SECTION 1

ENERGY AND VULNERABILITY

ENERGY AND VULNERABILITY (1.0)

Introduction and Overview (1.1)

The fact that the United States depends on imported petroleum to meet almost half of its demand has become widely recognized. The numerous economical, political, social, and environmental repercussions that could result from this dependence, however, are not yet fully realized. As Joseph Nye says, "Oil is the heart of the energy security problem and will remain so for at least the next decade."[1]

Because the energy sector is vital to the industrial, agricultural, communications, and other sectors of a society, a failure in the ability to produce and distribute energy throughout the United States would leave the country unable to support or defend itself. In short, the present energy situation makes the United States vulnerable. Our national security is at risk.

> Vulnerability refers to the degree to which an energy supply and distribution system is unable to meet end-use demand as a result of an unanticipated event which disables components of the system. The kinds of events referred to are sudden shocks, rare, and of large magnitude.[2]

There are two major forms of vulnerability against which the United States must protect itself. The first is the insecure availability of imported energy supplies and strategic materials necessary for adequate levels of defense, economic growth, and stability.

The second form of vulnerability is the centralized nature of the American energy system. Because energy is vital for maintaining the U.S. economy, an adversary would enjoy a strong strategic advantage by crippling that energy system. Centralized energy facilities add to the degree of vulnerability of the U.S. energy systems because, as enemy targets, they are larger and there are fewer of them.

A strategy of targeting centralized energy facilities, for example was successfully used against Germany during World War II. Today, the existence of centralized energy facilities is recognized as a primary source of national vulnerability. Studies have demonstrated the likelihood of targeting refineries in the advent of modern war, and various other facilities including nuclear power plants.

One strategic solution that would decrease vulnerability is the implementation of dispersed and renewable energy sources. Increased use of dispersed energy sources and a transition to renewable sources in the industrial, agricultural, commercial and residential sectors would ultimately result in independence from foreign energy sources. In addition, the vulnerability of the centralized energy system, dependent on a limited number of massive facilities, would be substantially reduced.

The story of how cheap, easily available petroleum fed the industrialized nation's insatiable appetite for increasingly large shares of energy is by now well known. What is not as widely published nor understood is why Americans refused to recognize the peril that dependence upon a few unstable nations, inexperienced in playing a central role in international politics, brought to the entire U.S. economy. Even the "oil crisis" in 1973-74 that resulted in quadrupled prices in oil didn't reverse the trend of continually greater dependence on imports from a very small number of suppliers. The industrial economies grew at an average annual rate of 3.4 percent during 1970-78[3], and the real price of oil actually fell in 1974-78.[4]

The events of 1973-74 were considered a unique and isolated experience. American life, considerably dependent of foreign supplies of oil, continued with only slight acknowledgement that cheap and abundant oil would never be available again. Evidence of this lack of concern was demonstrated by the initial reluctance of Congress to pass President Carter's proposed "moral equivalent of war." Instead, a weakened National Energy Policy Act passed in 1978. In order to lessen dependence of foreign supplies, the Act called for heightened production and consumption of domestic sources, consisting chiefly of coal and nuclear fuel. The production of these energy resources, however, entails a number of economical, social and environmental concerns, which have greatly hindered their accelerated usage.

Not until the Iranian Revolution of February, 1979, did the Amercian public begin to acknowledge how serious a threat this excessive dependence on imported petroleum represented. "The oil lost in the first half of 1979 amounted to only one percent of the world total, yet inadequate preparations and panic responses produced gasoline lines and a 120 percent price increase."[5]

Although most OPEC countries "produced above their announced ceilings in early 1979 to help consumers cope with the Iranian shortfall, "many of the world's leading oil producers recognize the exhaustibility of their resources and have reduced production levels. "OPEC exports are expected to decline from 28.3 million barrels per day in 1979 to 22 million in 1985 and to 17.29 million by 1990."[6]

Our dependence on a small group of unstable, unpredictable nations results in a serious supply vulnerability. The largest oil producing country, Saudi Arabia, is no longer able to moderate the more extreme members of OPEC who wish to cut back production and raise prices to the limits that the market will support. In addition, the United States has become increasingly dependent on nations that, to one degree or another, regard the West an an enemy and show little compunction in subordinating oil supply to other considerations.

The Department of Energy estimates the domestic cost to the U.S. economy would be $323 billion of ten million barrels per day (mbd) were curtailed for a year (slightly more than Saudi Arabia's production level) and $686 billion if the entire Persian Gulf oil supply (so precariously reliant on the Straits of Hormuz) was suspended for one year.[7]

In spite of the fact that the U.S. is the second largest producer of oil, contributing 8.5 mbd to the world's supply, we are simultaneously the largest importer, requiring over 6.4 mbd.[8] Proved domestic crude oil reserves have declined sharply, following the discovery of Alaskan reserves in 1970. The rate of production has declined with the decrease in reserves, resulting in a decreased production rate of sixteen percent from 1970 to 1975.[9] As the rate of growth in energy demand continues to climb, it becomes very unlikely that the U.S. can depend solely on domestic resources to meet its oil demand.

Natural gas trends have been very similar to those of domestic oil reserves and production. Proved reserves also declined after 1970 and decreased rates of production followed, having peaked in 1973.[10] As with oil, the U.S. is not only one of the largest natural gas producers, but is also one of the largest importers. Imports comprise about five percent of total natural gas consumption, as compared to over 36 percent of total petroleum consumption.[11]

U.S. coal reserves, on the other hand, are plentiful. Over 600 million tons of coal are produced in the U.S. every year. There are a number of well-known environmental liabilities inherent in the mining, transportation and burning of coal, however.

Nuclear power has been considered a major solution to energy needs for the last few decades. However, it has become one of the most controversial issues in America today. The lack of a viable nuclear waste disposal program, the fear of nuclear accidents, and the threat of proliferation all add to the public's growing resistance to atomic power providing more than its current eleven percent contribution to electric generation.

Additionally, there is no place to store the radioactive materials without risking radiation exposure of some kind. Waste is being temporarily stored until facilities and handling methods can be developed that will alleviate the dangers of radioactive contamination.

Likewise, the possibilities for accidents in nuclear power plants either elicit absolute opposition or are unequivocally defended by technologists who contend that the chances of a life-threatening accident are miniscule. As long as events such as the near-meltdown at Three Mile Island provide support for the opposition's viewpoint, the debate will continue.

The issue of nuclear proliferation also provokes debate. Because the topic is so controversial and complex, it warrants some elaboration. The production and use of nuclear fuels for civilian power generation can lead to the use of bomb-grade radioactive materials which enhances the spread of nuclear weapon capabilities to several nations. This increases the potential for nuclear terrorism and nuclear warfare.

Currently, the United States employs light water reactors (LWR's) to generate electricity. "Ordinary LWR's use a low enriched fuel (about three percent

Uranium-234 and 97 percent Uranium-238) which is useless for bombs. . . without further enrichment."[12] National policy prohibits the export of enrichment technology from the United States due to proliferation concerns.

A conventional assumption has been that spent fuels would be reprocessed to produce fresh fissionable fuels for reuse. Eventually LWR's would be replaced with "breeder" reactors that breed additional fuel (Plutonium-239) in the fission process, thus alleviating dependence on dwindling supplies of Uranium-235. However, the breeder reactor nuclear fuel cycle can produce weapons-grade plutonium more readily than conventional nuclear fuel cycles. Both breeder reactor development and fuel reprocessing from LWR's have been delayed by the U.S. government because plutonium might be exposed to potential misuse through proliferation. The debate now centers around whether we should maintain our policy of breeder reactor technology prohibition and continued dependence on diminshing uranium supplies or develop breeder reactors. Active development of breeder reactors is underway by several European nations, but even with full development, several decades will be required to reach maturity in such programs. The Harvard Business School's Energy Project summarized the breeder issue as follows in their report, Energy Future:

> Contrary to a widespread impression, even the world's most technically advanced breeder reactor development program (in France) is decades from making any significant addition to that country's nuclear power supply. . . Events beyond the early 1990's are, of course, anyone's guess, but the history of the light-water-reactor development effort cautions against expecting too much too soon from a new and highly complex technology. Certainly for the indefinite future there would seem to be little or no realistic possibility that breeder reactors could have any practical effect on the waste disposal problem.[13]

This study considers the use of dispersed, decentralized, and renewable energy resources as a long-range strategic energy option. Numerous reports exist today that discuss the likely contribution renewables can offer in the near and distant future. There is considerable divergence among the resulting projections and forecasts, however, due in part to the variable and conflicting assumptions employed.

The realization that greater energy efficiency, conservation and development of renewable energy resources can help to decrease our dependence on foreign oil has become more widespread. Public acceptance is growing due to favorable demonstrations of successful renewable systems. The technologies that were once too expensive and exotic to consider are now cost-effective in a number of cases.

Strategic Materials and Vulnerability (1.2)

The resources required to produce many components of a number of conventional and alternative technologies are referred to as "strategic materials." These minerals and metals are necessary to a number of key U.S. industries, including aerospace, electrical equipment, nuclear power, and communications.

The issue U.S. policymakers face today regarding strategic materials is our reliance on imports. The United States currently imports between 90 and 100 percent of most of these elements. "It is scarcely an exaggeration to suggest that the West is every bit as vulnerable to chaos from a cutoff of strategic minerals as it is to an oil cutoff."[14] Table 1.2-1 illustrates U.S. dependence on some of these strategic materials.

Many of these materials exist in presently or potentially unstable regions of the world, such as South Africa, Cuba, Brazil, Zaire, Morocco, Jamaica, and Zambia. In addition, the Russians have been establishing contacts and power bases in or around many of these regions, causing concern about the future availability of supplies. The problem is not only the uncertainty generated by dependence upon unstable regions, but also the threat to national security that this situation poses since many of these materials are crucial for advanced military hardware in addition to power generation. Table 1.2-1 shows some of the extent of this reliance.

A number of critical and strategic materials are used in the construction and maintenance of a wide range of energy facilities, power plants, and heat engines of various kinds. As a genral rule, higher technology equipment and equipment which must operate at high heat ranges, require the use of specialized, exotic and strategic materials to a greater degree than simpler, somewhat lower technologies. The Nuclear Regulatory Commission (NRC) has studied the requirements of nuclear power plants, which use materials such as aluminum, antimony, asbestos, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, mercury, nickel, platinum, silver, tin, tungsten, and zinc. Table 1.2-2 lists the materials needed for reactor cores based on U.S. experience in the construction of large nuclear power plants.

Unlike other energy technologies, many of the critical materials utilized for reactor cores cannot be recycled in the future due to excessive radioactive contamination. This unique feature of nuclear power adds significance to policies which commit large quantities of scarce, strategic materials to this sector of the energy economy. Other energy technologies, such as new synfuels processes, are also heavy users of critical materials. Vast increases in synthetic fuels production or the construction of large, modern power facilities will require substantial amounts of these threatened and dwindling materials.

Legislation has been enacted during the past 30 years which attempts to protect the United States' military interests from disruptions in the flow of strategic materials. The Defense Production Act of 1950 "can be used to stimulate domestic production of metals and materials that are critical to national security."[15] Title I sets priorities and allocations under the Defense Materials and Defense Priorities

Table 1.2-1[16]

U.S. RELIANCE ON STRATEGIC MATERIALS

Material	Percentage of U.S. Consumption from Imported Materials
Titanium (rutile)	100 [f]
Columbium	100 [d]
Tin	100
Beryllium	100 (approx.) [b, c]
Germanium	100 (approx.)
Platinum	100 (approx.)
Manganese	98 [c]
Tantalum	96 [c, d]
Aluminum	93 [a]
Chromium	90 [a, c]
Cobalt	90 [c]
Nickel	77 [e]
Tungsten	59
Copper	n.a.
Molybdenum	n.a.

a Reliance on politically unstable regions.
b U.S. has large potential supply.
c Reliance on politically unstable African region (e.g. South Africa)
d Reliance on politically unstable Asian region (e.g. Thailand)
e U.S. has large potential resources, but domestic production has been limited due to technological and environmental problems.
f Reserves have been identified in the U.S., but none mined.

Systems regulations; Title 3 enables the government to underwrite the expansion of domestic production of strategic materials and raw materials for which the U.S. has a high degree of import dependence; and Title 7 lists administrative regulations which implement the rest of the Act.

Table 1.2-2[17]

ESTIMATED QUANTITIES OF MATERIALS USED IN REACTOR CORE REPLACEABLE COMPONENTS OF WATER-COOLED NUCLEAR POWER PLANTS

Material	Quantity Used in Plant,[a] kg	World Production,[b] metric tons	U.S. Consumption metric tons	U.S. Reserves,[b] metric tons	Strategic & Critical Material[c]
Antimony	1.7	65,400	37,800	100,000[d]	Yes
Beryllium	2.8	288	308	72,700	Yes
Boron	3,363	217,000[e]	79,000[e]	33×10^6	No
Cadmium	206	17,000	6,800	86,000	Yes
Chromium	109,000	1,590,000	398,000	2×10^6[d]	Yes
Cobalt	61	20,200	6,980	25,000[d]	Yes
Gadolinium	2,650	8[f]		14,920[g]	No
Iron	443,000	574×10^6 [h]	128×10^6 [i]	2×10^9 [d]	No
Nickel	55,000 314,000	480,000[i]	129,000[i]	181,000[d]	Yes
Tin	24,000	248,000	89,000	57,000[d]	Yes
Tungsten	9.3	35,000	7,300	79,000	Yes
Zirconium	1,106,000	224,000[e]	71,000	51×10^6	No

a Quantities used are modified from the final ER for Hope Creek Generating Station, Table 10.1, Docket Nos. 50-354 and 50-355.

b Production, consumption, and reserves were compiled, except as noted, from the U.S. Bureau of Mines publications "Mineral Facts and Problems" (1970 ed. Bur. Mines Bull. 650) and the "1969 Minerals Yearbook."

c Designated by G.A. Lincoln, "List of Strategic and Critical Materials," Office of Emergency Preparedness; Fed. Regist. 37(29):4123 (Feb. 26, 1972).

d World reserves are much larger and U.S. reserves.

e Information for 1968.

f Production of gadolinium is estimated for 1971 from data for total separated rare earths given by J.G. Cannon, Eng. Mining H. 173(3):187-200 (March 1972). Production and reserves of gadolinium are assumed to be proportional to the ratio of gadolinium to total rare earth content of minerals give in "Comprehensive Inorganic Chemistry," Vol. 4, ed. M.C. Sneed and R.C. Brasted, D. Van Nostrand Co., Princeton, N.J., 1955, p. 153.

g Reserves include only those at Mountain Pass, Calif., according to the "1969 Minerals Yearbook."

h Excludes quantities obtained from scrap.

i Production of raw steel.

j Metallic zirconium accounted for 8% of total U.S. consumption in 1968.

The Strategic and Critical Materials Stockpiling Act resulted in a national stockpile of vital minerals. Presently, the total value of the stockpile inventory is about $13 billion, but there are shortages and imbalances in several key categories that would require an estimated $6 billion to bring the inventory to stated goals. The 1981 fiscal budget allocates $170 million for additions to the stockpile, and it is likely that a larger request will be submitted next year.[18]

The National Strategic Information Center (NSIC) recently released a White Paper urging increased efforts to "beef up American stockpiles" by adhering to "resource war" tactics. The report suggests that the U.S. should design new alliances and be prepared to intervene militarily, to be guaranteed access to Mideast oil and southern African minerals. The report discusses U.S. dependence on foreign supplies. Even though there are presently sufficient supplies to meet industry's demands, the report states that the "U.S., and its allies, are increasingly unable to exert sufficient influence on the world scene to guarantee a continued flow of raw materials from the Third World--and immediate action needs to be taken."[19]

In addition, set-aside quotas have been established which mandate a monthly percentage of the materials production to defense-rated orders; the remaining materials are free for market consumption.

One way to alleviate imported materials-dependent vulnerability is to stimulate U.S. Domestic production. The issue of increasing American mining of these crucial minerals is being addressed in the Congress. Senator James A. McClure (R-Idaho), Representative James Santini (D-Nevada) and Senator Harrison Schmitt (R-New Mexico) have warned of threats to national security due to reliance on foreign mineral resources.[20]

The United States has vast resources of its own, but thus far it has been "uneconomical" to substitute the more expensive domestic resources for cheaper foreign resources. The proponents of increased domestic production hope to pass legislation revamping tax codes, anti-trust laws and environmental regulations, in addition to opening federal lands to mineral exploration.

Representative Santini, Chairman of a House mining subcommittee, in a recent hearing on the "International Resource War: Minerals Held Hostage," recommended a policy to steer the U.S. away from our growing dependence on imported minerals. At the Santini hearings, former NATO Commaner-in-Chief Alexander Haig said: "Should future trends, especially in southern Africa result in alignment with Moscow of this critical resource area, then the U.S.S.R. would control as much as 90 percent of several key minerals for which no substitutes have been developed and the loss of which could bring the severest consequences to the existing economic and security framework of the free world."[21] The Russians may be simply acting in their own self-interest to insure supplies and "will be forced by economic realities to continue trading their minerals on the open world market."[22]

The possibility of curtailment of imported strategic materials renders the United States as vulnerable as our dependence on OPEC oil. The energy production and distribution industry is dependent on strategic materials which further deepens our vulnerability. In the past, economic considerations based on the price of a desired material were the main criteria used to determine amounts of domestic production vs. importation. Now, policymakers are learning to weigh national security against price. In some cases, it is becoming expedient to pay a higher price in dollars to stimulate domestic production of a vital resource than to import cheaper materials and pay the price of energy and materials supply vulnerability.

Centralization of Energy Systems and Vulnerability (1.3)

Vulnerability is apparent in the evolution of the U.S. energy network. With the rapid industrialization of the United States during the late 1800s, it became evident that the introduction of larger facilities led to profitable economies of scale. Marginal costs decreased as greater numbers of goods were produced. Centralization likewise applied to the American energy production and distribution system, and today the concentration of facilities has become an integral characteristic of the economy's energy sector. (See Section 2.7, "Energy Systems and Economies of Scale" for further discussion.)

The trend toward centralization is illustrated by the electric power industry. Initially, electricity was produced in small, localized plants. The numerous small-scale electricity-producing stations gradually consolidated as improved technologies allowed increased production and more efficient distribution facilities. Demand for electric power doubled every ten years on the average, while the price of electricity in cents per kilowatt hour dropped, in real terms.

American society depends on large-scale power plants for the operation of food production and distribution, transportation, communication, and for the ability to defend itself. In short, it depends on energy for survival. Because the life blood of a modern, highly industrialized economy is its energy sources, the larger and more concentrated these sources are, the more vulnerable the economic system and armaments production are to total disruption if the energy sources are attacked or interrupted by other means.

Petroleum and Vulnerability (1.3-1)

The petroleum industry, for example, is very vulnerable. From the time petroleum is pumped from wells until it is distributed as refined products, it follows an increasingly centralized production chain. The centralization of petroleum operations and the development of sophisticated equipment for operating and communications make it highly vulnerable to an attacker's disruption.

Domestic production of crude petroleum is probably the least vulnerable step in the oil chain. Oil fields are dispersed over wide areas of the country, increasing the likelihood that at least some production will be maintained if a portion of the nation's oil fields is damaged or destroyed by disaster, sabotage or nuclear attack. However, approximately 50 percent of U.S. crude oil production is dependent on electric power in one way or another, adding to its vulnerability.[23]

Transportation of crude oil is done primarily by pipeline, a system which has some measure of protection in a natural disaster or nuclear attack since most pipelines are buried. However, pumping stations needed to move oil through the pipelines are located aboveground at approximately 50 to 100 mile (80.45 to 160.9 kilometers) intervals along the more than 66,000 miles (96,540 kilometers) of crude pipeline.[24]

The importance of transportation to the petroleum industry was emphasized in a U.S. Department of Interior report which estimated that each barrel of crude oil produced in the U.S. is transported 600 to 800 miles (965.4 to 1,287.2 kilometers) before its final use.[25] Only about one-fourth of American crude oil does not move by pipeline. The ships, trucks and railroads used to transport this oil are also vulnerable to either direct or secondary damage; for instance, trucks surviving an attack may not be able to move over damaged roads.

The next step, refining of crude oil is considered the most vulnerable point in the petroleum system and probably the most vulnerable component of the energy industry. Nearly all crude oil is converted to gasoline and other products before use, and loss of refineries to perform this conversion would devastate the American economy. Large refineries are considered to be a prime target in a nuclear attack because of their crucial role in the economy and because they are the most concentrated segment of the petroleum chain.

Over 38 percent of domestic crude production was refined in the Gulf region of the U.S. in 1974. These refineries are concentrated in a relatively small Gulf Coast area of Texas and Louisiana, which in 1979 had 61 of the country's 311 petroleum refineries. Another 42 refineries are in California and other concentrated areas are Detroit, Chicago, Philadelphia and New York. The California, Great Lakes, Middle Atlantic and Gulf region refineries together account for about 71 percent of the U.S. refining capacity.[26]

The petroleum industry's reliance on electric power for many of its operations complicates the vulnerability picture since electric utilities also are vulnerable to nuclear attack. "Auxiliary power is available in some (refining) plants but the lack of power will shut down most operations," states one study of the petroleum system's vulnerability.[27]

Some of the federal research on energy vulnerability has suggested industry changes that would reduce damage done in a nuclear attack. However, these solutions, such as building petroleum refineries underground, maintaining separate electric power sources for each refinery and building refineries with fallout protections, are generally acknowledged to be uneconomical in an industry in which market considerations, transportation and crude oil supply are major factors determining site location for plants.[28]

Natural Gas and Vulnerability (1.3-2)

The natural gas industry is similar in many respects to the petroleum industry. Gas collected in the field must be moved to a processing plant before being transported for use in homes and industry. Production of natural gas is concentrated in only a few states. In 1978, Texas, Louisiana, Oklahoma, New Mexico, Kansas, Wyoming and Alaska produced 92.8 percent (19.97 trillion cubic feet) of the marketed natural gas originating in the U.S. The same year, Texas and Louisiana alone exported 8.24 trillion cubic feet, which was 18.1 percent of the domestic gas sold in the interstate market.[29]

Natural gas production, like crude oil production, is less vulnerable than other aspects of the industry because it is dispersed over a large area. Pipelines (77,766 miles (125,125.49 kilometers) were operating 1979) gather the field gas which must go to gas processing plants before distribution. The gas processing step is roughly comparable to refining in the petroleum industry, but is is less complicated. In 1974, there were 763 such plants in the country.[30]

Over 260,000 miles (418.340 kilometers) of transmission lines carry the gas from the processing plant to storage tanks. Transmission pipelines are considered vulnerable to sabotage and to ground shock waves from a nuclear attack. The greatest vulnerability in transmission is the fact that pipelines and compressor stations are run by automated systems. Complex communications equipment is vital to this operation, and few people are skilled in repairing it. Thus, even lightly damaged equipment could be rendered unusable if no one with the expertise survived to make repairs.

Coal, Electric Power and Vulnerability (1.3-3)

Most energy vulnerability analyses have concentrated on petroleum, natural gas and electric power. Coal is a less complicated industry, but it remains vulnerable because of its great dependence on two other resources: electric power and transportation.

The coal industry is dependent on electric power for both strip mining and deep mining. Transportation of coal is done by railroad (about half the coal mined in the U.S. moves by rail), barge, and truck, and these modes of transportation ultimately depend on oil for the diesel fuel they need to operate. Damage to the transportation system, or the presence of fallout in in areas that must be crossed to transport coal, would also reduce the availability of this fuel.[31]

Electric power generation depends on fossil fuels, falling water or uranium, which are converted into electric current. In 1979, 48 percent of the nation's electricity was generated by coal, fifteen percent by natural gas, thirteen percent by petroleum, twelve percent by hydropower and eleven percent by nuclear energy.[32]

However, those statistics vary considerably in different areas of the country. New England, for instance, relied on coal for only seven percent of its electricity, while petroleum provided 60 percent. But nationwide, electric utilities are the country's biggest coal consumers, burning about 70 percent of the coal produced in the 1970s, compared with fifteen of the nation's natural gas consumption and ten percent of its petroleum. In sum, the electric power industry is vulnerable to the availability of resource supplies as well as the threat of nuclear attack.

Nuclear Power and Vulnerability (1.3-4)

Increasing attention is being paid to the possibility of an enemy attack upon nuclear power plants and its subsequent effects. Currently, about eleven percent of all U.S. electrical power is supplied by nuclear installations. Since nuclear power plants constitute less than 200 potential targets (including near-term proposed additions) and have the added risk in some cases of being very close to large pupulation centers, they are prime candidates for strategic nuclear targeting or conventional bombing.

Other reasons nuclear power plants may be chosen are outlined by Bennett Ramberg:

> They might be atacked because they are a guise for a nuclear weapons program. They might be threatened or destroyed because they represent one of the greatest concentrations of capital investment a country is likely to possess. A party with a stake in an ongoing conflict between two countries might consider sabotaging a facility as a means to escalate the conflict. Finally, large numbers of people in many countries have become acutely concerned about possible releases of radionuclides from power plants. Taking advantage of this fear, a belligerent could use the threat of radioactive contamination resulting from a successful attack as a means of coercion.[33]

Several studies also hypothesize recovery times necessary for resumption of a stable, productive economy. Again, the estimates all depend upon the assumptions made for the respective scenario. A centralized energy system that depends on relatively few power plants as compared to a dispersed network of small-scale power stations, however, would require a longer recovery period to rebuild huge power generating facilities and replace the other components of the complex energy system.

> The overall dependence of the American economy on large quantities of electrical power and fossil-fueled transportation systems, combined with the vulnerability of petroleum refining facilities and significant dependence on foreign petroleum, suggests that the magnitude of the difficulty in meeting energy needs may be one of the most critical determinant(s) of the nation's long-term ability to recover economically...[34]

The likelihood of an assault upon domestic nuclear power plants must also be taken into account when attempting to measure the degree of U.S. vulnerability. Not only does the possibility of an external bomb attack exist, but recently the threat of damage to nuclear plants has expanded due to an increasing number of sabotage and terrorist attacks.

Terrorism and Vulnerability (1.4)

Terrorism, according to the U.S. Department of Justice is "the calculated use of violence to obtain political goals through instilling fear, intimidation or coercion. It usually involves a criminal act, often symbolic in nature and intended to influence an audience beyond the immediate victims."[35]

During 1977 there were 106 acts of domestic terrorism.[36] Terrorism cannot be compared with usual criminal acts -- it is an act directed against all of society, deliberately designed to shock, dismay and enrage.

The motive for sabotage may be equally political, but the goal is largely functional, that is, to destroy a capacity or disrupt a process typically relating to material production and often for the purpose of hampering a nation's war effort or defensive capability. The strategy may involve an intent to unsettle governmental or military authorities, or even undermine public confidence in those institutions, but the principal thrust is political. Relatively trivial incidents of sabotage are occasionally associated with labor disputes or the effort of an aggrieved party to extract revenge, or even simple extortion, but the primary concern remains in the area of defense production and capability.

There is little doubt that electrical power and fuels transported over long distances by complex routes make them vulnerable to terrorist attack and sabotage. Virtually the entire electric grid in this country consists of overhead transmission lines. Pipelines carry most of our natural gas and pipelines (some 260,000 miles (418,340 kilometers) of trunklines and gathering networks) are major carriers of petroleum products. These elements of the system (especially their function components, such as substations and switching centers in the case of electric power transmission, and aboveground valve, cutoff and pressure regulator sites for gas and oil pipelines) are essentially unguarded, vulnerable to a variety of weapons, and difficult to repair.[37] Nevertheless, refineries, processing plants and power facilities must be considered prime targets for internal attack.[38]

Similarly, the high degree of interconnections in the electric power system mitigate the consequences associated with the loss of any single power station. This last point is also true of such central facilities as refineries: "One should not underestimate the costly damage that is possible to an oil refinery, but the temporary loss of the products from one or several plants would be greatly detrimental to total energy flow, except in the local market."[39]

On the other hand, there are energy systems which almost seem to invite disruption by internal attack. For example, more than half of the natural gas in the United States flows from or through Louisiana, raising the spectre that a few well-executed attacks could severly cripple the nation's supply. Similarly, over 2.5 million barrels of light petroleum products flow through four major lines from the Gulf Coast to east-central and eastern states every day.[40]

To date, the major terrorist groups have shown no inclination to attack U.S. energy facilities elsewhere.* As shown in Table 1.4-1, energy related attacks in the United States (all bombings) have been very minor in scale, have resulted in little damage, and have caused almost no interruption of service. By and large, they have been motivated by the rather mundane grievances of domestic groups.

It may be, however, that increased attention to the energy crisis and the heightened public perception of vulnerability in energy supply may soon attract the attention of more dangerous groups. Certainly the ongoing controversy over nuclear power will make nuclear power plants increasingly attractive targets. It seems unlikely that any but the best financed and most technologically sophisticated terrorist groups would be able to cause more than isolated damage.

* Note: On February 6, 1972, the Black September groups blew up two gas processing plants in Rotterdam which represents the only energy-related attack by the seventeen largest terrorist organizations between 1968 and 1978. More significant was the attack on South Africa's SASOL plant (synthetic oil) this year by Black Nationalists.

Table 1.4-1[41]

INCIDENTS OF ENERGY-RELATED TERRORISM

FACILITY	DATE/REFERENCE	WHO	REASON	DAMAGE	INTERRUPTIONS
Transmission towers owned by Public Service Elec. & Gas in Cedar Grove, NJ	NYT, 11-6-68, 40:1	unknown	unknown	tower footing damaged	none
Shell Oil Co. gasoline pipeline in Oakland, CA	NYT, 3-19-69, 28:4	unknown	unknown	fuel carried by creek to nearby community, three injuries	none
Four transmission lines in Colorado	NYT, 4-16-69, 54:1	"campus revolutionary"	electricity ran to local defense plants	not available	not available
Refinery owned by Humble Oil in Linden, NJ	NYT, 1-27-70, 1:5 and 56:4	United Socialist Revolutionary Front	get political prisoners freed	"millions of dollars" to four units	production halted but no interruption
Transformer in Puerto Rico	NYT, 1-1-75, 36:1	assumed Puerto Rican Nationalists	assumed in protest of visit by Kissinger and Rockefeller	app. $100,000	east part of island without power
Pipeline in Puerto Rico	same as above	same as above	same as above	not available	not available
Six transmission towers near Oakland CA owned by PG&E	LAT, 3-22-75, I, 25:4	New World Liberation Front (NWLF)	rate protest	slight	none
Substation owned by PG&E near San Jose, CA	LAT, 4-19-75,	NWLF	rates	app. $15,000	12,000 homes without power
Substation owned by Seattle Light in Seattle, WA	NYT, 1-2-76, 45:2	George Jackson Brigade	not available	not available	2,000 without power
PG&E substation near San Jose, CA	NYT, 1-2-77, 17:1	NWLF	rates to low-income consumers	not available	not available
PG&E substation near Cupertino, CA	LAT, 1-28-77, I, 3:6	NWLF	same as above	"substantial"	power out to 21,000 for 30 minutes
PG&E substation near Oakland, CA	LAT, 4-16-77, 28:3	NWLF	same as above	not available	power out to 5,000
Four PG&E transformers in Sonoma, CA	LAT, 4-19-77, I, 2:5	NWLF	same as above	not available	power out to 8,000
Alaska Oil Pipeline	NYT, 7-29-77, 7:1	local miner	"disgruntled by line's construction"	pipe ok, insulation damaged	flow halted for repairs
PG&E substation in Sausalito, CA	NYT, 8-30-77, 10:6	assumed NWLF	rates	not available	blackout in Sausalito
Alaska Oil Pipeline	NYT, 2-18-78, 18:6	unknown	unknown	1" hole in line; 8,000 barrels lost; unassessed environmental damage	none
PG&E substation in Concord, CA	LAT, 3-16-78, I, 23:3	NWLF	rates	not available	power out to 50,000

Natural Disasters and Vulnerability (1.5)

Severe weather conditions and other natural disasters, such as earthquakes, can create paralyzing conditions conventional energy facilities, grids, and transportation/distribution systems.

Severe winter weather, such as that experienced in 1976-77, creates such conditions. During that winter, barge traffic was blocked by iced-over canal conditions, power lines froze and toppled, truck movements carrying fuel, food and vital commodities slowed to a virtual standstill. These conditions affected the entire northeastern U.S. and temporarily crippled vital energy transportation systems. Other natural disasters such as floods, droughts, tornadoes, and hurricanes have caused havoc to energy and utility systems.

Other more far-reaching disasters, such as major earthquakes, are highly disruptive events which can cause long-lasting damage to energy systems. A recent National Security Council (NSC) committee study on earthquake vulnerability estimates the probability of a massive California earthquake to be 50 percent or higher within the next 30 years. Such an earthquake could have a magnitude in excess of 7.0 on the Richter scale.

The NSC study estimates that a major earthquake would cause between $15 to $70 billion in damage depending on which area of the state was affected and other conditions such as time of day. For an earthquake of 7.5 magnitude striking the Newport-Inglewood fault in the immediate Los Angeles area, damage would be in the $70 billion range and fatalities would range from 4,000 to 23,000.[42]

According to the NSC study, "most systems for communications, transportation and water and power generation and distribution are as a whole resistant to failure, despite potentially severe local damage, because of their network-like character. These systems would suffer serious local outages, particularly in the first several days after the event, but would resume service over a few weeks to months. The principal difficulty will be the need for these systems in the first few days after the event when life-saving activities will be paramount."[43]

Region IX of the Federal Emergency Managaement Agency (FEMA) has prepared a draft Earthquake Response Plan for the San Francisco area, and is now working with the State of California on plans for a potentially disastrous Southern California earthquake. The NSC study points out that as such plans are developed, the possibility of predicting such a major earthquake may increase. If this happens, "decisions (to act on such a prediction) may include such possibilities as the mobilization of National Guard and Department of Defense resources prior to the event, the imposition of special procedures or drills as potentially hazardous facilities such as nuclear reactors or dams..."[44]

The NSC study notes that:

> All major transporation modal systems be affected: highways, streets, and bridges, mass transit systems,

railroads, airports, pipelines and ocean terminals. There will, however, be major variances in losses among the modes. From a purely structural standpoint the more rigid and/or elevated systems such as railroads and pipelines which cross major faults on an east-west axis will incur the most extreme damage with initial losses approaching 100 percent. Other major systems such as highways, airports and pile-supported piers at water terminals with better survivability characteristics will fare much better with damage generally in the moderate range of 15-30 percent. During the 1971 San Fernando earthquake, numerous freeway overpasses collapsed. Improvements in design for new overpasses and a program of retrofitting for older overpasses have moderated this problem, but significant damage must be anticipated to unmodified structures. These transportation facility loss estimates are stated in terms of immediate post-quake effects. They do not reflect the impact of priority emergency recovery efforts or the inherently significant degree of redundancy and flexibility in the transportation system. Consequently, there will remain an unquantified but significant movement capability. Finally, these loss estimates do not take into account the questions of availability of essential supporting resources, particularly petroleum fuels, electricity and communications. In the initial response phase, these could prove to be the most limiting factors in the capability of the transportation system.[45]

Certainly, the potential for widespread disaster is considerably less in the case of a major earthquake than with a nuclear attack or major sabotage event affecting national energy systems. However, as this new NSC study confirms, disruption is heightened because of the increasing centralization and complexity of key energy and transportation systems. In the case of California, an additional level of precaution may be called for because of the location of five coastal nuclear power plants. (Only one is licensed, but four plants are either under construction or ready for licensing.) Even if these plants are not directly affected by an earthquake, disruption in the grip may prevent them from delivering crucial power to affected areas for lengthy periods.

Energy and War: Historical Lessons (1.6)

The concept of targeting energy facilities during times of war is not new. Enemy energy sources have been attacked in recent conflicts including World War II, Korea, Vietnam, the 1973 Middle East conflict and the 1980 Persian Gulf war. The World War II examples of Germany and Japan offer a clear-cut demonstration of the strategic disadvantages of centralized vs. decentralized energy systems.

The German Example: Centralization (1.6-1)

Electric power was, together with coal, the most vital part of the German energy system, and for a number of reasons it was even more vulnerable to attack.

> In 1933 the installed capacity of electric motors represented 73.2 percent of all industrial motive power in Germany. By 1944 probably 80 percent of the motive power was derived from electrical sources. Although most of the electricity consumed by German industry was used to produce mechanical power, i.e., to run electric motors, a significant proportion was used in industrial electric ovens and in industrial electrolytic processes, the principle end products of which were aluminum, magnesium, chlorine, and caustic soda and potash. Finally, electricity was indispensable for the synthetic production of oil, rubber and nitrogen.[46]

Coal was the primary source of electric power generation in Germany. In 1941, 80.2 percent of the electricity produced by the public power plants was obtained from coal, and the remaining 19.8 percent from water power, with about twelve percent coming from run-of-river or low-head hydroelectric plants and eight percent from high-head hydro plants. For the private, industrial electric power plants, water was even less important. Coal again ran about 80 percent of the plants, gas about ten to fifteen percent and water about five percent.[47]

> Of the 80.2 percent of public plant electricity generated from coal, 44.4 percent was from brown coal and 35.8 percent from bituminous coal. Because brown coal has a low heating value, and hence would make transportation costs uneconomic, brown coal stations tend to be located either directly on or close to the coal fields from which they are supplied. Such stations are usually public, rather than private, except when an industry is also located in or near the field and has its own captive power plant. Bituminous coal stations on the other hand, are generally situated close to their potential consumer, i.e., either near or in large cities or close to the industrial plants which they service.

> In 1939 there were 8,257 electric generating stations in Greater Germany, including both public and private plants. Although most of the stations were small, the greater part of the capacity was derived from a relatively small number of large stations. For example, 79.6 percent of all the stations had capacities of 1,000 kv-a or less, but the 113 stations (representing only 1.4 percent of the total) having over 50,000 kv-a capacity produced 56.3 percent of all the current generated, and accounted for 51.0 percent of the electric power capacity. The 416 stations having over 10,000 kv-a capacity, though representing only 5.0 percent of all the public and private stations, accounted for four-fifths (81.9 percent) of the power generated, and constituted 75.8 percent of the capacity.[48]

Although this concentration of electric power production was much smaller than the notable plant concentrations in other industrial fields, it was nevertheless a significant concentration for an industry as widely dispersed as electric power and made the industry vulnerable to wartime attack. Following the start of the war, there was a substantial increase in the number of giant private generating plants which were constructed in connection with the expanding synthetic oil and synthetic rubber industries which were large consumers of electric power.

> Of the 8,257 generating stations in Germany, only about one-fourth (23.8 percent) were public stations. However, these 1,964 stations accounted for slightly more than half (55.8 percent) of the total power production, as well as slightly more than half (57.9 percent) of the generator capacity. Private generating plants, though numerous, were for the most part, small, while the public plants, though fewer in number, tended to be larger. The public power stations having the largest capacitities produced the overwhelming bulk of the public power. For example, the 192 public stations having more than 10,000 kv-a capacity produced 91.1 percent of the power generated by all public plants and accounted for 88.7 percent of the public capacity. Although the private plants followed the same pattern, they did so to a lesser extent, since only 70.3 percent of the private power was produced by stations falling in the same capacity size group.[49]

Geographical concentration also existed, and while electric generating stations were located throughout Germany, there were five main concentrations of generating capacity, each of which was dominated by one or more of the large public plants. Each area also had a number of large private power plants. The public generating plants were interconnected by means of the various transmissions and distribution networks forming the national grid system. Beginning with the war, most of the large private industrial power stations having a surplus of power were tied into the public utility network. Early in the 1930s the utilities had begun to construct interconnections of generating stations, and subsequently from the main substations, in order to supply areas in an ever widening circle. The existence of the national grid caused the Allies to question the vulnerability of the electric power system: "The mobility of electric power, except under limited conditions... would permit the Germans to spread the loss at any point throughout the region attacked, and probably throughout German."[50]

In contrast to this assumption, however, was the concern of German officials that the Allies would recognize the strategic vulnerability of Germany's centralized power system. Dr. Roser, Chief Electrical Engineer for RWE, Germany's largest utility, expressed this concern when he stated, "The war would have finished two years sooner if you (the Allies) had concentrated on the bombing of our power plants earlier... . Your attacks on our power plants came too late. This job should have been done in 1942. Without our public utility power plants we could not have run our factories and produced war materials. You would have won the war then and would not have had to destroy our towns. Therefore, we would now be in a much better condition to support ourselves. I know the next time you will do better."[51]

Underscoring the surprise of German officials that the Allies did not target and destroy power plants was Reichminister Albert Speer's (Minister for Armament and War Production) comments, "I think that attacks on power stations, if concentrated, will undoubtedly have the swiftest effect; certainly more quickly than attacks against steel works, for the high quality steel industry, especially electro-steel, as well as the whole production of finished goods and public life, are dependent upon the supply of electric power... . The destruction of all industry can be achieved with less effort via power plants."[52] Agreeing with Speer, Reichmarschall Hermann Goering, Commander of German Air Forces, elaborated, "We were very much afraid of an attach on German power plants. We had ourselves contemplated such an attack in which we were to destroy power plants in Russia."[53] Figure 1.6-1 shows the effects on production from destruction of German electrical plants in Allied raids.

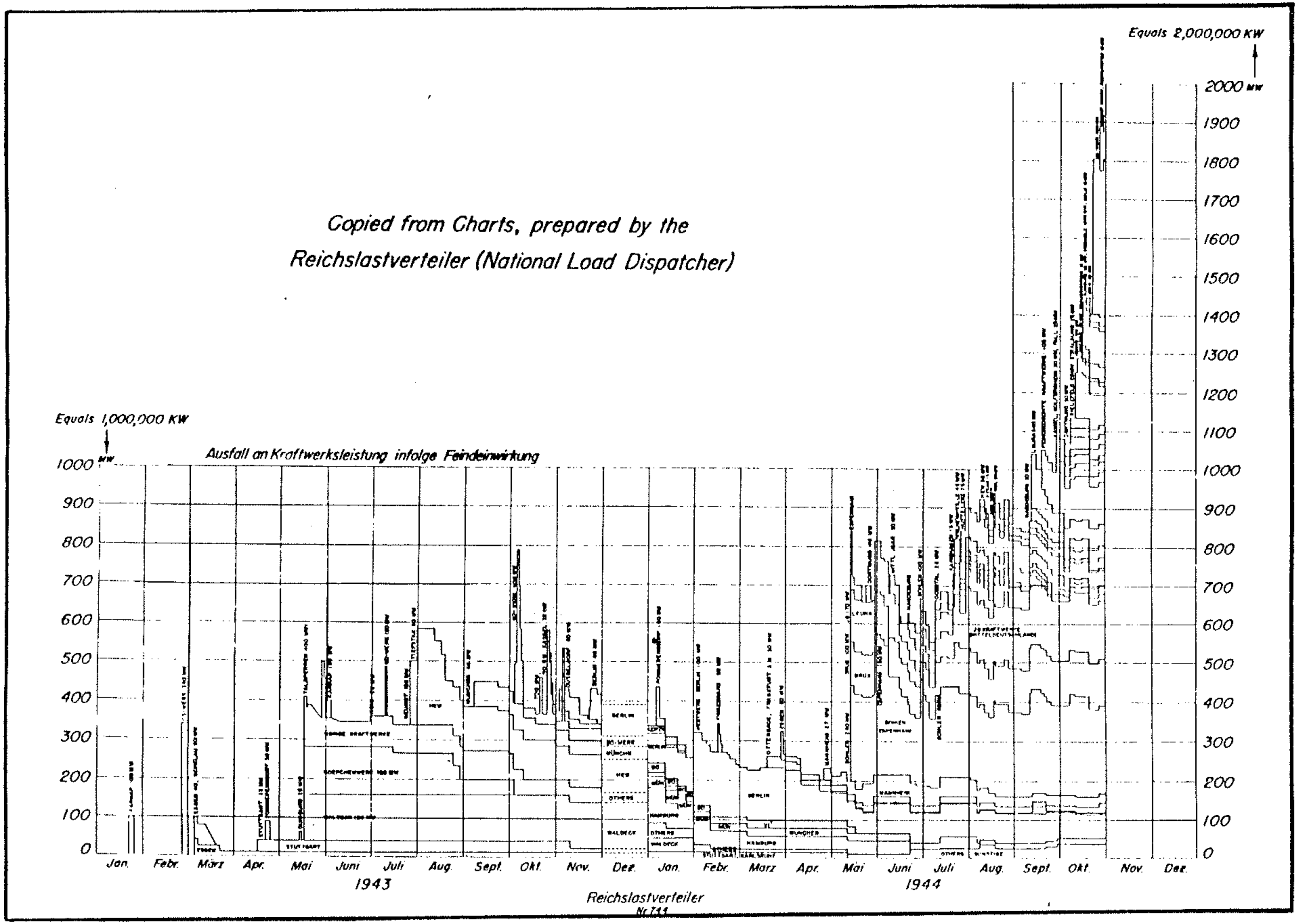
The German Example: Synthetic Fuels (1.6-2)

Not only did coal provide the major fuel resource for the production of electricity, but it was also the basis upon which the synthetic fuel industry developed. Germany developed a number of technologies to utilize synthetic fuels from fossil and biomass sources for automotive and other uses. Before war broke out, the Germans had pioneered a number of techniques to use liquefied gas (propane, butane) from the synthetic fuels plants. By 1941, over 150,000 vehicles were running on producer gas in the Reich and occupied territories. The fuel supply for this gas was a combination of coke, anthracite, charcoal, coal, peat and other sources.

Following a directive from Goering, plans were made to provide for an output of eleven million tons annually by 1944, mainly from a major expansion of the synthetic oils plants, and chiefly from the hydrogenation process. Eventually

Figure 1.6-1[54]

LOSS OF GERMAN POWER PLANT CAPACITY DUE TO ALLIED ACTION



eighteen hydrogenation plants and nine Fischer-Tropsch plants went into production.* Synthetic oil production expanded rapidly during the war, and an enormous amount of money and resources were devoted to this expansion. Annual production amounted to 1.6 million tons (1.5 billion kg) in 1938, 2.3 (2.1 billion kg) in September 1939, 3.3 (3 billion kg) in 1940, 4.1 (3.7 billion kg) in 1941, 4.9 (4.4 billion kg) in 1942, 5.7 (2.6 billion kg) in 1943, and had reached 6.0 million tons (2.7 billion kg) annually by the end of 1943. By early 1944, synthetic oil production accounted for more than half of the German oil supply.

The three major oil products of the synthetic process were aviation gasoline, motor gasoline and diesel oil. The hydrogenation process produced mainly aviation gasoline, with large amounts of motor gasoline and diesel fuel. About 90 percent of all Germany's aviation gasoline was produced by the hydrogenation process. Hydrogenation and Fischer-Tropsch produced 32 percent of the motor gasoline, 36 percent of the diesel oil, and a total of 39 percent of all petroleum products.

At the midpoint of the war, the German goal of equipping a quarter of a million vehicles to use alternative fuels was apparently reached. By March 1944, more than 80 percent of large vehicles had been equipped to use alternative gaseous, liquid and solid fuels. German filling stations were established to dispense wood chips and alternative fuels; special spare parts inventories were developed as well. Special "Imbert" gas units were utilized on automobiles and trucks. To maximize usage, the Reich granted a subsidy for vehicle conversion, ranging from RM (Reischsmark) 400 to RM 1,000 per vehicle.[55]

The synthetic fuel industry was concentrated near the major coal mines in the Ruhr Valley, and thus were susceptible to enemy attack. Because the Allies' prime targets were initially strategic military facilities, they failed to take advantage of Germany's energy vulnerability until very late in the war. When the Allies did destroy Germany's main synthetic fuel and electricity producing plants, the German war economy was essentially incapacitated. Figure 1.6-2 illustrates the dramatic effect of Allied bombing on synfuel production in Germany in 1944.

The history of the Allied bombing attacks upon Germany in World War II demonstrates that with the growing interdependence of energy intensive economies, the more concentrated and centralized the energy sources, the more vulnerable the economy to a wartime attack. The instigation of attacks upon the energy production and transportation systems brought rapid and excessively damaging results, particularly with the attacks upon the means to transport coal and produce synthetic fuels.

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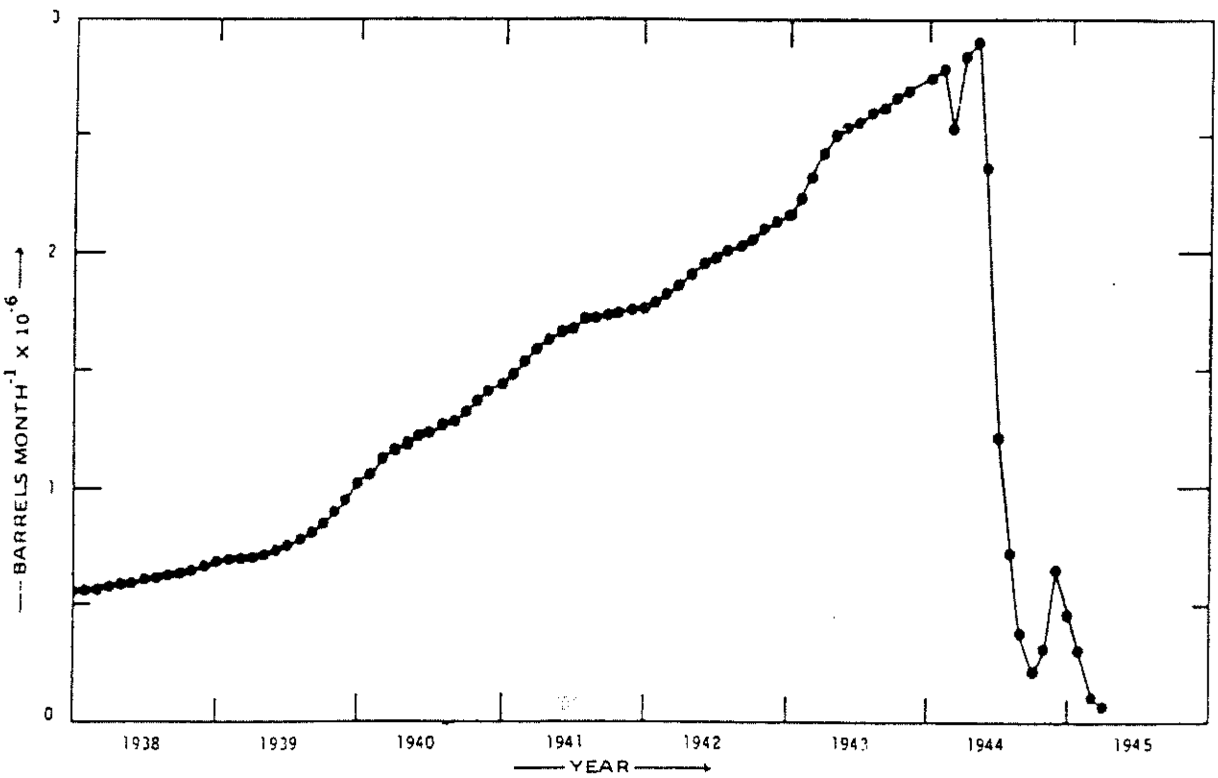
* The Fischer-Tropsch process for producing oil from coal was developed in the 1920s in Germany. Modifications of this design are still widely used (such as the coal/synfuel plants in South Africa), in which hydrocarbons are synthesized from coal-derived hydrogen and carbon monoxide.

Figure 1.6-2[56]

AIR RAID DAMAGE TO GERMAN SYNTHETIC FUEL PRODUCTION



The Japanese Example: Decentralization (1.6-3)

Japan, on the other hand, had a very decentralized energy network during World War II, making her power-generating stations a very low-priority target. According to the U.S. Strategic Bombing Survey (Pacific), "the electric power system of Japan was never a primary strategic target"[57] because most of the power requirements of Japan were "so numerous, small and inaccessible that their destruction would have been impractical, if not impossible."[58]

As Table 1.6-1 illustrates, the total air raid damage to the Japanese utility grid consisted of bombing hits on 35 power plants. Of this, only nine hydro plants were hit, and the total damage to Japan's hydro-electric capacity was .27 percent of the total air raid damage. Over 99 percent of the damage was sustained by attacks on conventional, large steam plants. Figure 1.6-3 illustrates the contribution of small hydro and steam to Japan's total electrical generation capacity during the war. Figure 1.6-4 contrasts dramatically the extent of the electrical capacity loss from Allied air raids on Japanese steam plants (large and centralized) vs. that from small hydro plants (small and dispersed).

Table 1.6-1[60]

TOTAL AIR AID DAMAGE TO GENERATING FACILITIES OF THE JAPANESE UTILITY SYSTEM

Name of Company	Hydro or Steam	Generating stations damaged	Loss of capacity because of air damage (kw)	Percent of total loss of capacity	Amount of damage in yen	Percent of total damage
Nippon Hassoden	Hydro	4	22,700	1.76	208,200	0.26
	Steam	20	1,249,250	96.92	78,497,600	96.46
	Total	24	1,271,950	98.68	78,705,880	96.72
Kanto Haiden	Steam	1	9,500	.74	690,067	.85
Chugoku Haiden	Steam	1	4,500	.35	1,780,000	2.19
Shikoku Haiden	Steam	1	0	0	26,758	.03
Kyushu Haiden	Hydro	3	0	0	9,100	.01
	Steam	1	3,000	0.23	142,900	.18
	Total	4	3,000	.23	152,000	.19
Hokkaido Haiden	Hydro	2	0	0	5,900	.01
	Steam	2	0	0	14,000	.02
	Total	4	0	0	19,000	.03
Total	Hydro	9	22,700	1.76	223,280	.27
	Steam	26	1,266,250	98.24	81,151,325	99.73
	Total	35	1,288,950	100.00	81,374,605	100.00

Figure 1.6-3[61]

MAJOR SOURCES OF JAPANESE ELECTRICITY GENERATION

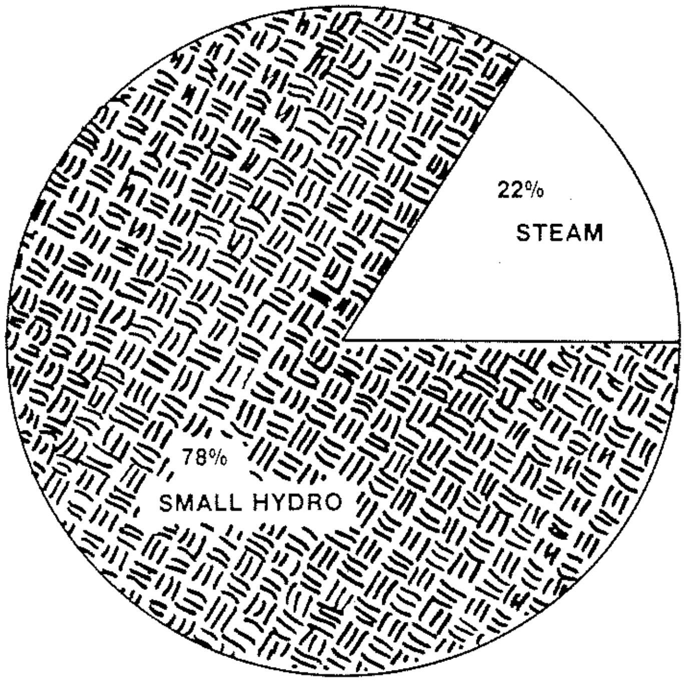
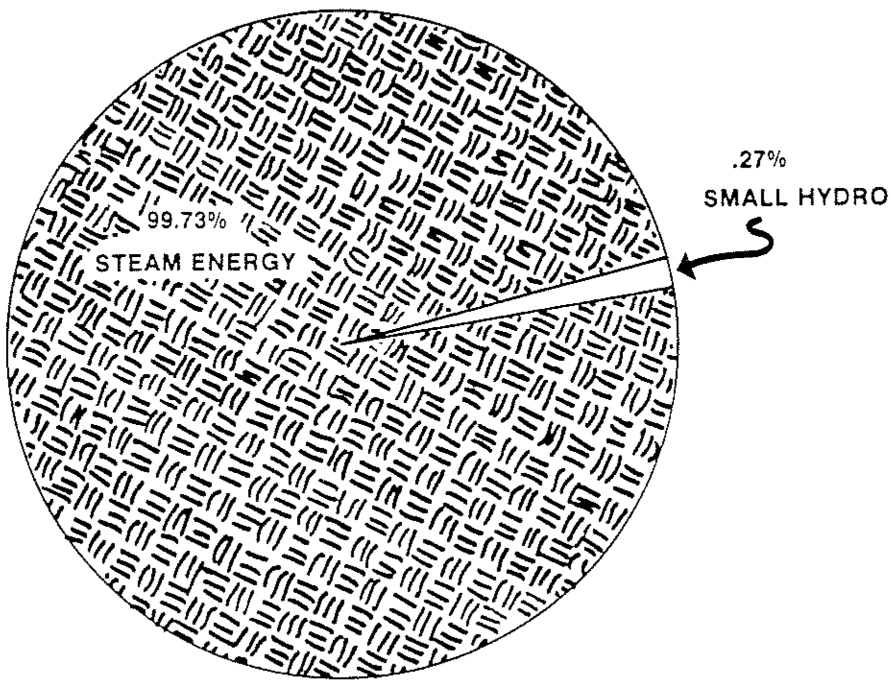


Figure 1.6-4[62]

PERCENT AIR RAID DAMAGE TO JAPANESE
SMALL HYDRO AND STEAM ELECTRICITY PRODUCTION



In 1944, the total generating capacity on the home islands was 10,120,000 kilowatts (10,120 MW). Generation in the peak war year, 1943, was 38.4 billion kilowatt-hours from all sources including utility, railway and industrial facilities. Water power from small hydro plants provided 78 percent of the total electricity in the system, with the remainder of use supplied by steam plants (mostly antiquated coal plants). During the war the largest hydroelectric plant in Japan was 165 MW plant on the Shinanogawa River. This plant supplied only 2.7 percent of annual electrical consumption.[59]

Japan was never able to increase the overall level of electrical system expansion during the war. However, the U.S. electrical war economy grew at an annual rate of 33 percent (compared to the Japanese electrical system growth of only three percent per year). The Strategic Bombing Survey points out that "Japan could, with relative ease, have increased her production of kilowatt hours over the 1943 level—so far as the capability of her predominantly water-driven generation system was concerned."[63] However, supplies of necessary materials were diverted to war effort, rather than increasing the size of the electrical system.

In its formal conclusions, the Allied Bombing Survey stated:

> Most of the power requirements of Japan, however, come from hydro generating plants, which are so numerous, small and inaccessible that their destruction would be impractical, if not impossible. If their supply could be eliminated or drastically curtailed by some other means, electric power supply could be reduced to a point where the shortage would assume economic importance. It has been shown that neither the transmission nor the distribution system is, of itself, vulnerable."[64]

<u>Vulnerability of Facilities Since World War II (1.6-4)</u>

Since World War II, power plants and electrical facilities have become prime targets.* During the Korean war, the United States made an early decision not to bomb large hydroelectric dams along the Yalu River, but reversed the decision two years later in 1952. As Bennett Ramberg points out, "the decision was reversed...when negotiations deadlocked and destruction of the plants seemed necessary to hasten the war's conclusion and to make more difficult the repair work the Communists were doing in small industrial establishments and railway tunnels."[65]

During the Vietnam war, the United States destroyed some electrical facilities, but this was never a major strategic commitment. As with Japan during World

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* In the early days of the Cold War, during the Berlin crisis (1948-49), the "Joint Outline War Plan," recently declassified by the U.S., called for a potential bomber strike against the Soviet Union with 150 neclear weapons. Code named "Trojan," the plan's top priority was elimination of Soviet refineries, especially those producing aviation fuel, with the objective of eliminating fueling of the Soviet Armed Forces.[66]

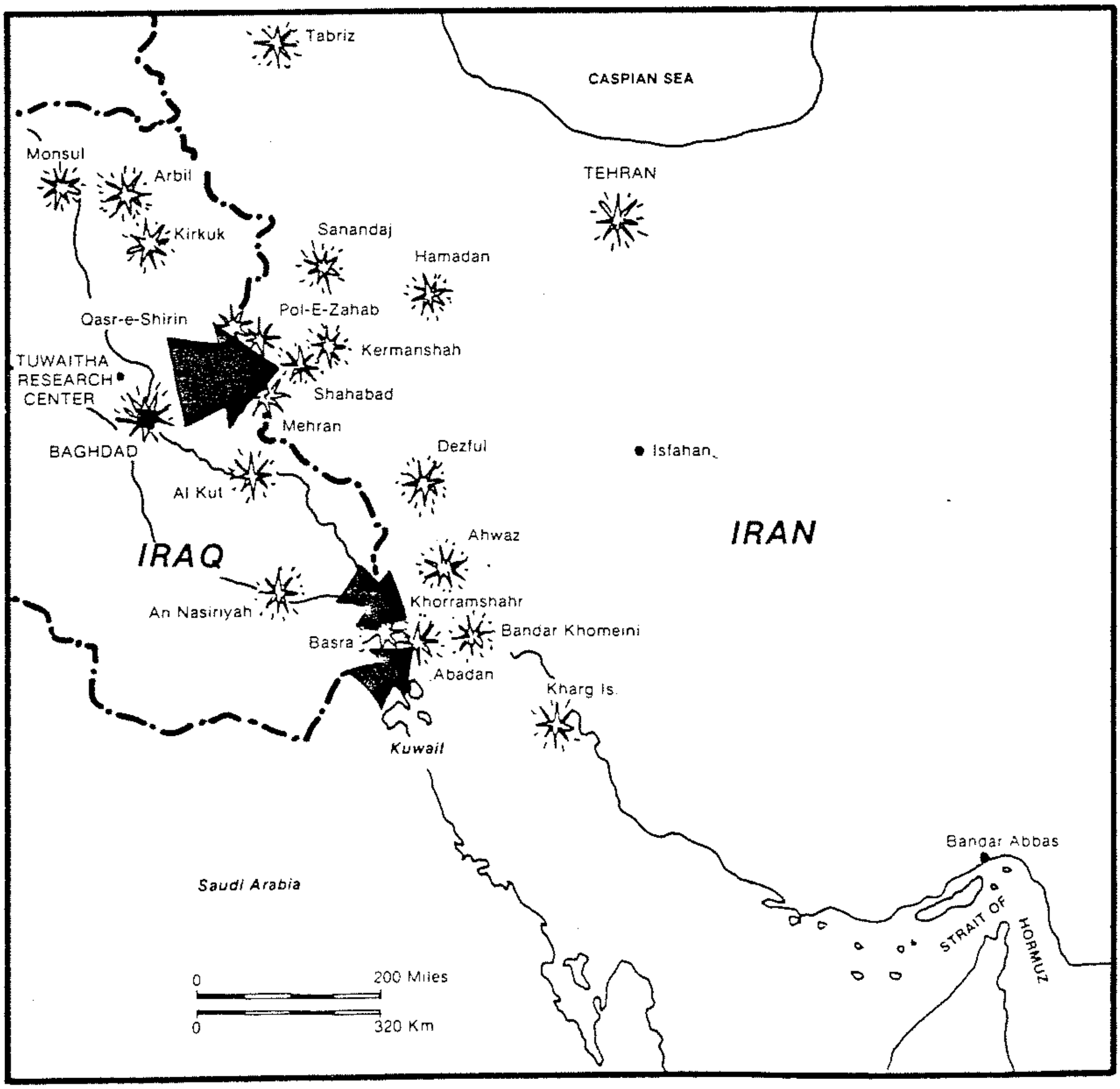
War II, most power plants in Vietnam were too small and scattered to be primary targets. Decentralization of the electrical system preserved substantial capacity.

In the Middle East, during the 1973 war, Israeli warplanes bombed power stations at Damascus and Homs, Syria, "to subdue Syrian military activity and to deter other countries from entering the conflict."[67]

Power plants and oil refineries have been targeted, most recently during the 1980 war between Iran and Iraq. The Abadan oil refinery complex at Kharg Island was bombed. This lesson in vulnerability affects the entire industrial world, as critical oil supplies must pass through the narrow Straits of Hormuz currently threatened by military actions.

Figure 1.6-5[68]

THE EXTENT OF THE FIGHTING



In fact, the Persian Gulf war may prove to be a threatening indicator to the future, as most primary energy targets, ranging from refineries to key oil fields to the Iraqi nuclear research center, Tuwaitha, were selected for bombing forays. The September 30, 1980 attack on the French-built Osirak and Isis research reactors of the Tuwaitha facility raised the spectre of radioactive fallout from conventional bombing. Although officials of the Nuclear Regulatory Commission contend "that there (is) very little risk that bombing a research reactor would ever cause a significant fallout problem" a worst-case scenario allows for radioactive pollution to spread at least a mile or two from the reactor.[69]

"Bombs, presumably delivered by Iranian pilots, hit the research site about ten miles from the center of Baghdad. They damaged an auxiliary building and forced the French technicians working on the project to leave. The attack did not damage the reactors, but it did shut the program down indefinitely."[70]

The only missing element in this Middle East duel was the presence of nuclear-tipped warheads.