bibliography of references available on heat, radioactivity, and power plant siting. They can be obtained by writing to one's congressman or senator. There is also the Dennison and Elder Report from the Canadian Center for Inland Waters, a report on thermal inputs to the Great Lakes. Another one of interest is Thermal Pollution, State of the Art, by Parker and Krenkel, from Vanderbilt University in Nashville, $4.00. It is a good rundown on the problem: how the data is gathered, how you can analyze problems. Various organizations put out annual reports. Some of the information presented here is from the Niagara Mohawk Annual Report. Every power company does this, telling what they are doing and what they have planned. For a broader view of power plant siting and the energy problem in general, the September 1971 "Scientific American" has a very nice summary of a whole series of problems arising in relation to energy and power, including how these affect the biosphere, the energy resources of the earth, how energy flows through our industrial society, and decision-making.

Questions

1) Question
Could I ask one that is non-technical concerning the use of power of words? My blood pressure went up every time you emphasized demand and I noticed throughout your talk you referred to people demanding power eight times and mentioned casually need twice. I was wondering if this is a personal bias of yours--are you trying to brainwash us, or is this so important that people are actually demanding it as a lifestyle?

Response
I' you choose to think back 20 years to how you lived in 1950, at that time you were using about one-half the power for you to live as you do today. What has caused this tremendous increase in the total use of electrical energy? Have you really needed that tremendous increase to survive? To enjoy life? To live at a reasonable rate? To live better than any other country in the world?

2) Question
In 48 years I've used wood, fuel oil, coal and many other things. I can't remember every demanding electricity. I simply use it because it's more convenient, it's there, it's available and so forth. So, tying in with the users today, I am questioning whether we are actually demanding this lifestyle or whether it is being forced upon us because it's so much more convenient.

Response
Nobody forced you to turn on your first light switch.

"Okay, I just wondered why you hate to use 'need'."

I feel rather strongly it is our demand and not our need that presents a power problem.

3) Question
Do homes or industry really create the "demand" you refer to?

Response
I don't have all the figures on that. I do know that 50 percent of, let's say, Niagara Mohawk's generation is for industrial use and the other 50 percent for residential. But regardless of where it is going, we as a people get the benefits, require the benefits and demand the benefits.

"No, my point is this, when people talk about the doubling of power demand every 10 years, I'm wondering whether it is reasonable to assume that this doubling is going to continue at the same level."

Response
It's impossible to say that it's going to end in Year X. If we were to assume that, we would be short changing the ingenuity of certain manufacturers that provide electrical gadgets we may buy. They will definitely continue to produce these gadgets as they have in the past. The electricity demand curve goes back to 1900, and has been increasing approximately the same way since 1900. I have absolutely no evidence to indicate that the curve is changing substantially--if I allow 15 percent on either side.

Now many people are looking to mass transportation and the question of what do you use for mass transportation always arises. Very often they come up with either turbine-driven vehicles or electrical-driven vehicles. This curve could change slightly, but for the moment I see no large change in our way of living that is going to make that curve bend over and come down to even doubling in every 30 years, so we would have a greater lead time in our planning. If you can show me any evidence to the contrary, I'd be very interested in seeing it.

4) Question

Do you have any other data on nuclear or thermal generating sites on Lake Ontario? Some total of what exists now and what has been proposed for Lake Ontario?

Response

The plants I mentioned are plants for which I have written reports, not newspaper reports, but written reports indicating these either exist or are planned. The ratings they are given, whether it be 500 or 800 megawatts, always come from a report I consider to be reliable. There are hearings on power plant siting, but beyond that, I have yet to see a report listing sites and approximate megawatt ratings. (See map and table at end).

In the long range, if you go to the Elder report, and look beyond 1980, you can get any number of planned power generating stations. Exact siting is still being discussed, simply because all of the sites haven't been bought. When they are bought you'll have a better idea of where the power companies are going to build.

5) Question

For environmentalists, isn't it a little too late to initiate discussion once the sites have been bought?

Response

For environmentalists, I talk about the Bell Station or the Easton or Shoreham--three power plants that have been planned and, for the time being at least, have been delayed or stopped entirely. So in the terms of planning a nuclear power plant, you're talking of perhaps seven or eight years before it goes on-line, years in which an environmentalist can react.

With the amount of data available today the environmentalist can apply it to a proposed site. He can also begin taking his own data there. Likewise, there are many studies going on that may be applicable to siting. We had been studying the 9-mile point site two or three years before we had any interest in nuclear power generation. We were interested in some other things out there and had this as background data. One of our greatest problems is that so much data has been collected which isn't getting out and being used. But there is a tremendous amount of data for Lake Ontario. The International Field Year on the Great Lakes should be doing a tremendous amount to draw that together. The New York State Sea Grant Program should also bring a substantial amount of information to the public on power generation as it becomes available through the program's research projects. And, we are trying now to ally with several other organizations involved in the problems of power generation so we don't duplicate but provide a good use of efforts.

II. Power Plants and Thermal Control

Condenser Requirements

Let me begin with some data related to water use by power plants put out by the Water Resources Council. In 1965 in the North Atlantic region (Delaware to Maine), 10,000,000 gallons per day of fresh water were used for condenser steam in power generation plants. An additional 11,000,000 gallons of saline water were used for the same purpose each day in that region. By the year 2000, fresh water daily use will have increased nearly threefold to 28,000,000 gallons and a sixfold rise to 68 million gallons is expected in the use of saline water.

Water-Cooling Methods

There are several methods of obtaining cool water to condense steam used by power plant turbines. These are:

1. The "once-through" system, in which water is taken directly from some natural source, cools the steam by means of indirect contact, and is returned directly to its original source. This raises the temperature of the water roughly one gallon per kilowatt per minute by 20 degrees Farenheit.

2. Cooling towers allow air to pass through the water traveling to the top of a tower and back down, evaporating it. It works on the same principle as if you splashed some cold water on your hand and let it evaporate to cool you off. A natural draft cooling tower uses the natural flow of air in the tower, while in a mechanical draft cooling tower, forced air may be substituted for natural air drafts. Fans, of course, use up some of the electricity produced by the plant.

Drawbacks of cooling towers include:

a) They are highly visible, often 300-400 feet in width and height;
b) They are very costly, ranging from 5 to 15 million dollars plus one-quarter to one-half million dollars a year for operation and maintenance;
c) They may change the weather conditions of their localities by producing clouds or fog which, in turn, produce rain, storms or icing.

3. Research is also being done on <u>dry-cooling systems</u>, in which cooling water would always be contained in pipes, working on the same principle as a car radiator. This system would be more expensive than wet cooling towers.

4. Another alternative, viable only where there is sufficient land (approximately one acre per megawatt), is a <u>cooling pond</u>. This is an artificial lake where water is simply held until it returns to its natural temperature. To reduce necessary acreage and/or time, pumps may be used to spray water into the atmosphere. These ponds also may cause local icing and fogging.

There is no way known to avoid the production of thermal output. Even in a fossil fuel plant, heat is being rejected into the environment. The efficiency of fossil fuel plants run from 35 to 42 percent; that is, less than one-half of the heat energy produced is directly translated into electrical energy. Nuclear plants reach a maximum efficiency of 33 percent, but more often run at 30 percent efficiency. Thus, for every one megawatt of electricity, approximately two megawatts of heat must be eliminated. That heat must go somewhere.

<u>Thermal Discharge into Great Lakes</u>

For instance, the heat flow released in Buffalo was 5.37 BTU (British Thermal Unit) per hour per unit area in 1968 from fossil fuel and nuclear plants, steel operations and sewerage. It is expected to increase fourfold, to a figure of 21.48, by the year 2000. (Information from the Dennison and Elder report).

This means that whereas in 1968 Lake Ontario received .09 BTU per hour per square foot, it is expected to have risen to .27 by 1980 and to quintuple that figure by the year 2000. In that time, Lake Erie will go up by a factor of ten; Lake Huron by a factor of 38-40; Lake Michigan, which has not received much waste thus far, is not expected to go up, due to preventive legislation; Lake Superior is seen as rising by a factor of 10, but is far below all other lakes right now.

Lake Ontario will receive the most heat per unit of the Great Lakes; Erie is not far behind. Thermal discharge problems can definitely be anticipated in these lakes.

You then may face being caught saying, "All right, a power plant is going in, what kind of thermal discharge will it have" and "what do I want to do about it? Could I actually go and ask it to go to closed circuit, dry-cooling, so that no vapor would be released into the atmosphere?" That is the most expensive solution you could ask for. It would mean a considerable amount of power would have to be used to run the fans, and the area would become noisy. The technology for that size of unit (about 1,000 megawatt) has not been tested--at this point. However, Consolidated Edison is doing a series of studies to look into closed-circuit dry-cooling. For the moment, most people are looking into some form of wet cooling but, especially in valleys, are trying to stay away from the cooling tower. So we are back to asking the question which way does an industry go?

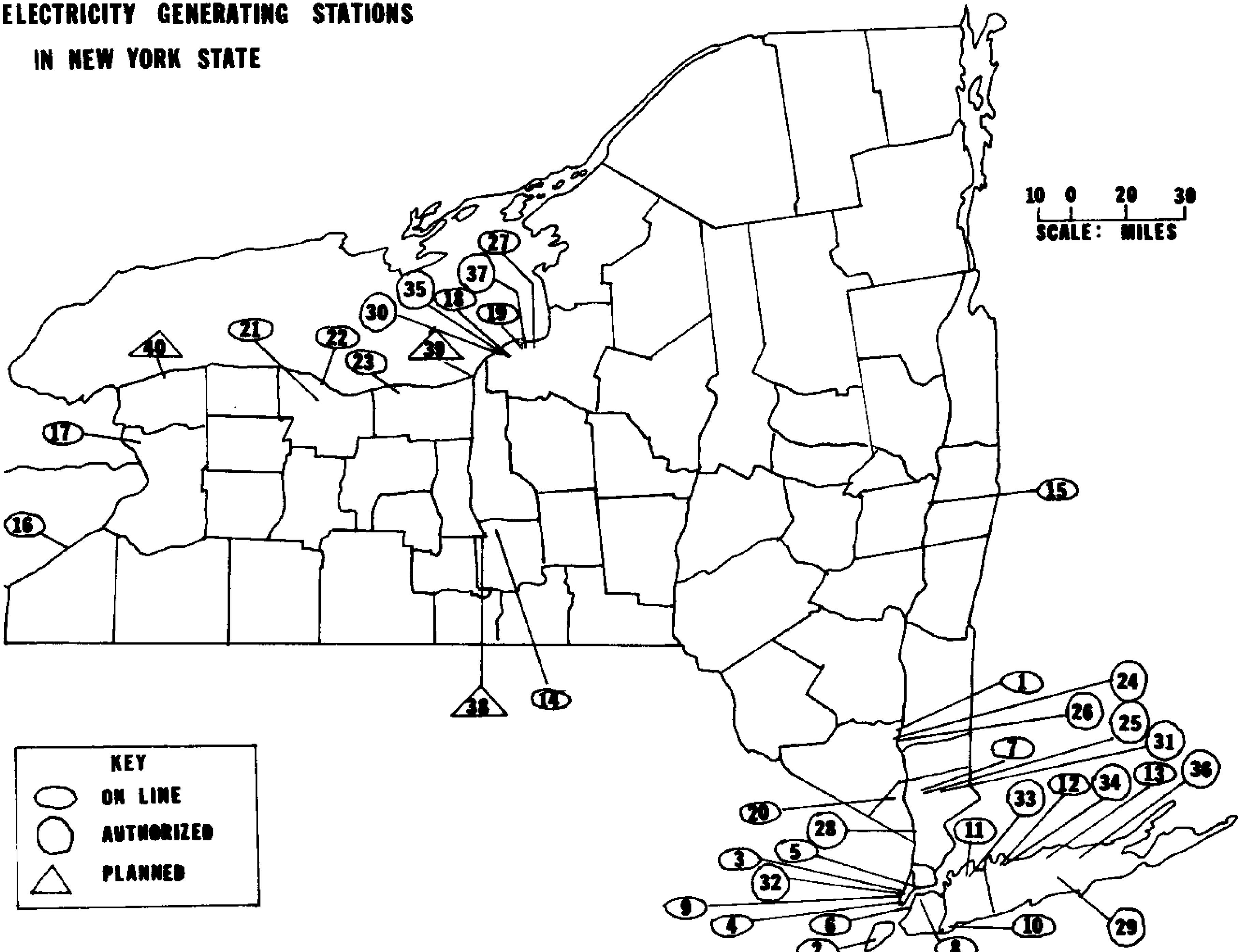
In Wisconsin and Michigan power companies are pushing more and more toward having the cooling pond on their own site and they are using the idea of the spray pond. A spray pond might only be 1/20th or 1/50th the size of a natural cooling pond so cooling water could be kept on their own site and the icing and fogging problems, hopefully would be localized.

One acre per megawatt may be a cooling pond design figure but this depends greatly on where the plant is located and on meteorological conditions. A 1,000 megawatt nuclear plant can use as few as 50 acrés in a spray pond and still cool. These other design figures--one acre per megawatt, for example, are just not necessary. Spray cooling is currently being tested by Detroit Edison for a remote cooling site. They are going to take their facilities off a lake, off a river, and they want to go back in the boondocks and say I am going to put my plant there, I am going to have my own spray pond, I'm going to cool my own water. This is just how they feel at this point.

Question
Wouldn't they still need water to make up for evaporation loss?

Response
Yes, in fact they hope to find a good enough site where they might not need a river but could use wells and their own reservoirs to provide "make-up" water. You can quickly calculate the amount they would need, it's roughly 1-2 percent of their total flow. The University of Wisconsin is doing studies in central Wisconsin on the effects of spray ponds, in terms of ecological change. Will a spray pond or will a cooling pond cause ecological changes we wouldn't care for. There is substantial data available on the natural heat cycle of lakes and what it does to nearby areas. This can be applied to the use of cooling ponds.

ELECTRICITY GENERATING STATIONS IN NEW YORK STATE



#	Company	Station & Unit	Type	Status Existing (E) Authorized (A) Planned (P)	Megawatts	Current Scheduled or Proposed Date of Service
1	Central Hudson	Danskammer	Fossil	E	537	-
2	Con Edison	Arthur Kill	Fossil	E	843	-
3	Con Edison	Astoria	Fossil	E	2117	-
4	Con Edison	East River	Fossil	E	697	-
5	Con Edison	Hell Gate	Fossil	E	455	-
6	Con Edison	Hudson Ave	Fossil	E	784	-
7	Con Edison	Indian Point	Nuclear	E	275	-
8	Con Edison	Ravenswood	Fossil	E	2181	-
9	Con Edison	Waterside	Fossil	E	650	-
10	Long Island Ltg. Co.	E. F. Barret	Fossil	E	669	-
11	Long Island Ltg. Co.	Glenwood	Fossil	E	475	-
12	Long Island Ltg. Co.	Northport	Fossil	E	755	-
13	Long Island Ltg. Co.	Port Jefferson	Fossil	E	454	-
14	N. Y. State E&G	Milliken	Fossil	E	276	-
15	Niagara Mohawk	Albany	Fossil	E	476	-
16	Niagara Mohawk	Dunkirk	Fossil	E	561	-
17	Niagara Mohawk	Huntley	Fossil	E	721	-
18	Niagara Mohawk	Oswego	Fossil	E	321	-
19	Niagara Mohawk	Nine Mile Point	Nuclear	E	620	-
20	Orange & Rockland	Lovett	Fossil	E	465	-
21	Rochester G&E	Beebee	Fossil	E	212	-
22	Rochester G&E	Russell	Fossil	E	254	-
23	Rochester G&E	R. E. Ginna	Nuclear	E	517	-
24	Central Hudson	Roseton #1	Fossil	A	600	5/31/73
25	Con Edison	Indian Point #2	Nuclear	A	370	7/73
26	Central Hudson	Roseton #2	Fossil	A	600	8/31/73
27	Power Authority	J. A. FitzPatrick	Nuclear	A	821	11/73
28	Orange & Rockland	Bowline Point #2	Fossil	A	600	5/74
29	Long Island Ltg. Co.	Holbrook GT	Fossil	A	318	5/74
30	Niagara Mohawk	Oswego Unit #5	Fossil	A	850	10/74
31	Con Edison	Indian Point #3	Nuclear	A	873	11/74
32	Con Edison	Astoria #6	Fossil	A	800	Spring/75
33	Long Island Ltg. Co.	Glenwood GT	Fossil	A	318	5/75

#	Company	Station & Unit	Type	Status Existing (E) Authorized (A) Planned (P)	Megawatts	Current Scheduled or Proposed Date of Service
34	Long Island Ltg. Co.	Northport #4	Fossil	A	386	5/76
35	Niagara Mohawk	Oswego Unit #6	Fossil	A	850	11/76
36	Long Island Ltg. Co.	Shoreham #1	Nuclear	A	820	5/77
37	Niagara Mohawk	Nine Mile Point #2	Nuclear	A	1100	11/78
38	N. Y. State E&G	Bell	Nuclear	P	830	Winter/79
39	Rochester G&E	Sterling	Undecided	P	1000	Winter/80
40	N. Y. State E&G	Somerset #1	Nuclear	P	1200	Winter/82

RADIOLOGICAL CONSIDERATIONS IN NUCLEAR POWER PLANT SITING

Address by Mr. Vance L. Sailor, Physicist
Brookhaven National Laboratory
Upton, New York

Introduction

I shall discuss some of the radiological considerations that must be taken into account in the siting of nuclear power plants and facilities associated with the nuclear power industry. These involve three general areas: 1) routine emission of radioactive effluents, 2) the management of low- and high-level radioactive wastes, and 3) accident potential.

I shall first describe how things are supposed to work. Later, I will review how they have actually been working. Then we can draw a few general conclusions about siting restrictions.

The Sources of Radioactivity

Most of the radiological problems associated with nuclear energy are related to the fission products formed as the nuclear fuel is consumed. These are the "ashes." As you probably know, energy is released from the uranium nucleus by causing it to fission--to break apart into two or more chunks. Most of these leftover pieces are not ordinary stable atoms, but must undergo a series of radioactive decays before they become stable. About 90 radioactive isotopes have been identified among the fission products.1/

Each of these isotopes has a characteristic half-life, which is the time required for half of the atoms of that variety to undergo radioactive decay. The half-lives vary from a fraction of a second to more than a million years. Some examples are shown in Table 1.

Table 1. Examples of Radioactive Fission Products

Element	Isotope	Symbol	Half-Life
Hydrogen (tritium)	3	T^3	12.33 years
Selenium	85	Se^{85}	39 seconds
Krypton	85	Kr^{85}	10.6 years
Rubidium	86	Rb^{86}	18.6 days
Strontium	90	Sr^{90}	28 years
Strontium	92	Sr^{92}	2.7 hours
Ruthenium	106	Ru^{106}	1.01 years
Iodine	129	I^{129}	17-million years
Iodine	131	I^{131}	8.05 days
Cesium	137	Ce^{137}	30 years

Some additional radioactive isotopes are formed by neutron bombardment of materials in the reactor core. These are called activation products. One notable example is nitrogen-16 (N^{16}) which has a 7.13 second half-life. N^{16} is important because it is formed from oxygen, which is quite abundant in the reactor (the water coolant) and emits a very penetrating gamma ray. Other activation products are formed from the elements in stainless steel.

The main safety problem associated with nuclear facilities is keeping these radioactive products out of the biosphere as completely as possible.

Routine Radioactive Emissions

As a practical matter it is impossible to contain 100 percent of the radioactivity. Let us consider the ways in which the difficulties arise. As the cooling water circulates through the reactor core it picks up some radioactivity in the form of dissolved salts and entrained gases. These are partly activation products from the water and core structure and partly fission products from the fuel. The uranium fuel is sealed in metal tubes but usually a few fuel pins will develop leaks that allow fission products to escape into the cooling water. Also, in spite of the fact that new fuel pins are carefully cleaned, a small amount of uranium dust remains on the outside (this is often called "tramp" uranium). Fission products from tramp uranium are free to dissolve in the water.

1. Liquid Wastes

During plant operation it is necessary to remove dissolved materials and gases, to keep the water very clean. A small part of the water inventory is continuously repurified. Other liquid wastes accumulate at the plant from the cleaning of tools used in refueling, from the laundering of clothing worn during maintenance operations, and from cleaning up minor leaks, etc.

The dissolved materials pass through a series of evaporators, filters, resin beds, etc., that traps most of the radioactivity[2]. These treatment facilities are periodically cleaned out and the trapped wastes are packaged as solids. The packaging must meet federal and state regulations that apply to the shipment[3] and burial of low-level wastes.[4] There are several special burial sites in the country which have been selected on the basis of favorable geological characteristics.

After the liquid wastes pass through the many stages of treatment, the end product is a lot of very clean water containing a small residual amount of radioactivity. One isotope that does not get removed appreciably is tritium (T^3) since it behaves chemically like ordinary water. The processed water is held in tanks so the residual radioactivity can be measured; then if it meets federal regulations[5] it is released at a controlled rate into the condenser water discharge. An example of the isotopes and maximum quantities released are shown in Table 2 [6] Because of the large volume of condenser water the discharge is diluted by a large factor.

Table 2. Maximum Liquid Radwaste System Release Concentrations From a 820 MWe Boiling Water Reactor (BWR)

Isotope	Half-Life	Release Rates (μc/day)	Discharge Concentration (μc/ml)	Limits of 10CFR20 (μc/ml)
Sr^{89}	50.4 day	8.0×10^4	3.0×10^{-8}	3×10^{-6}
Sr^{90}	28 yr	4.0×10^3	1.5×10^{-8}	3×10^{-7}
Cs^{137}	30 yr	8.0×10^4	3.0×10^{-8}	2×10^{-5}
Ba^{140}	12.8 day	2.4×10^5	9.2×10^{-8}	3×10^{-5}
I^{131}	8.05 day	8.0×10^4	3.0×10^{-8}	3×10^{-7}
Co^{58}	72 day	4.6×10^5	1.8×10^{-7}	1×10^{-4}
Co^{60}	5.27 yr	4.6×10^4	1.8×10^{-8}	5×10^{-5}
T^3	12.36 yr	1.2×10^6	4.6×10^{-7}	3×10^{-3}

2. Gaseous Wastes

The gas extracted from the cooling water goes into holdup tanks where it can be surveyed for radioactivity, then passes through a series of filters for removal of particulate matter and after a delay is discharged to the atmosphere. The amount of radioactivity discharged into the air depends on the delay time.

At this point we must distinguish between the two common reactor types, the pressurized water reactor (PWR), and the boiling water reactor (BWR), since they have different characteristics.

In the case of a PWR, the steam that drives the turbine is formed in a secondary water loop so none of the reactor coolant passes through the turbine. The volume of gas removed from the reactor coolant is small, thus it is practical to store this gas for several weeks before the tanks fill up. Consequently there is time for all of the short-lived isotopes to die away. About the only radioactive gas left is Kr^{85}.

The situation is different with a BW. The steam for the turbine is formed in the reactor vessel, so the reactor coolant passes directly through the turbine. The N^{16} formed from the neutron reaction on oxygen travels with the steam and produces a strong radiation field around the pipe that carries the steam to the turbine. (To reduce exposure to plant employees, this pipe should have several feet of concrete shielding around it.) Since N^{16} decays very quickly it does not create any additional problems.

On the exhaust side of the turbine, the steam is condensed to form a partial vacuum. As a result of this vacuum, there is a tendency for air from the room to leak into the condensed steam through various seals in the turbine, pumps, valves, etc. The radioactive gases in the condensed steam mix with air and consequently the total volume of gas which must be handled is much larger than in the case of a PWR. Because of the large volume, the gas from a BWR cannot be retained very long. The older plants have holdup times of only 20 minutes or so, but newer plants are installing various trapping systems that will allow holdup times of several hours or even several days. The longer holdup times are desirable to allow the shorter half-lives to decay. Table 3 shows how emissions decrease with holdup time[6].

To recapitulate, nuclear plants discharge small quantities of radioactive liquid wastes at a controlled rate via the condenser water and radioactive gases into the air. Both types of discharge are continuously monitored and both must be less than the limits set by the Atomic Energy Commission[5]. The environs are regularly surveyed for buildup of radioactivity. I will discuss the radiation doses to humans later.

Table 3. Emission Rates of Noble Gases from a 820 MWe Boiling Water Reactor (BWR)

Isotope	Half-Life	Micro-Curies per Second (Ci/s)					
		Decay 0	Decay 30 Min	Decay 8 Hr	Decay 24 Hr	Decay 3 Day	Decay 9 Day
Xe^{143}	1 sec	502,000					
Kr^{94}	1 sec	1,500,000					
Kr^{93}	2 sec	2,440,000					
Xe^{141}	3 sec	2,700,000					
Kr^{92}	3 sec	4,050,000					
Kr^{91}	10 sec	3,030,000					
Xe^{140}	16 sec	2,450,000					
Kr^{90}	33 sec	2,280,000					
Xe^{139}	41 sec	1,920,000					
Kr^{89}	3.2 min	881,000	1,320				
Xe^{137}	3.8 min	1,020,000	5,290				
$Xe^{135(m)}$	15 min	158,000	41,600				
Xe^{138}	17 min	450,000	132,000				
Kr^{87}	1.3 hr	102,000	77,800	493			
$Kr^{83(m)}$	1.86 hr	15,100	12,500	397	2		
Kr^{88}	2.8 hr	96,600	85,400	8,120	254		
$Kr^{85(m)}$	4.4 hr	31,200	28,500	5,480	480		
Xe^{135}	9.2 hr	89,600	89,500	43,900	15,100	387	
$Xe^{133(m)}$	2.3 day	930	924	820	688	376	62

Xe^{133}	5.27 day	24,900	24,800	23,600	21,900	17,000	7,860
$Xe^{131(m)}$	12 day	74	74	73	70	63	44
Kr^{85}	10.4 yr	37	37	37	38	38	37
APPROXIMATE TOTAL		24,000,000	500,000	83,000	39,000	18,000	8,000

Refueling

Most of the radioactivity produced by the plant remains sealed in the fuel pins. About once a year it is necessary to refuel part of the core. The plant is shut down and the burned-out fuel is removed to a storage pool where it remains for several months to allow some of the radioactive isotopes to decay.

Subsequently, the fuel is transported to a fuel reprocessing center. There is one in New York State, near Buffalo--Nuclear Fuel Services at West Valley. This is also one of the low-level waste burial sites mentioned earlier. Fuel shipments are made in massive casks which weigh from 30 to 120 tons. These shipping containers must meet the specifications against damage in event of accident set out in the regulations[3].

At the fuel reprocessing plant the spent fuel is dissolved and processed to recover the remaining uranium and the plutonium formed in the reactor. The waste products contain an enormous quantity of radioactivity--those isotopes which have half-lives longer than a few weeks. These high level radioactive wastes are stored in underground double-walled tanks for as long as five years to allow further decay.

The fuel reprocessing plant discharges some radioactivity into the environment. At the present time all of the remaining radioactive gases--mostly Kr^{85} and some tritium as water vapor--are discharged through a stack. Unless iodine filters are provided, I^{129} will also be discharged. Water used in the chemical processing, laundry, cleaning, etc. dissolves some radioactive salts. This water is passed through a series of treatment facilities to remove most of the radioactivity. As in the case of the power plant, after many stages of treatment, the facility ends up with a lot of water containing small amounts of radioactivity which is discharged into the environment.

The liquid and gaseous discharges from the plant are continuously monitored and the environs surveyed for buildup of radioactivity.

The Management of High-Level Wastes

The system for handling high-level wastes from commercial nuclear power plants has not yet been implemented but the procedures have been fully engineered and tested. Because the amounts of high-level wastes that have accumulated to date are small, the need is not yet pressing. However, it would be desirable to have the system working routinely within the next five years. The delay has been caused by the inability of officials to agree on a site for its first Federal Repository[7].

The liquid wastes will be converted to solids--in the form of ceramic-like beads or glass. These will be packed in steel containers and shipped to the Federal Repository for permanent storage. Articles contaminated by any transuranic isotopes (neptunium, plutonium, americum, etc.) will be placed in the same federal repository as the high-level wastes. The wastes will remain radioactive for the rest of human history and long beyond even that.

About 15 years ago a committee of the National Research Council (National Academy of Sciences) was given the task of selecting a suitable location for permanent storage of the radioactive wastes to be anticipated from the commercial use of nuclear energy. In 1957, the committee identified the bedded salt deposits, which underlie large areas of the United States, as the most likely candidates for the job[8/]. These had several desirable properties: 1) they were common formations giving a wide choice of sites; 2) they were geologically very old and tectonically stable; 3) salt (sodium chloride) has good heat conduction properties, undergoes plastic flow to seal holes, and does not exhibit any disqualifying radiation damage effects; 4) the bedded salt is totally isolated from aquifers; and 5) in some regions of the U.S. the formations are deep underground, making them inaccessible to casual exploration in future centuries.

The feasibility of using such formations was tested in an experimental program over a ten-year period and the results demonstrated that the salt formations did indeed behave as predicted under radiation of far greater intensity than the wastes would emit, and that high-level wastes could be safely and easily handled in salt mines[7/, 9/].

The total volume of wastes to be generated is small. A power plant producing 1000 MWe will yield only about 80 cubic feet per year. A 1200-acre salt mine will hold all wastes expected for the next three decades.

Radiation Doses

1. Units of Measurement

Radiation doses to humans can be expressed in terms of a unit called the "rem" (roentgen equivalent man)[10/]. The practical working unit of this is 1/1000 rem--the millirem (mrem). I will express all values in terms of the mrem. This unit expresses the energy absorbed in a unit weight of tissue, and thus is related to the biological effect of absorbed radiation. Different types of radiation can be expressed in terms of the mrem and thus reduced to a "common denominator" [11/].

In order to specify a radiation dose more completely, the parts of the body or the particular organs subjected to exposure must be described, e.g. "whole-body", skin, gonad, thyroid, bone marrow, lung, etc. Unless otherwise noted I shall list "whole-body" doses.

2. Regulation of Radiation Exposure

In the United States, radiation standards are set by the Federal Radiation Council (FRC), a cabinet level, Presidential advisory body. Recently the staff of the FRC was incorporated into the Environmental Protection Agency.

The FRC has recommended that the annual doses from man-made sources other than medical do not exceed the following values:

Occupational (to workmen in radiation professions and industries)	5000 mrem/yr
Individuals in the general public	500 mrem/yr
General public*	170 mrem/yr

The guidelines specify maximum permissible concentrations in air and water of individual radioactive isotopes and combinations thereof. The AEC, in its statutory duty to regulate atomic energy, must use the FRC guidelines as the basis for its detailed regulations.

Since public exposure to man-made radiation (other than medical) has been very small, no attempt has been made to allocate the doses among various activities which produce exposures. (In the U.K., 20% of the recommended limits has been assigned to disposal of radioactive wastes from nuclear power plants.) The AEC regulations state that exposures to the public shall be kept "as low as practicable" relative to the upper limits, without defining in detail what is meant by "as low as practicable." However, the technical specifications for each license that has been issued has converted this vague terminology into specific limits for each individual facility which cannot be exceeded.

The AEC is currently considering a change in regulations that would limit nuclear power stations of the PWR and BWR variety to a maximum annual "fence-post" dose of 5 mrem/year from gaseous releases, and a similar dose from liquid releases (taking into account pathways to man).

3. Monitoring of Radiation

Several agencies monitor radiation releases including the U.S. Public Health Service (now a part of the EPA), the AEC, and state agencies. In New York State, the Bureau of Radiological Pollution Control, Department of Environmental Conservation, holds responsibility for continuing surveillance of all nuclear facilities in the state.

*Standards mean that while some individuals in the general public may receive a dose of 500 mrem/yr. the average dosage for the entire population should not exceed 170 mrem/yr.

4. Natural Environmental Radiation

During the past 25 years, the health physicists have been very busy measuring the radiation levels in our surroundings, and we now have a good understanding of the natural radiation that has always existed on earth. This natural radiation comes from radioactive minerals in the soil, water, and air; and from cosmic rays from outer space. It is of the same general type and quality as that produced by man from his medical and nuclear activities. I think it is quite instructive to review the sources and amounts of natural radiation[12].

One of the largest sources comes from potassium--a common element in the earth's crust and in sea water. The "standard man" contains 140 grams of radioactive potassium, emitting a very penetrating gamma ray and also a less penetrating beta particle. Thus, we continually irradiate ourselves. The dose is about 20 millirems each year. When we gather in a crowd we irradiate each other--the dose rate would about double in a dense crowd. Married couples who sleep in a double bed irradiate each other about 1 mrem's worth each year. Some of the typical dose rates are listed in Table 4. As you see there are other natural radioactive minerals in our bodies. The amounts of these depend on the sources of the drinking water. For example, in some regions of the Mid-west, in Illinois, Iowa and Wisconsin, the drinking water is taken from artesian wells which have very high radium content. The people who live there have as much as four times the amount shown in Table 4.

Table 4. Typical Whole-Body Dose Rates Standard Man from Natural Sources

Source	Dose (mrem/year)
Internal	
Potassium-40 in Human Body	20
Other Radionuclides in Human Body (C-14, Rn-222, Ra-222, -228, etc.)	3
External	
Gamma rays from soils and rocks	50
Cosmic rays at sea level	28
Cosmic rays at Denver	67
TOTAL (Depending on Location):	75 to 225

The dose rate from rocks and soil depends very much on the local geology. Where I live, on Long Island, the rate is lower than shown in the table since the local sand has relatively little radioactivity. In parts of New England, where there is a lot of granite, the soil and rock dose can be several times larger. We, of course, alter our environment by building shelters. These partially shield out the radiations from the outdoors, but often the building material itself is very rich in radioactivity. Grand Central Station, for example, is constructed of fairly "hot" rock, and the dose rates inside run as high as 500 mrem per year[13]. Incidentally, the stone for Grand Central was quarried at Millstone Point, Connecticut, near New London. It gots its name because it was one of the main sources of millstones in colonial days--our predecessors ground their grain with rock that is actually a low-grade uranium deposit. This same stone is in many public buildings--the U.N., the Statue of Liberty, and many of the better-built court houses in the east.

The dose rate from cosmic rays depends on altitude--as you go up, the radiation intensity increases. It averages about 28 mrems at sea level and reached 67 mrems in Denver. The cosmic ray activity fluctuates from day-to-day. Of course, if you travel in an airliner you get up pretty high and the cosmic-ray dose rate gets fairly big. On a flight to the West Coast and back a passenger accumulates about 5 mrem.

Thus it can be seen that radiation is a part of our natural environment and always has been. The dose people receive varies over a wide range depending on where they live. The average dose rate in the U.S. is about 127 mrem/yr. This varies from around 75 mrem/yr for people who live in wooden houses on the beach to as much as 225 mrem/yr for residents of parts of Colorado.

Man-Made Radiation Doses

The largest single source of man-made radiation is from medical x-rays. According to a recent announcement of the Food and Drug Administration the estimated average genetic dose was 36 mrem in the year 1970 in the U.S.[14]. The corresponding whole-body dose would be about twice this, i.e. approximately 70 mrem.

Fallout from nuclear weapons testing is in the range of 2 to 5 mrem/yr. Other man-made radiation sources include wristwatch dials, color TV sets, etc.

Doses from Nuclear Power Plant Effluents

Continuous monitoring plus detailed site surveys by the various agencies show that "fence post" doses (the dose that a hypothetical person would receive if he stood at the plant boundary, unsheltered, 24 hours a day, all year, in the direction of maximum average wind) from gaseous emissions from American commercial nuclear power plants have generally been in the range of 5 mrem/year or less, and no significant buildup has been detected in water, silt, or marine biota[15,16].

The largest off-site doses for which I can find records occurred at the Humboldt Bay Power Plant (Unit No. 3) near Eureka, California, where the estimated doses were 50 mrem in 1965 and 35 mrem in 1966[17].

The dose decreases with distance approximately as shown in Table 5. Thus if the annual fence post was 5 mrem, the annual dose to people living within two miles of the plant would be approximately 1/3 mrem.

The data show that the doses from nuclear power plant effluents are generally much less than natural background and very small in comparison with variations in natural background. An official of EPA has recently stated the average annual exposure due to nuclear power is less than 0.01 mrem[18].

Table 5. Approximate Doses from Gaseous Effluents Averaged Over Population Living within Circle of Radius R of a Nuclear Power Station. Model Assumes Uniform Population Distribution, and 1/4 Mile Site Radius.

Radius (Miles)	Fractional Part of "Fence Post" Dose
1/4	1
1	0.31
2	0.07
5	0.02
10	0.01
50	0.001

Doses from Fuel-Reprocessing Plant

Nuclear Fuel Services (NFS), located at West Valley, New York, is the only commercial fuel reprocessing plant in operation in the U.S. as this report is being given. Others will be in operation soon.

Surveys by New York State[16] and the U.S. Public Health Service[19] indicate that off-site doses are below the 500 mrem/yr guidelines, but are probably in that general range. Radioactivity has been detected in fish, deer, milk, vegetables, soil, etc. in the vicinity of the plant. New water treatment facilities began operation in May 1971 which were expected to reduce the release of radioactivity in liquid wastes[16]. Although concentrations do not appear to exceed the AEC guidelines, they apparently fail to meet the "low as practicable" criteria, because on December 20, 1971 the AEC issued interim regulations for NFS which are designed to restrict emissions to 10% of the AEC guidelines[20].

It is indicated that NFS has been emitting some plutonium and iodine-129 from the stack[16,20]. Plans for modification of stack filters have been mentioned[20].

Nuclear Accidents

There have been no accidents in the commercial nuclear power industry that have caused death or injury to members of the general public. This safety record and the technology behind it is reflected in the actions of the private insurance industry which shares the indemnity risk with the federal Price-Anderson insurance. The private pools have increased their coverage and have refunded more than half of the original premiums[21]. The private insurance nuclear pools represent the largest single event coverages ever provided by the insurance industry.

Reactor safety has been based on the following philosophy:

1. select a reactor design which is inherently stable and tolerant of abnormal operating conditions;
2. provide instrumentation, control systems, and essential operating systems which have high reliability, many redundant backup systems that are mutually independent;
3. assume, nevertheless, that failures will occur and provide engineered safeguards which mitigate the consequences of failure.

The AEC has the responsibility of protecting the public against reactor accidents. The criteria for power plant designs are set forth in the Code of Federal Regulations[22]. It is recognized that the accident probability can never be reduced to zero, even though it can be made very small. The engineered safeguards are provided to protect the public from serious consequences in the event of a low-probability accident.

Among other things, these safeguards consist of containment and emergency core cooling systems (ECCS). The containment is designed to prevent uncontrolled release of radioactivity in the event of a rupture of the reactor pressure system. It consists of a massive, air-tight, reinforced concrete "bottle" around the reactor.

The ECCS provide cooling to the core in the event of a massive instantaneous break in one of the primary coolant pipes. The purpose is to prevent the reactor fuel from melting which would very likely cause containment failure.

At the present time, public hearings are being held by the AEC in Washington, D.C. to examine the adequacy of the criteria for ECCS[23]. Several substantial questions have been raised as to whether or not the ECCS would provide the desired protection in the event of the worst conceivable pipe break[24]. The outcome of these hearings cannot be predicted at this time.

Siting Limitations

Siting criteria for nuclear power stations are published in the Code of Federal Regulations[25]. These provide the basis for evaluating whether or not a proposed site and a specific reactor design will provide adequate protection for the public. The criteria are such as to effectively require zones of low population in the vicinity of a reactor. Siting in densely populated areas becomes prohibitive in terms of engineered safeguards.

Many members of the scientific community are basically opposed to siting power reactors in densely populated areas under any circumstances[26], and probably the mood of the general public agrees with this stand. It seems unlikely that nuclear power stations will be permitted in such areas for a long time to come.

The denial of sites in metropolitan areas, e.g. in New York City, creates a serious problem that has been eloquently described by L. Roddis, President of Consolidated Edison of New York[27]. It is, of course, economical to generate the electricity as close to the load as possible. Furthermore, people living in rural areas remote from the city have no burning enthusiasm for providing sites in their neighborhoods to generate electricity for the city. The solution to this impasse will be difficult.

Conclusion

It appears that, at the present time, restrictions on nuclear power plant siting are imposed primarily by criteria for protecting the public in accident situations, rather than by population exposure from radioactive emissions during routine operation. These restrictions will probably continue to prevent the construction of nuclear power plants within the large metropolitan areas where the power is needed.

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PROBLEMS OF ENERGY AND THE AMERICAN ECONOMY

Address by Joseph C. Swidler, Chairman
New York State Public Service Commission

'The premonition of the apocalypse springs eternal in the human breast' -- a statement appropriate to the sense of doom felt in considering the contrast between the declining energy resources on the one hand, and the rapidly expanding use of them on the other.

Anticipating Fuel Shortages

The American people are accustomed to cheap energy--to such a degree that very few people realize it is the foundation of our affluence. It is an affluence borrowed by mining expendable resources, depletable resources and, by taking for granted unlimited amounts of readily available fuel and electric power. Most people see very little connection between the frustration of efforts to increase energy supply and their own comfort and standard of living. They think that somehow there will always be enough energy--there will be enough electric power to take care of them. They do not visualize that a day could come when our economy could falter, when we could have a severe burden of unemployment, when we could have a drastic impact on standard of living, when we might be unable to meet our responsibilities of providing new economic opportunities for people newly on the job market. They do not see a day when we are handicapped in attempting to take care of our problems of race and poverty because we are dealing from an inadequate resource base with respect to energy.

So far we have managed to paper over this problem, partly by using up fat, and by importing; but I think that we are reaching a point when we must face up to planning for adequacy of energy supply or meet the consequences.

Let me tell you about the fuels situation, as distinguished from the electric power situation. Of course electric power depends upon fuels. Between 25 and 30 percent of primary fuel sources are used in electricity.

We require a great deal of energy that does not take the form of electricity. Two-thirds of our energy needs are now being met directly by petroleum in one form or another: by either oil (something like 60%) or gas (which alone accounts for about one-third). Most people are surprised by this statistic. Natural gas accounts for about 1/3 of total energy requirements in the United States. That includes the energy used for mobile equipment and automobiles.

As far as gas is concerned, the situation is already very critical. Our reserves, which kept increasing every year from 1968 (these are proven resources), have begun to decline. They have declined every year since 1968--if you exclude the Prudhoe Bay reserves in Alaska. At the same time, demand has crept up at the rate of about a trillion cubic feet a year. When I was chairman of the Federal Power Commission the rate was about 10 or 11 trillion cubic feet a year, it's now more than twice that--in the order of 24 trillion cubic feet a year. Total reserves are down now to about 260 trillion and that isn't like having a reserve of oil on the shelf you could pour out as fast as you need it until it's all gone. As wells are depleted, they lose deliverability. You can't take it out as fast as you'd want as pressure declines.

The actual rate of deliveries is declining. Every major pipeline serving New York, except Tennessee Gas, has been curtailing deliveries for the past two years, despite their contracts. It's not only impossible to get additional supplies, but, without any notice or warning except a few hours perhaps, their customers are told that there will be a cutback of 5, 10, 20 percent for such and such a period. In the meantime they are trying desperately to buy emergency supplies in the fields of Texas and Louisiana. I think this is a state of disarray in energy supply most people are not even aware of, and it is very serious.

Gas distributors and the pipelines are reacting to some degree by purchasing Liquid Natural Gas (LNG) from abroad. Deliveries have begun to arrive. This traffic is in an infant stage now and will be increasing. But this is indeed an expensive alternative and of course it involves the security problem of depending upon foreign sources. They are also building some substitute natural gas plants in this country, so called SNG, mostly from petroleum sources: from naptha, some domestic in origin, and a good deal of which is imported. Even this will not make up all the deficits which will increase from year to year unless something drastic and unexpected should occur.

With coal the situation is quite different. It's fair to say that there are large coal supplies, perhaps enough for a couple of hundreds of years. But the Eastern coals are high in sulphur, and the air pollution regulations now preclude the use of coal in most locations along the East coast. There hasn't been a coal-burning electric generating plant started in the Northeast in a good many years.

Many plants have been converted from coal to oil. The last coal burning unit in New York City, at one time entirely supplied with coal, has been switched over; no more coal is being burned there. This is true of many other places on the East coast. So, despite the desperation of our need for additional fuel resources, coal use is on a plateau and, by the estimates of Public Service Commission economists who are very knowledgeable (our Chief Economist was formerly the Chief Economist in the Bureau of Mines), coal use is expected to decline substantially between now and 1980 and 1985, perhaps picking up thereafter as a result of developments in coal gasification.

Barriers to Nuclear Plants

It is a fairly familiar story that it's almost impossible to complete a nuclear plant. It is very hard to get one started. And even if you do get one started, there are many, many hurdles before it can be completed. A series of operating licenses are required, in addition to numerous regulatory delays accompanied by orders requiring installed equipment to be torn down and replaced with something else. This is a process politely known as "retro-fitting." The contractors have their own problems building the plants, partly as a result of the retro-fitting problem, and they too are delayed. As a result, it takes about twice as long to build a power plant in this country as it does anywhere else in the world. Eight years is now kind of a minimum for building a power plant in the United States, and the costs of these delays are very, very great. So, our own estimates of the growth in the use of oil are not as optimistic as those of the petroleum industry. That is, we think the growth will be faster, and the national deficits will be larger.

Perilous Predictions

The petroleum industry, in making its calculations for oil use, has assumed that coal would be burned at the rate of about 800 million tons a year by 1980, and that 120 thousand megawatts of nuclear capacity would be completed by that date. We are not nearly as optimistic on either of those assumptions. According to either the petroleum industry's assumptions, or our own, there will be a very considerable shift to oil, because there is no other place for the deficit in energy use to go. If you can't use coal, and you don't have gas, and you can't get your nuclear plants on the line, then you insinuate a new oil burning plant into your program. Or if the consumers who burn fuel directly can't get gas, they switch to oil.

Dangers of Importing

Our current use of oil is at the rate of about 16 million barrels a day, of which about five million are imported. Over 90% of the oil used in the power plants on the East coast is imported. That's not a very comfortable fact for those of us who have some responsibility for power supply as we look at some of the risks of interruption of oil deliveries, perhaps as a part of a conflagration in the Middle East due to bargaining between sheiks or other rulers of the oil producing countries. It's very easy to visualize incidents which could lead to an interruption in oil deliveries.

As a nation we are now dependent on imports for almost one-third of our oil. At one time the question of oil import policies was quite an important one: "Should we open up the gates to provide competition?" We don't have much choice about it anymore. There was an announcement in the papers today that the President is raising oil import quotas by another 400,000 barrels a day. You will see further announcements of that sort. Our estimates are that by 1980 we will be importing about as much oil as we are using today, and our imports then will be 16 million barrels a day. Of that, about 5 million barrels will be coming from Western Hemisphere sources and about 11 million barrels will be coming from the politically volatile areas of North Africa and the Middle East.

Limited Supplies

Look at the implications of that kind of dependence on oil imports. Only a few years ago we were an oil exporting nation, we were rich in energy. We had flush fields in East Texas. We passed a lot of laws in the 30's to prevent overproduction of oil because it was wasting our resources. The states limited the productivity of their wells. Now there is almost no excess production of oil--we have no elbow room--there is no fat anymore. At the time of Suez, when supplies were interrupted to the Western World, we could increase domestic production because we had some spare capacity. That's gone now. In another Suez, rationing would be inevitable. So you have a very, very ticklish, risky situation so far as national security is concerned.

By 1980 I also expect we will be spending about 20 billion dollars a year for oil imports; and our balance of trade, which has already turned negative (partly as a result of the increases we are already making in oil imports), will be that much worse. How are we going to maintain our international trading position in these circumstances?

It's obvious to me that 20 billion dollars a year for oil is going to be a very damaging thing for this country to suffer. And perhaps even more serious than that is the question of the availability of world supplies.

The producing countries of the world have been gradually increasing their royalties, their participation, and their share of the profits. They have begun to realize a certain degree of affluence, so their trading and bargaining positions have improved. No longer are they dealing from desperation. Kuwait, the other day, said it was not going to increase its oil production, that it didn't want more money faster. It would stretch out its reserves and hold production steady at 3 million barrels a day. I think you will see more of this throughout the world. The rate of growth in oil use is faster in the rest of the world than it is in the United States because they are economies at an earlier stage of development and their rate of growth is quicker.

A combination of declining resources in some of these countries, a stabilization of production in other countries, an expanded demand in Europe and throughout the rest of the world, are all going to make it very hard for us to find this 11 million barrels a day by 1980. There will also be a 1985, a 1990 and a 2000 and I just don't have the courage to project these figures that far.

One of the most worrisome things beyond the shifts from gas, coal, and nuclear energy to oil taking place is the very ominous shift from gas demand to electricity that's just beginning to appear because the controls on gas use are fairly new. Now we are starting to see people who would otherwise put in gas switching to electricity for many of their uses and processes. None or very little of this is included in forecasts of load. For instance, the Public Service Commission held a meeting with the executives of all the power companies and gas companies last week in New York City to try to appraise this factor. One or two companies said they had taken some of this into account, but most had not. This is a new phenomenon.

System Efficiency

It adds an increment to the power loads that will be very hard to meet, because with an eight-year planning and construction cycle, you can't start anything now that will be ready by 1980.

Our estimates for electric power next summer (this state now hits an overall summer peak which is worst downstate), indicate there will be a negative margin of reserve unless some plants which we don't expect to be on the line by then are unexpectedly completed early. I don't expect this is going to be a catastrophic summer, but I think we will see brownouts in New York City, and possibly in some of the rest of the State. Conceivably, if none of the doubtful units get on the line, and if we have poor experience in keeping the rest of the capacity operating, you might see some limited blackouts. I hope that is some comfort to you. It is very little to me because I expect to be around the summer after that and the summer beyond and the situation gets worse in succeeding years. As these loads grow, and as we see some of the shifts from gas to electric power, we will begin to suffer from this juxtaposition of loads in light of the fact that it seems to be impossible to get new power capacity on the line.

Many people ask the question "Is all this power necessary?", "Isn't the thing to do just not build the power plants?". Our studies tend to show that, by and large, this country uses electricity fairly efficiently--and that any drastic reduction in the rate of growth could only be purchased by risking a breakdown of the economic system we rely on for our economic needs. Electric power is about $2\frac{1}{2}\%$ of the GNP and fairly stable at that level. I don't see any way, short of using the weapons of a dictatorship, to achieve the kind of expansion that our society requires in national product, without growth in energy use and growth in electric power requirements.

Some people say, "Why don't we just cut out the electric toothbrush, all these appliances that are so non-essential?". I must admit to a constitutional objection to the kind of a regime where somebody says this appliance is all right but that one isn't. You can't have an electric toothbrush, you can't have an electric blanket, electric shavers are out, but hair curlers are all right. More important is that the so-called frivolous appliances are very small users of energy. An electric toothbrush uses 5 kilowatt hours a year, a thousandth of average annual use. People who are really serious about conserving energy should look at the major uses of energy; space heating, air conditioning, and heating water. Some people who work themselves up to a great anger about electric toothbrushes probably do so while taking a half-hour shower where they use up 50 or 100 times as much energy as an electric toothbrush does. The bulk of energy is used for the tasks of society and for the tasks of the home, for heating and cooling, taking care of food or temperature control, for cleaning dishes or cleaning your clothes. That's where the energy goes--not to mention T.V.

Economy-based Solutions

If we really want to do something about energy use, let's not be distracted by the frivolous appliances argument. Let us realize we can only do it by focusing on the uses which really show up substantially in the totals. These are the things that affect your standard of living. Some people say why not use inverted rates--why have rates that go down as you use more energy. Let's teach people a lesson. Let us charge them more per unit, the more they use. The trouble with that is, aside from great difficulties in administration, it means the abandonment of price as a director of the use of resources. Price is our prime guide to the use of resources. I'd like to dissociate this business of inverting rates from eliminating promotional rates. I favor eliminating promotional rates, and the Public Service Commission has done a lot to eliminate them. But the electric power industry is a prime example of the economies of scale whereby costs go down with volume. If you use the transformers and wires which serve you, and the related generating plant for more hours of the day, your energy costs less. If you have a larger generating machine you produce power at a much lower cost than with a small machine.

If you don't recognize these cost fundamentals you get a lot of strange results. For example, if you charge a manufacturer more per kilowatt hour, the more kilowatt hours he uses, when in fact it costs less and less the more kilowatt hours he uses, you get to a point where he says "I'll put in my own generating station." It's less efficient than that of the power company, it produces more pollution, but it enables him to get away from a bad pricing system that has no relationship to the cost realities. Moreover, inverted pricing can't be done on a single state basis because manufacturers would say, why should I pay two or three times what energy costs to produce here when I can go to the next state where they price it in relationship to cost and can buy it there at a much lower rate. A great deal of the industry and employment upon which our state economy depends would be lost that way.

Energy Conservation

There are ways to hold down growth and one of them is to look for waste. There is no excuse for waste as energy becomes scarcer and more expensive. A great deal of energy waste occurs in our homes for climate control, for heating and air conditioning. If all homes, for example, were insulated to the standard of the electrically heated homes, you could save about 40% of the energy. Our studies show that large buildings could be designed with shielding from the sun and wind, with heat absorbent glass, with various other features, so they would need only about half the energy they do now. You could avoid fixed windows which make it impossible, even in pleasant weather, to let the outdoors in.

There are even greater savings available in the transportation field if we could have smaller, more efficient cars running at an average of 20 miles to a gallon. The miles per gallon for automobiles has been declining from year to year, a few years ago it was over 15 miles per gallon, now we get about 13 3/4 miles to a gallon. We could save about 3 million barrles of oil a year by 1980.

We could have more efficient equipment. For example, most air conditioners are much less efficient than they need to be. The manufacturers save a little by putting in less insulation and less efficient motors. The best air conditioners use about 2/3 as much energy as the less satisfactory ones. This is a great area for energy saving.

We could do a lot by just being careful. Something comparable to Consolidated Edison's "Save a Watt" program---in just being sensitive to minimizing the use of hot water, being careful about the use of appliances, turning out lights, setting back our thermostats, all the little things--there can be a very substantial savings. With all of that we might bring down substantially the rate of growth in total energy use, now about 4.2% a year. If we could halve that--this would make a tremendous difference in the extent of our desperation in the energy picture. I think we ought to be working toward that goal.

Let me briefly tell you some of the things I think we ought to do besides carry out the energy conservation program. We need to recognize that power plants must be built somewhere and that society's needs must govern. It is impossible to have an organized, successful, viable society if any one of our 200 million people can interfere with the needs of all.

Reality, Research, Reason

There must be some authoritative way to reconcile environmental requirements and energy needs. We must recognize that power plants cannot be built in space, that they must have a locus here on earth, and that the neighbors of the power plants may not be happy. I know when I worked for TVA, as I did for almost 25 years, we took it for granted if we were building a dam there would be some unhappy people whom, if necessary, you moved with the aid of a judicial order. It just seemed obvious that if a project was required for the benefit of all the people of the Valley, we couldn't throw it out the window because somebody in the middle of the reservoir said "I don't want to move." Now the whole approach is changing, so we have come to the point where we don't have the resolution to deal with dissenters even after they have been given a full opportunity to present their position and to reason for the changes that they think are necessary.

We should maximize development of domestic fuel resources, we should have encouragement for drilling, and more lease sales by the Department of the Interior on terms assuring that the oil companies won't sit on the leases but will drill. We need more research, especially in the area of coal gasification, the breeder reactor, the fuel cell and combined cycle technology, and many other things. We should be spending at least twice as much money on energy research as we are now spending. We need to develop better procedures for environmental siting so we can resolve these environmental problems. We should find the best possible reconciliation, the best sites, the best way of adapting to environmental problems--and then get the plants built!

I think there are two final words I would like to say--one is that even on environmental questions we can't have perfect answers. It's obvious that as our society grows we must pay more and more attention to the environmental impact. But we can't go back to 1619. The Pilgrims are off the boat, and they have had children. We are now a society of over 200 million people, and we will never have the degree of pristine purity in our atmosphere that existed 350 years ago. Each increment of improvement becomes more and more expensive--you pay more and more to buy less and less. I think we need common sense to determine where we stop. You can go from oil with 2% sulfur to 1% oil for so much per unit of improvement, but when you go to 7/10 percent, sulfur removal becomes more expensive; when you go from 7/10 to 3/10 percent that step costs you about five times as much per 1/10 percent of sulfur as the initial step. And, if you go below that you are paying so much for just that one-tenth of 1% improvement (as compared to the many things that our society should be spending money on) that you have a hard job to justify it. To eliminate that last one-tenth of sulfur content costs more than the nine-tenths did. Therefore, I think we need a benefit-cost approach: is it worth it at each stage?, how can we best spend our money?

I want to repeat that I don't think we can solve the problems of our society by lying flat on our backs. Our problems of the environment, of poverty, and of employment, can only be solved in a thriving, not in a prostrate, society.

Question

I've got to be brief but I must say that I found your comments a backlash approach. The environmentalists have been saying "Look, there are certain things that bother us very much. We see emphysema rates are climbing at an astronomical rate and we can correlate this with increases in air pollution. We see the population explosion creating a situation where we've got an unsustainable growth rate on this planet earth, and we've got to somehow level off the rate of economic growth because it can't continue indefinitely. And energy is one of the factors in this equation. This is how this environmental thing got started. It wasn't just a cry to get sulfur fuels down to one-tenth of one percent instead of one percent sulfur, or something like that. That is a nit-picking detail on what is really a much broader, more fundamental concern.

One of the things I'd like to comment on is that I noted very carefully in all aspects of your talk on energy you eliminated any reference to solar energy and we have spent about 20 years (and correct me if I'm wrong) and 24 billion dollars in nuclear energy research and development in this country. At the present time this is giving us about 1% of our electric generating capacity. In view of the fact that there are large solar power plants, heating units, thermal electric generators, and so forth in operation in various parts of the world--it seems to me almost incredible to believe that if we had spent anything on the order of 20 years and 24 billion dollars on solar energy resource we would not now be producing far more than 1% of the electric generator capacity. So here's an alternative that has, I presume for some reason, been deliberately omitted from all your listed priorities. I want to know why was this ignored when we have substantial scientific organizations working in this area and a number of companies like Texaco with solar energy research stations at M.I.T., at Stamford, at the University of Arizona and so forth? Why did you omit it?

Response

I evidently didn't make myself clear. I favor tapering off the rate of growth. What I am saying is that it has to be done in an orderly way, we can't just chop it off--you can't use the meat-axe approach. I made some very specific and practical suggestions on how to do that and I believe these are as advanced, as practical, and as realistic as any that have been presented. I listen to a lot of rhetoric about how to level off the rate of growth but very few practical suggestions. I have devoted, and asked our staff to devote, intense labors to try and develop a practical way to do this without disrupting American society. I made some suggestions on how to do it and I favor more as we go along. I agree with you that at some point we must level off but I think you will have a catastrophe if you try to chop it off--there must be a transition. The whole point of what I said is that we must cut down on uses of energy--I tried to explain how desperate our situation is becoming. We must cut down on uses of energy and I think this involves cutting down ultimately on the part of our growth that represents the products of society with a large energy input.

On solar energy I have to take the word of other people, not being a scientist. My understanding is that solar energy presents a very long range solution with very, very great technological problems. The heat source is so diffuse that it would take many square miles of some heat absorbent material to get any substantial amount of electricity. You would have to cover over a large area.

Moreover, it isn't a steady source. Obviously, you don't get solar energy at night and you don't get it when it rains so you have to think in terms of areas like deserts--of high heat intensity and of fairly reliable sunshine and even then you may need to couple it with some storage arrangement. I think you would find a lot of people who would object to having our deserts covered over mile after mile with these heat absorbent structures. Every time you look at some way to eliminate one kind of environmental problem you get into another.

At any rate I understand this is something we couldn't possibly rely upon as a practical source of large scale energy input for a long time to come. As a laboratory curiousity, as a kind of thing that you use without regard to expense, on a lunar probe--certainly, it's been demonstrated. But as a practical way of taking care of the needs of Oswego or New York City, it is very, very far off--a generation or so--even if the breakthroughs come. In the meantime we must look to technologies which are further developed. Nobody claims to have any ideas as to how you could build a solar power plant today. I favor using some of our research money for solar energy--I believe in it, but I think we must use our research money in other directions too.

Question

Will or would a major decision on reliance on mass transit have significant influence on uses of oil?

Response

Yes, I think it would. And I think one of the things we need to do is to plan our cities so they don't require as much transportation. My own view is that rationing is coming. I just don't see where we are going to get indefinitely the energy inputs our society now seems to require, at least until there are major technological breakthroughs.

Let me say one more thing and then I will go. Talking about the fact that in trying to avoid one environmental problem you get into another. I don't know whether you saw the book review section of the Washington Post a few weeks ago, they had a picture of a church in England on the Downs, a lovely little church between two cooling towers. If you want to know quite how massive a cooling tower is--you should see the way this lovely church is dwarfed by these giant towers--they are about 350 feet high. Now, their stations in England are smaller than ours--cooling towers here would be about 500 feet. So, in trying to avoid the problem of heat dissipation into surface waters, when people say "Let's have cooling towers"--they just don't realize the environmental problem created by the cooling towers. I'm not saying that cooling towers aren't appropriate under some circumstances, but I do say they have their minuses and you are not apt to find a perfect solution--one that doesn't involve some adverse environmental impact. There is an environmental impact every time somebody builds a house, cuts down the trees and destroys property, and I don't think that a power plant is any different except that it is worse. You can minimize the environmental impact--and we should. It should have the absolute minimum environmental impact that you can justify on a benefit-cost basis. But you can't hope to avoid all the problems of combustion, all the problems of radiation, all the problems of heat dissipation, all the problems of land use.

Thank you very much.

PREDICTING THE PAST AND FUTURE IN ELECTRICITY DEMAND

Presented by Dr. Duane Chapman, Assistant Professor
Department of Agricultural Economics, Cornell University

(Co-authors: Timothy Mount, Cornell University and
Timothy Tyrrell, Oak Ridge National Laboratory)

I. Predicting the Past

Consider for a moment a hypothetical analyst working for the Federal Power Commission or the Edison Electric Institute in early 1965. At his morning coffee break he has been asked to project national electricity requirements for 1969 and 1970. He knows his job, and does it in a few minutes. Total sales grew 7.35% per year for the last five years from 1959 to 1964. So he predicts total sales will grow 7.35% per year for the next five years to 1.28 trillion kilowatt hours in 1969 and to 1.37 trillion kilowatt hours in 1970. For good measure he draws the graph in Figure 1 before leaving for lunch (omitting, of course, the actual sales for 1969 and 1970).

Seven years pass, a time of war and rebellion, inflation and unemployment, increasing affluence and hardening poverty. In early 1972 he recalls that prediction, and decides to check it against actual sales as reported in the Statistical Year Book.1/ Actual sales were 1.31 trillion kilowatt hours in 1969 and 1.39 in 1970. Our analyst calls a friend in his local utility to meet him for lunch, and together they note with enthusiasm the accuracy of their methods. They discuss the views held by some economists that rising environmental protection costs will change the pattern of growth. But they note the recent coexistence of recession and rapid inflation (which economists believed to be mutually exclusive), and conclude that economists could learn something from them about prediction. Total sales, they agree, will grow to 11.82 trillion KWH in 2000.

Perhaps this suggests a useful criterion for judging the value of economic analysis: can projection based upon more complicated assumptions give more accurate results than extrapolation?

In fact, the economic history of the post-war era indicates all causal factors influencing electricity demand have themselves changed quite predictably, and these changes have all pointed towards regularly increasing demand. As we shall see, this pattern will break in the near future (if indeed it has not already), and it seems unlikely that electricity demand will behave as nicely in the future as it has in the past.

First, we note that population and disposable personal income have increased regularly since the war, and these are important positive influences upon the purchase and utilization of appliances and lighting. For business and industry, value added or gross national product would probably be a more relevant income variable, and we note that here too there has been a nearly continuous increase since the war.

In addition, the average prices that consumers, business, and industry have paid for electricity have fallen since the war, and this has happened while most prices were increasing.

When we consider the past relationships between electricity prices and the prices of competitive goods, we see that electricity has become an increasingly better buy since WW II. Figure 2, for example, shows how average industrial electricity price has declined relative to capital costs as measured by the price index for nonresidential fixed investment. This picture is equally true for other factors. The average industrial and commercial electricity prices have fallen relative to unit labor costs, natural gas prices, total energy prices, and overall wholesale prices. The average residential electricity price has declined relative to overall consumer prices, natural gas prices, and fuel oil and coal prices. (These patterns are shown in the appendix). All of these ten relationships have changed in a generally smooth manner, and all of them are causal factors in increasing electricity use.

The influence of the prices of complementary goods is the same. The cost of electrical machinery for business has declined relative to overall wholesale prices since 1959, and the cost of household appliances has declined relative to overall prices since 1945.

To summarize, population, income, electricity prices, the prices of goods competitive to electricity, and the prices of appliances and machinery using electricity have all changed in directions which result in greater electricity demand, and each of these changes has been generally smooth.

Further, this pattern is essentially the same for all areas of the country for all consumer classes for the entire period since WW II.

The electric utility industry is to be credited for meeting our expectations. We have had accelerating consumption at a nearly constant exponential rate, a generally firm supply, and declining prices.

However, it seems likely that the factors causing this past growth are in the process of rapid change, and in the near future we are likely to see these factors pointing in different directions and changing at different rates than they have in the past.

If this divergence of causal factors from past patterns does in fact occur, it seems clear that electricity demand growth will depart from past patterns.

The primary effects would seem to be a reduction in the growth of consumption of metal products (including cars), plastics, chemicals, drugs, petroleum and gasoline, man-made fibers, and cardboard and paper products.[2]

In residential use, retardation in demand growth would probably affect growth in air conditioning, electric ranges and heating, lighting, clothes dryers, and possible electronic appliances.

Three forces are likely to modify future demand growth. They are (1) noticeably increased cost of envrionmental protection for one or more stages of the generating process for each method of generation, (2) possible reduction in the growth rate of population, (3) possible reduction in the growth rate of per capita income.

In the next section we review past and current research on electricity demand to determine the likely values and reliability of quantitative estimates of these different influences and the time path of response of electricity demand to changes in these factors.

The last section analyzes various administrative, legislative, and social policies in the context of available information on their likely consequences.

II. Quantitative Analyses of the Factors Influencing Electricity Demand: An Appraisal.

In the previous section, five different factors are assumed to be responsible for the growth of the quantity of electricity consumed. These factors are population, income, the prices of electricity, prices of competitive goods such as substitute fuels, and prices of complementary goods such as electrical appliances. Although the directions (positive or negative) of the relationships between each of these variables and demand can be described from economic theory, the relative importance of each factor can not be determined. The major objective of most quantitative analyses of electricity demand is to estimate a magnitude for each relationship. These estimates can then be used to predict the impact of a specific policy change on the quantity of electricity demanded. For example, suitable estimates would provide a guide to answering the following questions. Will the reduction in electricity demand be large or small if a tax on sulphur emissions results in a five percent increase of electricity prices, or if income per capita increases by six percent instead of three percent annually?

In most economic applications, the magnitude of the relationship between a variable and demand is measured as an elasticity.3/ Hence, one objective in a quantitative analysis is to determine accurate estimates for the elasticities of each variable.

Another consideration that should be discussed concerns the adjustment path through time of the quantity of electricity to changes in the explanatary variables. As electricity consumption is related to the stocks of electrical machinery and appliances, and the sizes of these stocks reflect past as well as current decisions, the current quantity of electricity demanded is also related to past as well as current values of the explanatary variables. This type of situation is familiar to economists and can be incorporated into the analysis.

FIGURE I. PREDICTING THE FUTURE FROM THE PAST

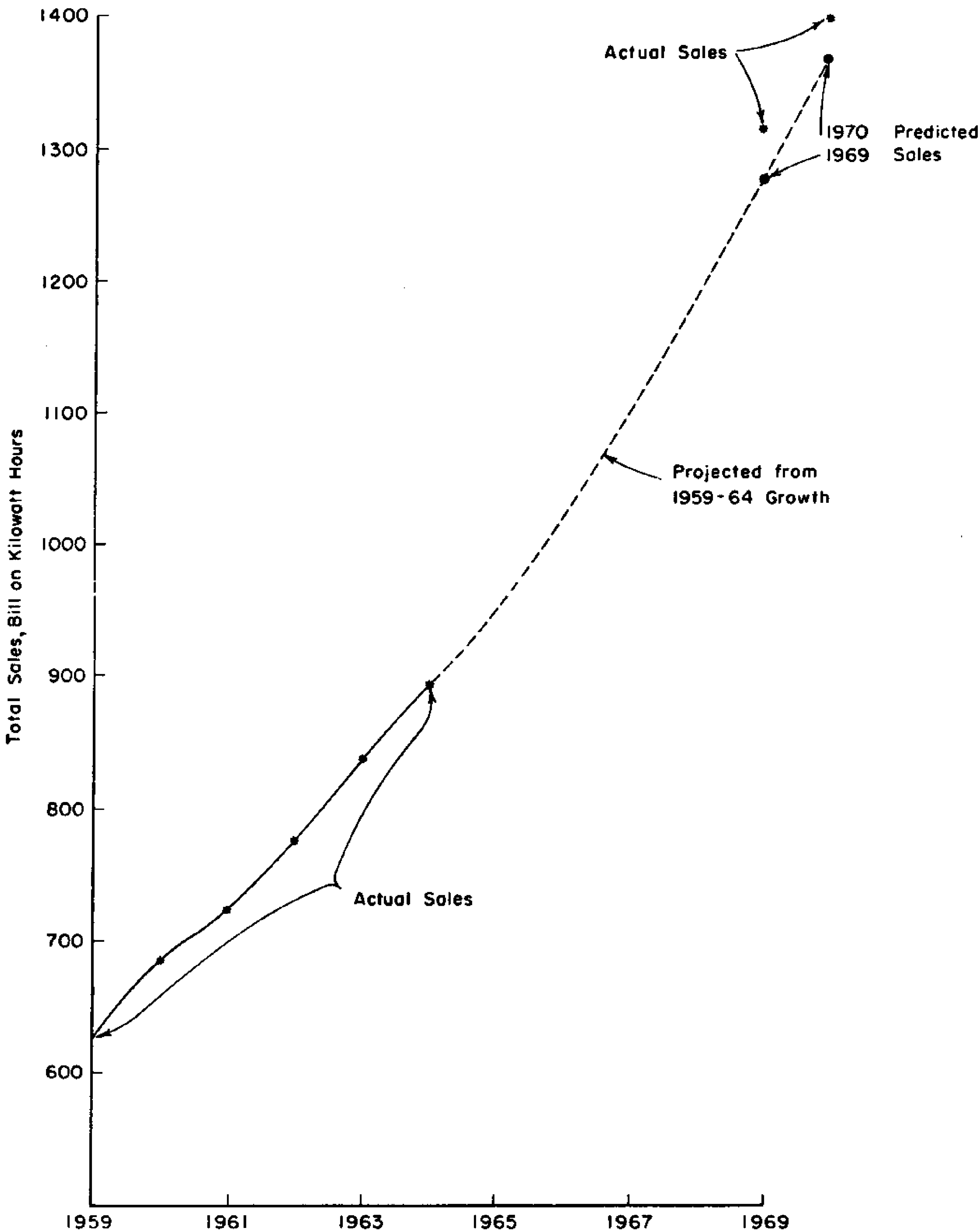


FIGURE 2. RATIO OF THE AVERAGE INDUSTRIAL ELECTRICITY PRICE TO THE IMPLICIT GNP PRICE DEFLATOR, NONRESIDENTIAL, FIXED INVESTMENT

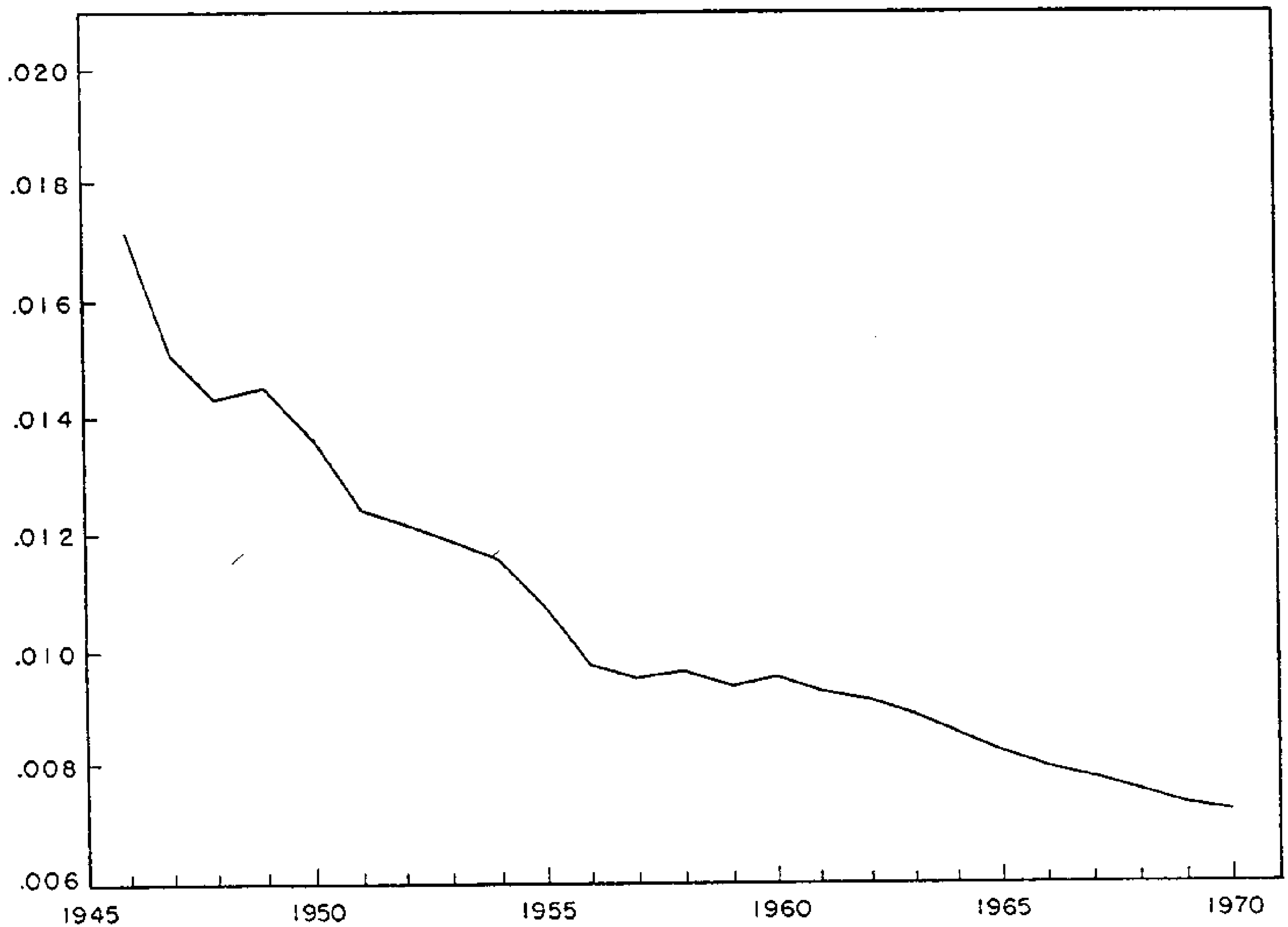
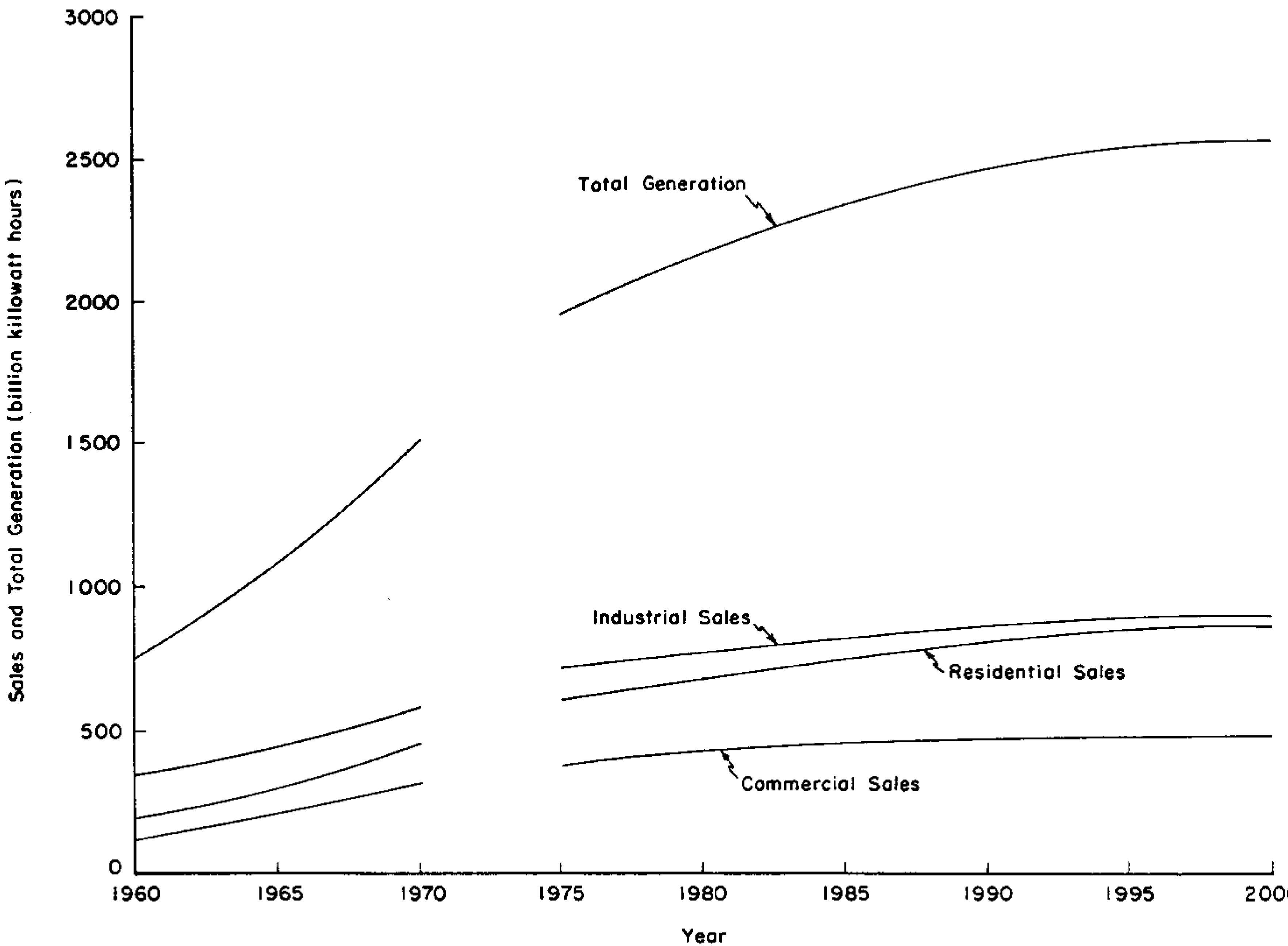


Figure 3: Zero Population and Income Growth Reached in 2000, 1970 Prices Maintained



It is possible to estimate both the short run elasticity (the response that occurs in a single time period) and the long run elasticity (the response after the adjustment process is completed). However, relatively few studies of electricity demand consider the time path of response.

Table I summarizes our view of likely short run and long run elasticities for selected major factors. These estimates are based upon other studies[4] as well as our own work[5] Given the difficulties in analysis discussed here, making such estimates is clearly a risky affair at present. The reader is given fair warning: Table I will be substantially revised in its final version. We have more confidence in the price, population, and long run estimates, and less confidence in the income, fossil fuel price, and short run estimates.

Table I. Summary of Electricity Price, Income, Population, and Fossil Fuel Price Elasticity Estimates

	Long Run	Short Run	Income Influences	Price Influences
Electricity Price				
Residential	-1.1	-0.1	Rising Income Lowers Price Elasticities	Rising Price Raises Price Elasticities
Commercial	-1.3	-0.2		
Industrial	-1.5	-0.3		
Income	+ .6	+ .08	Rising Income Lowers Income Elasticities	Rising Price Lowers Income Elasticities
Population	+ .9	+ .1		
Fossil Fuel Price	+ .1	+ .01		

III. Implication for Legislative, Administrative, and Social Policy

A. Internalizing Externalities.

This phrase is usually used in the sense that Federal and State legislation and administrative policies should cause private and public organizations to eliminate or reduce their actions which cause environmental degradation. The costs of such environmental protection are expected to be financed out of higher prices, appropriations, or profits. For electricity generation, the important types of environmental degradation are well known. The nature and extent of the damage from such activities is in general not well understood. Similarly, the costs of eliminating or reducing these effects are known with varying degrees of reliability.

Given the estimates of price elasticities summarized in the preceding section, it is apparent that substantial "internalization of externalities" will in turn cause reduction in future growth. Analyzing this impact can proceed in various ways. We may consider general cost increases or the cost of specific protection activities; we may attempt to analyze consequences on an aggregate national basis, or we can work with specific geographic areas.

Since the summer of 1970 the major purpose of our research has been to develop quantitative estimates of demand response to environmental protection policies, and we are now in a position to undertake the examination of demand response to externality internalization. In one study, we have explored the response of electricity demand in New York in each of the major classes to the increased costs that would follow the implementation of a Federal sulphur emission tax.[6] In some ways this is more difficult than an examination of general cost increases. It was desirable to work with 39 economic and engineering variables over a twenty year period. The results for the projections for 1990 for New York are of some interest, and are shown in Table 2.

Some surprises are evident. First, as expected, a tax high enough to motivate control causes a reduction in sulphur emissions and damage. But unexpectedly the tax-induced cost would have no noticeable impact on electricity demand growth. Consequently, given the assumptions of proportional capacity growth used in the paper, 21 new nuclear power plants of 1000 MWe capacity---or their equivalent---would be required with or without a sulphur tax.

In a qualitative sense the results of the New York study are applicable to the nation: it seems unlikely that the imposition of a sulphur emission tax in and of itself would have a visible impact on electricity growth. In this case "internalizing the externality" markedly reduces the externality and its damage, but does not modify demand growth.

Table 2. 1990 Projections for New York without and with a Federal Sulphur Tax

	Case A No Sulphur Tax	Case B Sulphur Tax
Generation, billion KWH		
Total	276.9	271.9
Coal	32.5	32.5
Oil	49.2	48.5
Nuclear	153.5	149.4
New Generation, billion KWH		
Total	181.5	176.5
Oil	24.9	24.2
Nuclear	149.2	145.1
New nuclear plants, 1000 MW	21	21
Sulphur, million tons		
In coal and oil	.271	.269
Proportion emitted	1.000	.100
Sulphur emitted	.271	.027
Damages, tax, control costs, million dollars/year		
Damage to New York	$157	$ 16
Change in damage	0	-141
Tax	0	5.4
Control cost	0	64.0
Damage plus control cost	157	80
Tax plus control cost	0	69.4
Tax plus control cost, cents/KWH	0	.026
1970 average price plus tax and control cost, cents/KWH	1.97	2.00

Source: see text.

The second study began from a different point of view.7/ We postulated different sets of assumptions for the Nation about future (1) environmental protection costs in electricity generation, (2) population growth, (3) income growth. Then, given the type of quantitative estimates in Table I, we examined how electricity demand growth would be modified by different possible patterns of these factors. Now internalization becomes an important modifier of demand growth. Let us take as a "baseline" projection the moderate price decline case. Here, as in the five other cases reported in Table 3, population and per capita income continue to grow at past annual rates of 1.3% and 3.0% respectively. The change in direction in cost pattern in Cases D, E, and F show significant reductions in demand growth. Similarly, if prices should fall rapidly over the rest of the century, demand growth may accelerate.

In summary, we can conclude that internalizing some specific costs such as sulphur removal may not noticeably affect demand growth, while a general policy of internalization may result in substantial modification of demand growth.

B. Efficient Environmental Protection Now Means Fewer Future Problems.

This is essentially a restatement of the preceding discussion from a different perspective. It means that effective regulation of airborne emissions, strip mining, oil spills, heat discharge, radioactive material disposal, etc. will reduce the scale of future problems by reducing the growth rate of demand and the need for new plants and capacity.

C. Extrapolation of Past Growth will be Inaccurate

In the first section it was noted that more accurate prediction than is possible with extrapolation should be a criterion for judging the efficiency of quantitative analysis of the factors influencing demand. It is clear to us that---in the absence of major new technological developments such as electric cars or nearly costless fusion power---increasing environmental protection costs will reduce the growth of electricity.

D. The Environmental Significance of Inverted Peak Demand Rates

There is much confusion surrounding this subject, and it is justified. Rate structures in most states will, at a given time of day or year, generally charge large users less per average KWH than small users. The last KWH will generally cost less than the average KWH. These characteristics have developed in response to a variety of economic influences. The more important of these influences are (1) economies of scale resulting in lower average cost for higher levels of generation and transmission, (2) the fair rate of return principle influencing profit and therefore rates, (3) joint costs of production are substantial, (4) load levelling with lower night rates is common, (5) very large users can negotiate rates with a utility, (6) most public and private utilities and the regulatory agencies expect efficient management to produce and sell electricity at minimum cost.

Table 3. Effects of Internalized Environmental Protection Cost on Demand Growth

	Prices			Total[a] Generation trillion KWH
	Residential	Commercial	Industrial	
A. 1970 Levels	2.10¢/KWH	2.01¢/KWH	0.95¢/KWH	1.5
B. Moderate Price Decline				
1. Rate of change	-2.1%/yr.	-2.3%/yr.	-1.4%/yr.	
2. 2000 levels	1.11¢/KWH	1.00¢/KWH	0.62¢/KWH	11.5
C. Decline at Past Rate				
1. Rate of change	-4.2%/yr.	-4.6%/yr.	-2.8%/yr.	
2. 2000 levels	0.58¢/KWH	0.48¢/KWH	0.40¢/KWH	35.9
D. Level at 1970 Value				
1. Rate of change	0	0	0	
2. 2000 levels	2.10¢/KWH	2.01¢/KWH	0.95¢/KWH	4.0
E. Moderate Price Increase				
1. Rate of change (2% of 1970 price per year)	+ .420 mills/ KWH/yr.	+ .402 mills/ KWH/yr.	+ .190 mills/ KWH/yr.	
2. 2000 levels	3.36¢/KWH	3.22¢/KWH	1.52¢/KWH	1.7
F. Rapid Price Increase				
1. Rate of change (5% of 1970 price per year)	+ 1.05 mills/ KWH/yr.	+1.005 mills/ KWH/yr.	+ .475 mills/ KWH/yr.	
2. 2000 levels	5.25¢/KWH	5.03¢/KWH	2.38¢/KWH	0.7

[a]Including other uses and losses

Inverted peak demand rates are connected to environmental protection in two ways. First, peak load units, whether pumped storage capacity or small fossil plants, seem to have a higher than average environmental cost per KWH. Second, in some areas environmental controversy surrounding new plant sites has restricted capacity growth, thereby increasing the peak demand capacity problem. Advocates of inverted peak demand rates see this as a partial solution to both problems. Higher rates for higher levels of use are expected to reduce the need for new plants by load levelling. These rates are expected to reduce air pollution from existing fossil peak capacity units. Finally, inverted rates are expected to reduce the peak load stress on system capability, thereby decreasing brownouts and voltage reductions.

The research described here indicates that peak demand would decline if peak demand rates were increased. The viability of this policy as a solution to short run problems must be qualified by the delayed nature of response as discussed below.

E. Social Policy: Population and Income Growth

It would be folly to suggest that electricity demand dictates population and income decisions, but the reverse relationship has been and will be important. Although electricity demand has grown much more rapidly than population or per capita income (and much faster than the product of the two), Table 1 indicates that these factors will influence future electricity growth. It is unlikely that ZPG and ZEG will commence today but it is possible that future growth in both population and income will be less than it has been since WW II.

One of our projections in the national study discussed above assumed that population growth would begin this decade at its past growth rate of 1.3%, but slowly fall year by year until zero growth occurred from 1999 to 2000. A similar assumption was made with real per capita income, so it rose 3% this year, but the growth rate slowly declined until zero growth occurred in 1999-2000. We added to these "ZPG 2000" and "ZEG 2000" assumptions an environmental protection policy such that electricity prices would no longer decline relative to other prices. This means that future savings in efficiency and returns to scale are assumed to be used to purchase growing environmental protection.

The result is shown in Figure 3. Note that sales to each consumer class as well as total generation grow at past rates in the near future, but stabilize at the end of the century, well below 11.5 trillion KWH generation.

F. The Timing of Demand Response to Modifying Factors

As observed in the preceding sections, there is good reason to expect that for all consumer classes electricity demand is influenced by the purchase of electricity using appliances, machinery and equipment, and by the rate of use of those appliances. Electricity prices, population, income, competitive fuel prices, electrical machinery prices, and prices of machinery competitive with electrical machinery all influence the purchase of such equipment. Therefore we expect a lagged response in electricity demand to changes in these factors. Each of the types of demand response discussed in this section should be envisioned as having a small but perceptible influence in the year of (or the first year following) the change in the causal factor. We are as yet uncertain of the length of time necessary for most of the full cumulative response to occur; a range of 3 to 10 years is the best estimate that can be offered today.

G. A Final Caution and a Conclusion

We must emphasize the preliminary nature of the numerical results discussed here. It is likely that some of these estimates will be substantially revised in the next few years. Nevertheless, there is sufficient information available to conclude that future electricity demand is not deus ex machina, but the sum of predictable responses to many separable choices.

FOOTNOTES AND REFERENCES

1. Edison Electric Institute, Statistical Year Book of the Electric Utility Industry, annual.

2. Based upon G. C. Gambs and A. A. Rauth, "The Energy Crisis," Chemical Engineering, May 31, 1971, pp. 56-68; K. P. Anderson, "The Demand for Electricity in California--Dimensions of Future Growth," WN-7550-NSF, Rand Corp., Santa Monica, Aug. 1971; and O. Culberson, "The Consumption of Electricity in the United States," ORNL-NSF-EP.5, Oak Ridge National Laboratory, June 1971.

3. The demand elasticity is defined as the percentage change of the quantity demanded in response to a one percent increase of an explanatary variable such as price. For example, a price elasticity of -1.5 implies that a 1% increase of price reduces the quantity demanded by 1.5%.

4. 1) F. M. Fisher and C. Kaysen. The Demand for Electricity in the United States. North Holland, Amsterdam, 1962.

   2) R. E. Baxter and R. Rees. Analysis of the Industrial Demand for Electricity. Economic Journal 78, 1968, pp. 277-298.

   3) P. W. MacAvoy. Economic Strategy for Developing Nuclear Breeder Reactors. M.I.T. Press, Cambridge, Mass., 1969.

   4) J. W. Wilson. Residential Demand for Electricity. Quarterly Review of Economics and Business 11, 1971, pp. 7-22.

   5) R. Halvorsen. Residential Electricity: Demand and Supply. Paper presented to the Sierra Club Conference on Power and Public Policy, Johnson City, Vermont, Jan. 14-15, 1972.

   6) K. P. Anderson. The Demand for Electricity: Econometric Estimates for California and the United States. RAND, Santa Monica, Calif. R-905-NSF, 1972.

5. The study is working with data from 1946-70 for each state and region for residential, commercial, and industrial users. Various functional forms, variables, and dynamic models have been examined. Results were published in Science, 17 Nov. 1972.

6. D. Chapman, T. J. Tyrrell, and T. Mount, "Electricity and the Environment: Economic Aspects of Interdisciplinary Problem Solving," presented at the American Association for the Advancement for Science meeting, Philadelphia, Dec. 26-31, 1971.

7. D. Chapman and T. Tyrrell, "Alternative Assumptions about Life Style, Population, and Income Growth: Implications for Power Generation and Environmental Quality," presented at the Sierra Club Conference on Power and Public Policy, Johnson City, Vermont, Jan. 14-15, 1972.

APPENDIX

The sources for the data for Figures 1 and 2 in the text and the following graphs are Statistical Year Book of the Edison Electric Institute, Business Statistics, Survey of Current Business, National Income and Product Accounts of the United States, 1971 Economic Report of the President, Gas Facts, Monthly Labor Review, and telephone communications with the Federal Power Commission and Edison Electric Institute.

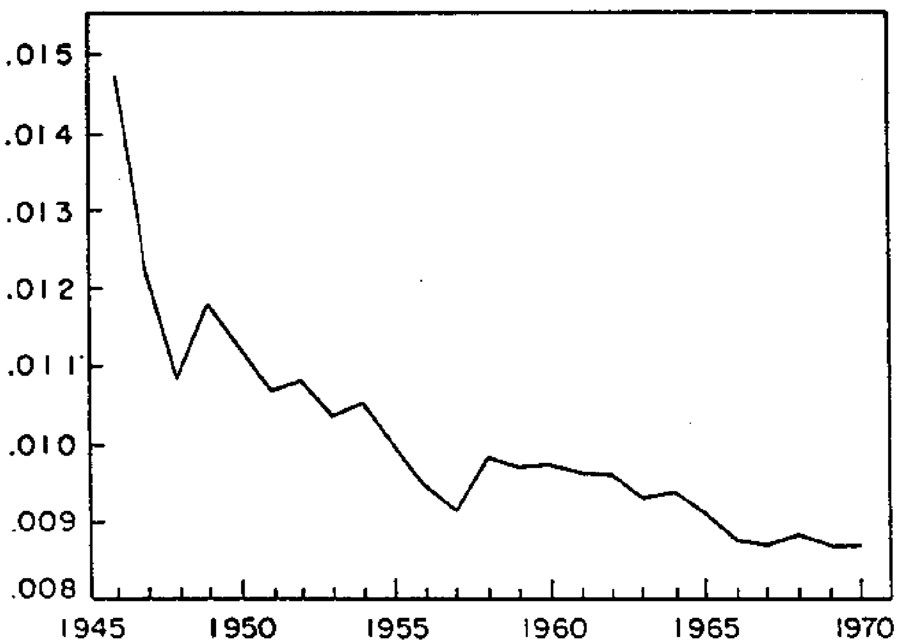


Fig. A1. Ratio of the average industrial electricity price to the total fuel and power wholesale price index.

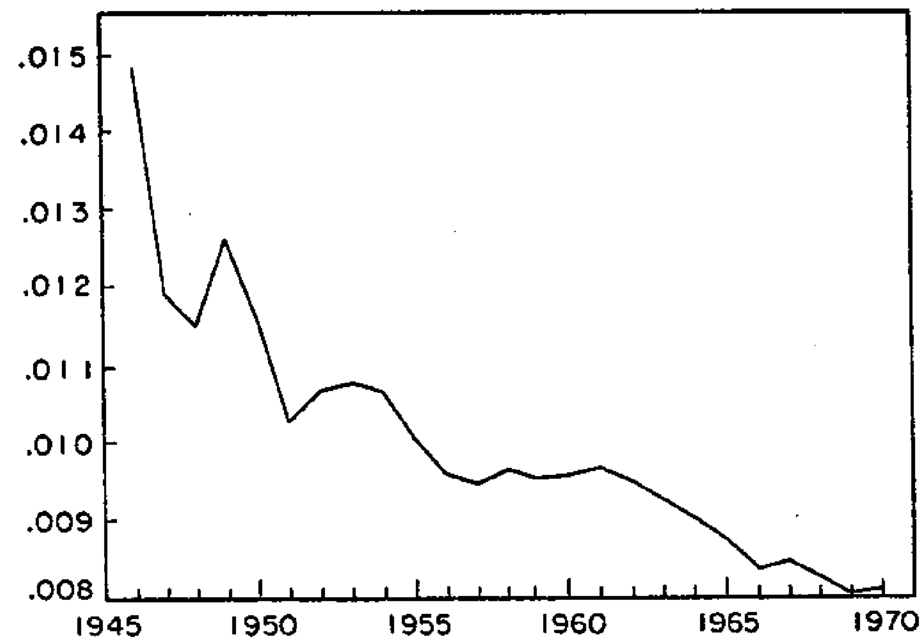


Fig. A2. Ratio of the average industrial electricity price to the all commodity wholesale price index

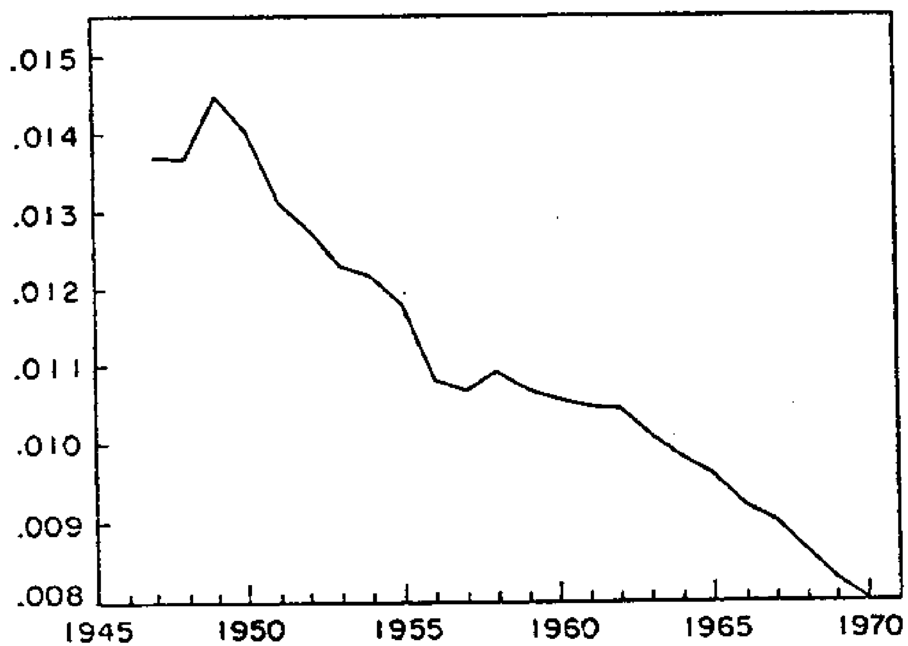


Fig. A3. Ratio of the average industrial electricity price to the unit labor cost.

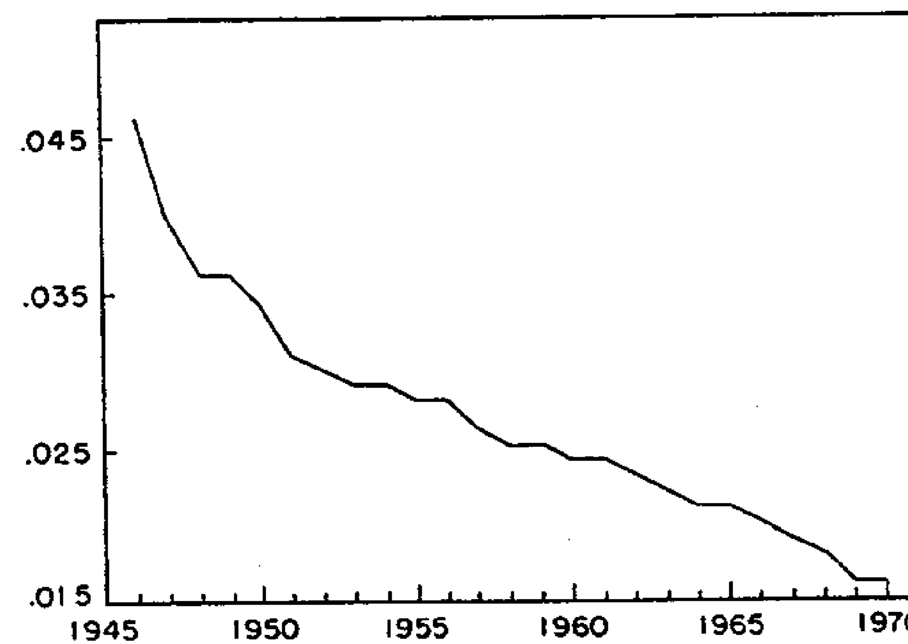


Fig. A4. Ratio of the average residential electricity price to the consumer price index.

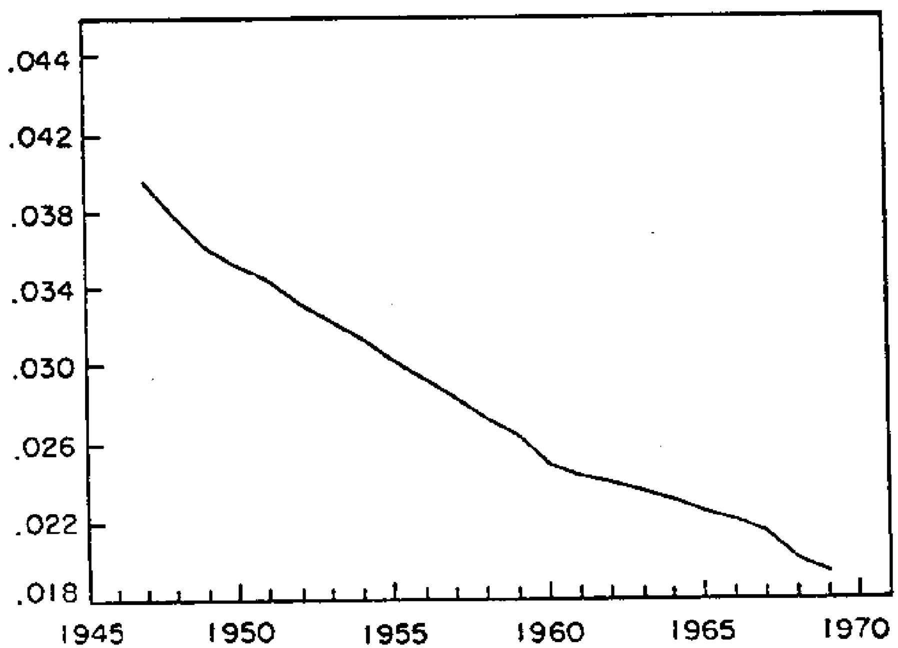


Fig. A5. Ratio of the average residential electricity price to the gas consumer price index.

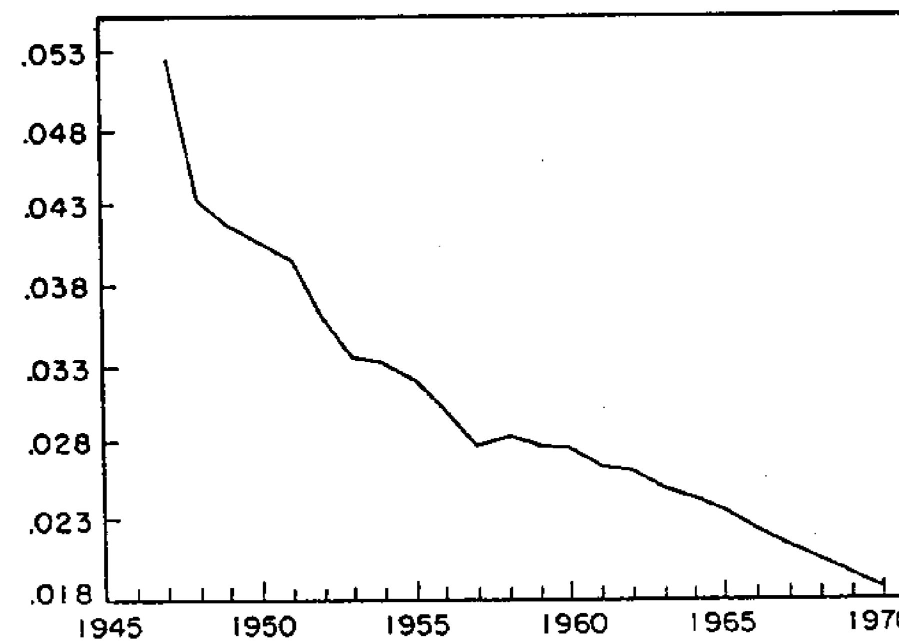


Fig. A6. Ratio of the average residential electricity price to the fuel oil and coal consumer price index.

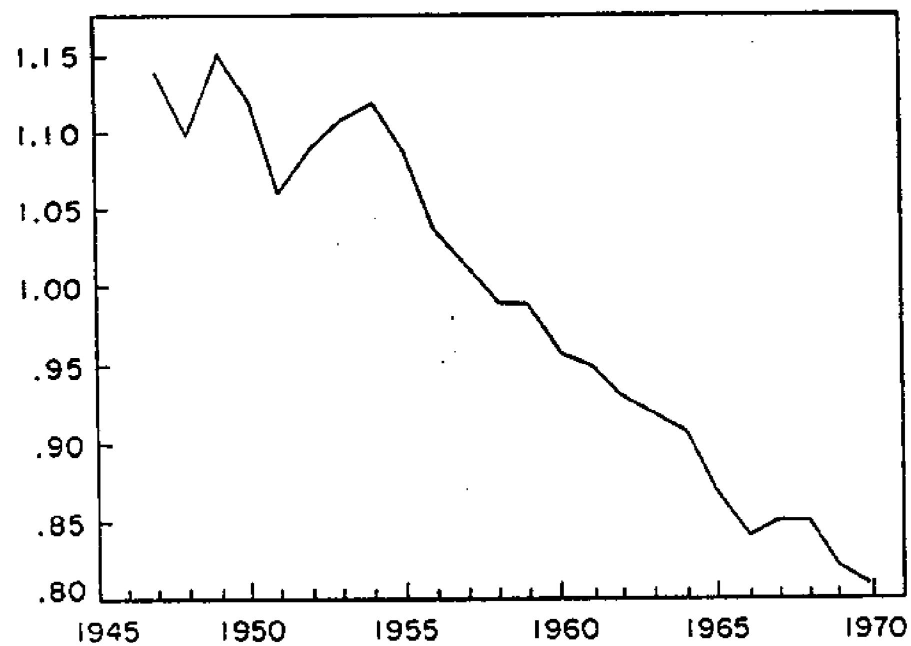


Fig. A7. Ratio of the household appliance wholesale price index to the **all** commodity wholesale price index.

ASSUMPTIONS AND BASIC PRECEPTS OF CONSERVATIONISTS

Address by Alfred W. Eipper, Associate Professor
Department of Natural Resources
Cornell University

The professional background of a great many conservationists is biology. Hence a number of the assumptions and precepts to follow are based on biological truths. For the same reason, many of them presuppose a long-time frame. Biologists tend to think in terms of decades and centuries, feeling that, because biological and population changes take so very long to implement, one has to start working now on problems that he hopes to solve 25 or 50 years hence. Also, the biologist has a "feel" for exponential functions, which tend to be the kinds of processes where deterministic action can only be effective near the beginning--toward the end of an exponential process, changes are likely to be taking place so fast that any useful action then is impossible.

So much for the introduction; here are some of the conservationists assumptions and precepts:

Carrying capacity. Every environment has its saturation point: Tasmania can only support so many sheep, the Adirondacks only so many deer, Lake Ontario only so many fish, and any particular part of the earth only so many people. Yet man, alone, of all the animals, has not experienced environmental saturation--yet. He alone does not know what it means to reach the carrying capacity of the environment, and this may be his Achilles' heel. If he is to forestall it, he has to be able to foresee it.

The conservationist assumes that growth is not necessarily good: growth in population, growth in life style, growth in numbers or sizes of automobiles and highways, etc. Furthermore, the conservationists usually would assume that growth is not necessary to man's welfare. They would even go a large step further and postulate that, indeed, continued growth, indefinitely, is not possible. Population in the United States is doubling every 65 years--every 35 years in the world as a whole, and this trend has remained unchanged throughout most of this century, including the past three decades. Growth of electrical demand is also steady. Electrical demand is doubling at least every ten years, according to utility company experts. Per capita electrical use is increasing five times faster than the population in this country, and each of us can ask himself the question: Will I need 10% more electricity this next year than this year? Why did I use 10% more electricity this year than I did last? This is what is happening, but the answers to this question are complex and go far beyond simply blaming industrialists for promoting electrical use and electricity-using products.

The conservationist also assumes that growth projections (predictions) are subject to change, that they must be changed, and that the change won't start until we start looking into means of changing growth. This in turn requires critical examination of reasons behind the present growth patterns.

Conservationists have some hard-core convictions about the decision-making process too. They believe that decisions about managing natural resources and energy resources must be public decisions, not unilateral decisions by any particular interest group. Thus the conservationist would argue that decisions about the relative merits of building a power plant on Lake Ontario, or the relative costs and benefits to society of using cooling towers are not matters to be decided only by the utility company, or only by the Public Service Commission, or only by the conservationists. As to how decisions are made, conservationists believe that they must be based on a rational consideration of all possible alternatives, and that now, conventional economic criteria cannot be used as a sole basis for estimating values and determining priorities.

Furthermore, the more farsighted conservationists have now realized that decisions cannot be made in a one-at-a-time sequence. Take Lake Ontario, for example: Do we simply look at the pros and cons of one power plant at a time or do we look at the impact of all the power plants on Lake Ontario? Clearly, we should determine as accurately as possible the total number of power plants we are willing to have this lake serve as an industrial sump for. The effect of one power plant on a lake the size of Lake Ontario is probably not easily predictable, but this is not the question. The question is what will be the effect of all the power plants that we are going to put on Lake Ontario? When we consider one power plant at a time, we neatly avoid facing up to that question.

Conservationists also have some pretty firm beliefs in the category of values, there is, for instance, that we have an obligation to future generations to maintain the quality of natural environment still remaining--that everyone has a right to a high-quality environment; no one has a right to pollute. Values imply payment in our economic system, although not all values are measurable in dollars by any means. But who pays for our energy and our use of resources? The conservationist would answer that all of us must pay for what we use, for our sewage treatment, for our electricity, for our coal, and also for the water used in generating electricity, and for the air used as a dumping site for the wastes of burning coal.

The conservationists tends to be haunted by a related question: Who pays for mistakes in judgment? We have seen too many ecological boomerangs, long lasting uncorrectable environmental damage from human actions when the results were unpredictable at the time these actions were taken. DDT, mercury, PCB's, acid rainfall--these are only a few of the examples of ecological boomerangs. Therefore, the conservationist is convinced that we must pay the full cost of the product, pay for "the bads along with the goods." More specifically, he is convinced we must start paying the environmental costs of producing goods and of producing energy. This is the economic approach to helping man achieve some steady-state adjustment to his environment.

Finally, the conservationist has some well-defined assumptions about the effects of a technology on the environment, based on looking back at all of our past experience with ecological boomerangs. Some of these are:

1. It is not a 50-50 chance that disruption in an ecosystem will have good or bad effects on that ecosystem. Anymore than it is a 50-50 chance that a blindfolded man poking a pencil into the works of a Swiss watch will improve or impair its operation. Both the ecosystem and the Swiss watch are extremely complicated mechanisms that have evolved over a long period of time, during which disfunctions were eliminated and improvements were incorporated.

2. These unforeseen effects of basic changes in an ecosystem, for example, the often unpredictable effects of heat on a lake are hard or impossible to correct after they have occurred. This is also true for the examples cited earlier, and for the carbon dioxide, radionuclides, particulate matter, lead, and oxides of sulphur and nitrogen that are now permanent additions to our atmosphere.

3. The ill effects of technology on our environment are not only difficult or impossible to foresee, they are likely to be difficult to prove later, even though they are there. Causal relationships between pollutants and environmental degradation can be implied from scientific investigation, but it is extremely hard to prove them because the interrelationships are so many and so complex. In similar fashion, no one will ever be able to prove (at least to the cigarette manufacturer's satisfaction) there is a causal relationship between smoking and lung cancer. There will always be some smokers who don't die of lung cancer, and some non-smokers who do.

4. The preceding leads to a fourth assumption about pollution problems: waiting for pollution damage to become clearly measurable before taking steps to correct it has been proved an untenable approach. There is a great deal we do not know about pollution problems, but we do know that the majority of our serious widespread pollution problems cannot be corrected by all of our shining technology put together.

As with any other pattern of logic, certain assumptions lead to other assumptions. I think the preceding assumptions form the background for some very basic assumptions the conservationist makes in approaching a proposal to inflict a technology on an ecosystem:

1. The burden of proof must be on the potential polluter to prove his technology will not damage the environment, rather than on the users of that environment to prove the technology will damage it.

2. We must employ the principle of prevention---"a stitch in time saves nine," and so on. When anything can be done to forestall possible ill effects of a technology on an ecosystem, in light of the preceding precepts, it should be done. This is not really such a startling assumption. Technologists employ it routinely. An engineer who is building a bridge always uses an I-beam five to ten times stronger than the maximum stress his mathematical planning tells him this beam will ever have to withstand. Why? Because you always build in a safety factor, to provide for possible unforeseen eventualities. And it is simply this safety factor that conservationists insist upon in the environmental problems they are embroiled with on Lake Champlain, Cayuga Lake, Lake Michigan, and Lake Ontario, to name just a few.

To sum it all up, a group of conservationists in the Chicago area came up with a bumper sticker to express their basic approach to the management of that most valuable resource, Lake Michigan:

DON'T DO IT IN THE LAKE!