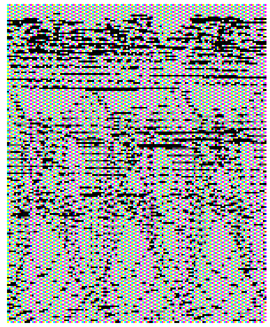

Strategic Attack of National Electrical Systems

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Abstract

The United States Air Force has long favored attacking electrical power systems. Electric power has been considered a critical target in every war since World War II, and will likely be nominated in the future. Despite the frequency of attacks on this target system there has also been recurring failure in understanding how power is used in a nation. In addition, air planners tend to become enamored with the vulnerability of electric power to air strikes, but analysis of the cause and effect relationships indicates that attacking electrical power does not achieve the stated objectives in terms of winning the war. Historically, there have been four basic strategies behind attacks on national electrical systems: to cause a decline in civilian morale; to inflict costs on the political leaders to induce a change; to hamper military operations; and to hinder war production. The evidence shows that the only sound reason for attacking electrical power is to effect the production of war material in a war of attrition against a self-supporting nation-state without outside assistance. The implication for future strategic air operations is important. Because attacks on electric power cause indirect collateral damage which can be politically counterproductive, and the military benefit is minimal, the United States should reject attacks on national electrical power systems in the near future.

About the Author

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Chapter 1

Introduction

Electrical systems have been a favorite target of air power since the Air Corps Tactical School (ACTS) first considered this target system in the 1930s. It has been designated as a critical target in every war since then, and will likely be nominated for attack in future air campaigns.[1] Nevertheless, there has been little thought given to understanding the conditions that determine when these attacks will be successful in obtaining the political objectives of any given application. Much of the time attacks on this system are advocated more out of institutional inertia than clear strategic thinking. In addition, there have been recurring failures in the understanding of electrical systems and how an enemy reacts to attacks on this system. If the Air Force is to believe in the utility of attacking electrical power, then some effort must be made to define the conditions for attacking and for predicting the effects of such attacks.

It is not surprising that targeting electrical power has not been closely analyzed, since there has been little thought given to the topic of conventional strategic attack in general, with only minimal debate about what targets should be attacked and why.[2] It is important to provide an intellectual foundation for strategic planning because interest in the idea of conventional strategic bombing as a tool for US policymakers has been revived by a number of recent events, including the increasing number of crisis situations in a multipolar world; the growing sophistication of weapons which makes the blunt instrument of military force more precise; and the belief that a strategic air attack will be able to enforce political demands without committing large numbers of ground forces with its concomitant domestic political problems.[3]

The conventional wisdom about targeting electric power holds that such attacks have wide ranging effects on a variety of institutions. Two political effects believed to result from the loss of electricity are, first, that it will diminish civilian morale, thereby forcing a change in the government's behavior, and second, that these attacks will raise the costs to the political leaders of a country pressuring them to change. Likewise there are two important military effects usually mentioned: either that the loss of power will have a direct impact on the fighting military forces or that it will cause a reduction in war production. These four arguments, either separately or in combination, have been used in the past to advocate attacking national electric systems.

My analysis shows that none of these arguments is sound. Attacks on electric power to reduce civilian morale have not been effective in changing political behavior. Attempts to influence governments through increasing costs by targeting national electrical systems have also been ineffectual because leaders of most regimes generally embark on actions with high resolve, and thus are unwilling to change their policies simply as a result of losing electric power. Moreover, political leaders and military forces are prepared for such contingencies, and are therefore well insulated from the loss of the national power grid and able to continue functioning. In contrast, attacking electrical power can be effective in slowing the production of war material, and in a prolonged war against a self-sufficient nation attacking electrical power would be prudent. Given the current limited nature of war against small powers, however, it does not appear that war production will be a factor in the near future. In addition, there are several drawbacks to attacking electricity, including the impact in terms of deaths and disease on the civilian population, and the potential negative international censure that could result from such actions. Because of current political and military conditions, the military benefit gained from attacks are minimal in contrast to their potential to be politically counterproductive.

To assess the effectiveness of electrical power targeting, I concentrate on how national electric grids work and the historical record of the effects produced by destroying electric power in past wars, I then seek to establish the effects of electrical power targeting with precision. This single target approach allows a detailed examination of the historical precedents over a wide range of conditions to discover if the findings are consistent and likely to occur in future cases. It also highlights areas of recurring failure in target selection. Finally, studying target systems in isolation allows a more detailed discussion of the system that would not be possible in a broader study of strategic targeting in general. [4]

Critics may object that isolating one system does not take into account the possible synergistic benefits that result from an attack on several systems in concert. Although this study concentrates on one system, in fact the historical data supporting the attacks has been evaluated synergistically. For example, in assessing the attacks on the North Vietnamese national power system there is no evidence to suggest that these attacks affected the air defense system, strained their logistics capability by increased petroleum demand for generators, or reduced their capacity to import goods. Moreover, spotlighting electrical power should exaggerate its effects because the ability of other systems to compensate for the loss is not considered. For instance, an attempt to hinder the air defense system of a country through the targeting of electric power to stop the air defense radars from working would not take into account the ability of the nation to compensate for the loss by launching more air defense aircraft.

This paper is arranged in three parts. The first identifies how a national electrical system operates and the potential effects of a large power interruption. The second part reviews historical United States Air Force thinking about the benefits of attacking electrical power systems. This review covers attacks in total war, which includes the theoretical teachings of the ACTS faculty and the strategic planning for World War II, as well as attacks in limited wars, including Korea, Vietnam, and Iraq.[5] The last part highlights recurring failures in attacking this system, proposes the conditions for attack, and the implications of these attacks in the current environment.

Notes

1. The most recent example may be George Kenney and Michael J. Dugan, "Operation Balkan Storm: Here's a Plan," *New York Times*, Monday, 30 November 1992.

2. In many circles, including the US Air Force, since 1945 the terms *nuclear* and *strategic* have become, regrettably, synonymous, see Phillip S. Meilinger, "The Problem with Our Air Power Doctrine," *Airpower Journal* 6, no. 1 (Spring 1992): 27–29.

3. See for examples of these points: Joseph F. Pilat and Paul C. White, "Technology and Strategy in a Changing World," and Thomas J. Welch, "Technology Change and Security," *Washington Quarterly* 13, no. 2 (Spring 1990): 79–91 and 111–120; T. Ross Milton, "Strategic Airpower: Retrospect and Prospect," and Dennis M. Drew, "The Airpower Imperative: Hard Truths for an Uncertain World," in *Strategic Review* 19, no. 2 (Spring 1991): 7–15 and 24–31; Jacquelyn K. Davis, "Technology and Strategy: Lessons and Issues for the 1990s," *Annals of the American Academy of Political and Social Science* 517 (September 1991): 203–16; Leon Sloss, "U.S. Strategic Forces After the Cold War: Policies and Strategies," and Barry D. Watts, "The Conventional Utility of Strategic-Nuclear Forces," in *Washington Quarterly* 14, no. 4 (Autumn 1991): 145–56 and 173–210; Frank Kendall, "Exploiting the Military Technical Revolution: A Concept for Joint Warfare," *Strategic Review* 20, no. 2 (Spring 1992): 23–30; Patrick J. Garrity and Sharon K. Weiner, "U.S. Defense Strategy After the Cold War," *Washington Quarterly* 15, no. 2 (Spring 1992): 59–76; and Richard H. Shultz, Jr., "Compellence and the Role of Airpower as a Political Instrument," *Comparative Strategy* 11, no. 1 (January–March 1992): 15–27.

4. I concentrate on the strategy involved in the targeting of national electric power systems and do not discuss delivery systems or munitions.

5. Although this paper will concentrate on the American targeting of electric power it has also been advocated for attack by other air forces. Like their US counterparts, the Royal Air Force also professed a doctrine of precision strategic bombing and early in World War II advocated attacks on the German power system, especially the hydroelectric dams in the Ruhr area. See Sir Charles Webster and Noble Frankland, *The Strategic Air Offensive Against Germany 1939–1945* (London: Her Majesty's Stationery Office, 1961), 98–99, 141–42, 461–62. The German Luftwaffe also considered attacks on electric power. During the invasion of Poland in 1939, they bombed electrical power stations in Warsaw to help speed the surrender of that city. Paul Deichmann, *The System of Target Selection Applied by the German Air Force in World War II* (Karlsruhe, Germany: 1956), 247–51, United States Air Force Historical Research Agency (hereafter cited as HRA) file K113.107-186. In June 1943 the Luftwaffe General Staff began planning an operation designed to attack the concentrated Soviet power plants used to supply the factories in the Ural mountains. Their efforts were stymied by a lack of long-range bombers, inadequate munitions, and infighting within the Luftwaffe. Before the attack could be undertaken the Red Army overran the bomber bases, putting the electrical power plants out of range for any attack. See Richard Muller, *The German Air War in Russia* (Baltimore, Md.: The Nautical & Aviation Publishing Co. of America, 1992), 162–200, 217–18. During the Iran-Iraq war both sides attempted strategic bombing, and although there were attacks on power plants, there does not appear to have been any systematic attempt to eliminate power production. See Efraim Karsh, *The Iran-Iraq War: A Military Analysis* (London: The International Institute for Strategic Studies, 1987); and Ronald E. Bergquist, *The Role of Airpower in the Iran-Iraq War* (Maxwell AFB, Ala.: Air University Press, 1988).

Chapter 2

National Electrical Power Systems

Though electrical power systems may be organized differently from country to country, the basic technical requirements for generating electricity are the same, making it possible to discuss, in general terms, the basic components of an electrical power system and the effects of an attack.[1] A generic electrical power system is composed of four separate subsystems: generation, transmission, distribution, and control. An understanding of how each of these works offers some insight into determining the vulnerability of the system, and highlights the benefits and drawbacks in attacking each part.

Generation

The generation subsystem is the heart, or source, of the electrical system and consists of the turbines and generators which produce electricity. In crude terms, bulk electricity is produced by applying force to the blades of a turbine which then causes an associated generator to rotate, producing electricity.[2] These turbines and generators constitute what is commonly called a power plant, which can be characterized by the method in which the turbine is turned. A steam, or thermal plant burns a fossil fuel, primarily coal or oil, to generate heat and produce steam which then moves the turbine blades. A nuclear power plant is nothing more than a variation of a steam plant which uses nuclear energy to produce the steam.[3] A hydroelectric plant uses the water stored behind a dam as its source of power for moving the turbine blades. Typically the turbine and generator are in the same building and in some cases may even be a single unit.

Power can be interrupted at the source in several ways. For a steam plant burning either oil or coal, the fuel can be interdicted while being transported to the plant. Attacking electrical power in this manner, however, would be a long-term process and the results, in terms of a loss in power, might not be felt for some time. This delay is due to the large amount of fuel normally stored at the plants and the number of targets such as trucks, railcars, or barges involved in supplying fuel to the plants.[4] As an example, one large electric company in Japan during World War II had the capacity to store 2,100,000 tons of coal. Although the exact length of time this supply would last depended on fuel consumption, under 1942 conditions this was a six-month supply.[5] Although attacking the national electrical system in this manner might eventually result in the loss of power, there are more direct ways to achieve this outcome.

The most immediate method for cutting off electricity in the generation phase would be to attack the buildings that contain the turbines and generators. Both of these machines make excellent potential targets because they are delicately balanced and rotate at high rates of speed[6] making them susceptible to damage from air attack. However, because the generator halls are generally of sturdy construction, they can shield these sensitive components from both damage and postattack assessment. An attack on a hydroelectric plant would be similar to a conventional steam plant if the goal was the destruction of the turbine or the generators; the bombing would be concentrated on the generator hall. However, the "fuel" for a hydroelectrical plant is the water stored behind the dam. Stopping this fuel would involve an attack on the dam or the penstocks, which are the tubes used to take water from storage to the turbine. An obvious drawback to this method of attack would be the effects involved with the breaching of the dam. The subsequent flooding would create political and public opinion difficulties that would diminish any potential benefit. Likewise, due to its proximity to the dam, bombing a hydroelectric generator demands careful consideration because of the possibility of damaging the dam.

There are similar difficulties in attacking nuclear power facilities.[7] While nuclear power is fundamentally the same as a conventional steam power plant in terms of powering turbines, it presents a new and growing problem for air targeting. In 1984 nuclear power supplied roughly 13 percent of the world's electrical production, and most analysts predict that it will supply about 20 percent of the world's electrical power by the end of this decade.[8] This growth in nuclear power increases the likelihood that this type of power plant may be part of a targeted electrical system. Interdicting the fuel supply for a nuclear power plant would be difficult since only small amounts of fissionable material are used to fuel a plant. Theoretically, attacking the turbines and generators would be no different than any other power plant; however, as mentioned above, given the close proximity of the generator hall and the nuclear reactor, this type of attack could create a nuclear incident that in a conventional, limited war would exceed the possible benefits of attacking this plant.

Attacking the generation portion of an electrical system is attractive for several reasons. First, it eliminates the power at the source, spreading the impact of electrical outages to a large number of users. Second, the generators and turbines are vulnerable to damage by bombing and are not easily replaced as spare units are not readily available. Destroying or heavily damaging these components will result in the long-term loss of power because the plant will be out of service for sometime.[9] When power is interrupted in the generation phase it can only be restored by repairing the damaged equipment or importing power from another plant. Finally, these units are expensive and represent a large capital investment for any country; if they are destroyed, this raises the cost to a nation for continuing the war.

Transmission

If it is not feasible or prudent to attack the generation portion of the electrical system (as in the case of nuclear power) it is usually possible to attack the transmission subsystem.[10] After electricity is generated it is sent to a step-up transformer located in the substation or transformer yard close to the power plant. Here the voltage on the generated power is raised (or stepped up) to a higher voltage for transmission, and sent along high voltage power lines to the various users.[11] The transmission system terminates at a transformer yard (substation) on the outskirts of a city, or other load center such as a large factory or military installation, where the voltage is reduced, or stepped down, and the electricity sent through the distribution network for use by the various consumers (fig. 1).[12]

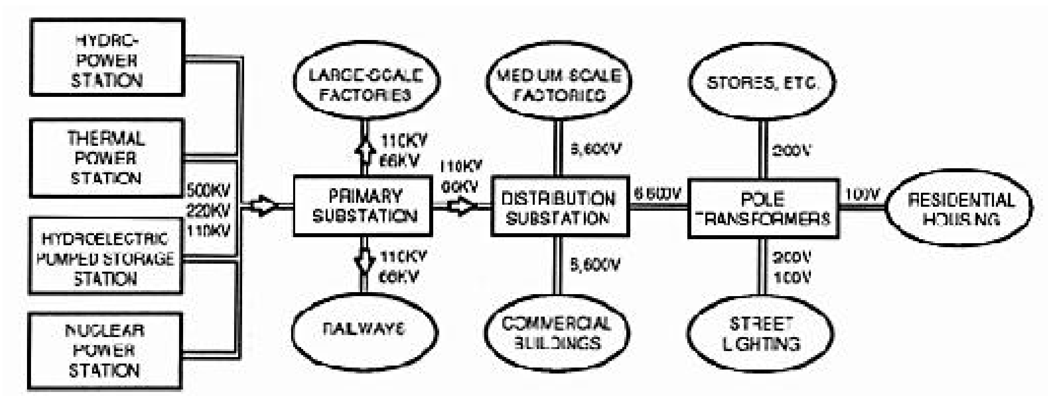


Figure 1. The Transmission System

While the primary purpose of the transmission system is to deliver power from the generators to the distribution networks, it is also the means by which generating facilities are interconnected. These interconnections allow for the economic exchange of power and, most importantly, improve the reliability of the entire power system by providing a means to transfer power from one area to another in an emergency.[13]

In the transmission subsystem the step-up transformers are the most lucrative targets. According to a study by the Office of Technology Assessment (OTA), the step-up transformers offer the "most serious combination of vulnerability and potential consequences."[14] The transformers' vulnerability stems from the fact that they are generally in open areas and are easily identifiable by the power lines converging in the transformer yard. Another advantage to attacking the step-up transformers is that they are not easily interchangeable between systems. The requirements for these transformers are unique because of the different voltages and physical arrangements of power plants, and as a consequence the transformers are generally custom-made and there is not usually a large reserve available.[15]

In terms of consequences, attacking step-up transformers is equivalent to attacking the generation facility. The power is still at its source and the effects will be felt over a wide area. Another advantage in attacking the transformers is that it interrupts the transmission network and can disconnect one system from another, which in turn reduces the capability of the interconnected network to import power from other areas and provide emergency power.[16]

While the results of an attack on the step-up transformers are similar to an attack on the generation facility, the long term consequences are slightly less severe. Despite the difficulty of finding replacement transformers, they are easier to repair or replace than a turbine or generator allowing a quicker restoration of power.[17] In addition, because power can still be generated, it is sometimes possible to bypass the destroyed transformers which then allows the electricity to flow.[18]

Once electric power leaves the step-up transformer facility and begins its movement to the distribution network its viability as a potential air target decreases dramatically. The transmission lines are difficult targets to damage through air attack; the only portion that can be damaged through conventional bombing are the pylons which support the wires. Unless this is done in large numbers, the wires can be replaced and power quickly restored.[19]

Distribution

The distribution network begins at the step-down transformer station that reduces the voltage used in transmission to a lower voltage suitable for dissemination to the various users.[20] Like the transmission lines, the distribution system is not normally an attractive target for air attack. Step-down transformer stations are smaller and more difficult to attack than the step-up transformer facilities at the power plants. In addition, there are numerous distribution systems supplied from one main power source. This allows the transformers to be more standardized and interchangeable making repairs or replacement easier.[21] Finally, an attack on a distribution system will have only a localized impact. While this may be beneficial in certain cases, where a localized outage is desired, generally there will be too many distribution networks to make this type of air attack worthwhile for the wholesale elimination of electric power.

Control

While the large number of targets and the localized effects of an attack on the distribution network argue in favor of attacking the source of power production, the integrated nature of an electrical system presents the most compelling argument. Most power systems are interconnected and this network, more commonly called the electrical grid, allows the transfer of power to serve as the emergency power supply for an area.[22] While this interconnection is physically accomplished through the transmission subsystem it is the control network which coordinates the interchange of power.[23]

Control systems are perhaps the most variable part of a power system. Control systems may be automated by computers or rely on manual operations for transferring power. Another difference is the disposition of the control systems. In some areas there may be one control center contained in one of the power stations, capable of controlling power throughout the system and accessing other systems.[24] In another area the control center may be physically separated from the generating facility but still capable of controlling the system.[25] As a result of this integration, extensive knowledge is required about how the national grid works, and how much of the total power capacity of a country is interconnected.

North America offers a good example of how power systems are interconnected for reliability. There are approximately 3,500 utilities in the United States and Canada which are organized into 150 control areas and four large geographic regions called "interconnections."[26] A control area defines a region served by an electrical power source that can regulate its own generation and exchange power with other systems.[27] The interconnections, on the other hand, are the basis of the emergency power supply system because each utility in the entire region can furnish power to any other.[28] The ability of the control subsystem to transfer electricity makes it necessary to attack a majority of the power system to prevent power from being transferred from areas that have not been attacked.

While an obvious advantage of a tightly interconnected system is the ability to transfer power from one area to another, the potential for a cascading failure presents a major disadvantage. Cascading failures can occur when there is little reserve power available and several large elements (power plants or step-up transformers) of an electrical system are attacked simultaneously. According to the OTA report, the failure of these components can lead to "the overloading and failure of other equipment and [the] breakup of the system into islands [of power] in an uncontrolled fashion."[29] While cascading failures are impossible to predict the results of such an event would far outweigh the effort involved in the actual attack.[30]

The results of an attack that concentrates on the control system are difficult to forecast. If the system cannot generate or transfer power then it is a moot point because there would be nothing to control. However, if there still was power available an operator in a control system could overcome partial failures and supply power to the priority customers by employing various measures, such as engaging the resident operating reserve, importing emergency power, reducing voltage to interruptible consumers, and finally reducing power to other users.[31] This ability to transfer power makes knowledge about the interconnections in a power system essential to forecasting the results of any attack.

Effects

Judging the impact of attacks on electric power is the most difficult aspect of evaluating the military effectiveness of this type of attack. While it is possible to measure how many planes attacked the target, the tonnage of bombs dropped, and even the results of the raid in terms of destruction to the physical structure attacked, it is more difficult to determine the actual impact of the raid on the opposing nation.

The effects of attacks on power systems can be divided into two broad categories: military and civilian. Military effects are defined as the impact of the loss of electricity on purely military operations, such as the loss of communications capability or the inability to employ air defense radar equipment. The civilian effects would include the impact of the loss of power on the social, political, and economic sectors of a nation. Clearly there is some overlap between these two areas but, in general terms, the loss of electricity impacts the civilian sector more immediately and more pervasively than the military.

The military is relatively unaffected by a loss of power for three reasons. The first is that, relatively speaking, the military consumes very little of a nation's electricity. In the United States, for example, the entire Department of Defense consumes only about 1 percent of the electricity, and much of that is for peripheral functions such as heating and air conditioning.[32] The amount that is consumed for essential functions such as communications, or computing is a fraction of the total. Although the military consumes only a small amount of power, generally they are a high priority user, meaning that if any power is available in the national grid, the military will likely be able to acquire it.[33]

Even if it were possible to eliminate a country's power system, only a portion of the military would be affected. This is because most ground tactical units (division or below) rely on their own organic sources of power.[34] As a result, the areas of the military most affected would be fixed installations, such as air bases, naval ports, or theater headquarters. However, because these sites are vulnerable to power interruptions, they are likely to be supplied with emergency power equipment such as generators. These units can be as large as 1,500 kilowatts and can be run for long periods of time with the proper maintenance. In both the Korean and Vietnam wars, American forces relied almost entirely on generators because the host nation's electrical system could not supply the power necessary. The South Korean system was limited and the supply of power was undependable. As a result, all the air bases had emergency power systems, and one base generated all of its own electricity.[35] In South Vietnam, US forces found two problems with the national system. The first was that the South's commercial power used 50 cycles, whereas most American equipment was designed to use 60-cycle power. Second, when American forces started arriving in large numbers in late 1965, and early 1966, the demand for power quickly outstripped the supply and most American fixed facilities used their own generating facilities for power production.[36] Even during Desert Storm, staged mostly from a country with a sophisticated national power system, there was, nevertheless, a need to supply auxiliary power for US forces.[37]

The combination of the small consumption of the national production of electricity by the military, the high priority for any power that is available, and the extensive use of emergency power systems, means that there is little overall effect on military operations due to the loss of the national power grid. If a nation chooses to rely on a national power system for daily military operations, there may be some initial confusion as the change to emergency power is made, but the long-term effects are more likely to be a result of a loss of war production than a direct impact on operations.

While the military is largely insulated from a loss of power, the civilian population is heavily affected. Although there is little statistical quantification of the civilian effects from the loss of power, some anecdotal evidence has been gathered from various power outages.[38] Based on these observations we can predict that the loss of electricity will likely cause the following civilian effects:

Transportation—Trains, subways, street lights, and air traffic will all be slowed or stopped.

Emergency services—Hospitals will be forced to use backup power. Police and fire department responses will be longer.

Public utilities—Water, gas, and sewer services will be interrupted, eventually causing health problems.

Industrial—Manufacturing will largely stop until power is restored (unless the plant has its own generating facility). In addition, losses may occur in sensitive processes such as steel manufacturing because of the sudden loss of power.

Computers and Telecommunications—The loss of power will interrupt computer operations and may result in the loss of data or other damage. Depending on the availability of emergency power, telecommunications will also be affected.[39]

While these general effects offer some indication of the impact involved with a loss of power, the precise impact will depend, to a large degree, on the country under attack, making it difficult to quantify or predict the exact civilian effect of an attack on electrical power in advance.

Overall, a national power system is exceedingly vulnerable to air attack and interruption. The generators and turbines spin at high rates of speed and are susceptible to damage from bombing. The transformer yards are in open areas and easy to find. In addition, spare parts for generators and transformers are not readily available because of the expense and custom-manufacturing required. The control system can mitigate against the damage caused by air attack by providing a means to transferring power. In short, the generation, transmission, distribution, and control subsystems each have benefits and drawbacks that must be balanced in light of both the political and military objectives of a campaign. The tendency, however, when discussing power systems is for the military planner to become enamored with this vulnerability without asking the more fundamental question: "Why are these attacks being proposed?" The next sections highlight the historical reasons why electric power has been attacked and the effects of these attacks.

Notes

1. Laura Gosline, Defense Intelligence Agency Analyst, interview with author, DIA Headquarters, 9 February 1993.

2. Burr W. Leyson, *The Miracle of Light and Power* (New York: E. P. Dutton & Co., Inc., 1955), 28–42; and Robert H. Miller, *Power System Operation*, 2d ed. (New York: McGraw-Hill, 1983), 14.

3. Donald G. Fink and H. Wayne Beaty, eds., *Standard Handbook for Electrical Engineers*, 12th ed. (New York: McGraw-Hill, Inc., 1987), 12-4, 5.

4. Leyson, 27–29.

5. United States Strategic Bombing Survey (USSBS)(Pacific), *The Electric Power Industry of Japan* (Washington, D.C.: Government Printing Office [GPO], May 1947), 16.

6. Leyson, 39–40.

7. Because dams and nuclear power plants contain what are termed *dangerous forces* the issue of attacking these targets is complicated by international law constraints. Article 56 of the 1977 Protocol I Addition to the Geneva conventions of 12 August 1949 lists the criteria involved with attacking these targets. Although the United States is not a signatory to this document, such guidance could affect future air attacks, see W. Hays Parks, "Air War and the Law of War," *Air Force Law Review* 32, no. 1 (1990): 202–18. Official Air Force guidance states that "target selection of such objects [dams and nuclear power plants] is accordingly a matter of national decision at appropriate high policy levels." See Air Force Pamphlet (AFP) 110-31, *International Law—The Conduct of Armed Conflict and Air Operations*, 19 November 1976, 5–11.

8. Peter R. Mounfield, *World Nuclear Power* (London: Routledge, 1991), 28; and Joseph A. Yager, *International Cooperation in Nuclear Energy* (Washington, D.C.: Brookings Institution, 1981), 9–11, 22.

9. A postwar analysis of the damage suffered by the German electrical system in World War II showed that if over 50 percent of the generating capacity of a plant were destroyed, it would result in the plant being out of service substantially longer than one with slightly less damage. The study also noted, however, that even with physical damage held constant the recuperation of a plant depended on many factors including the availability of spare parts; morale of the workers; and the number of trained repairmen. See Carl F. Kossack, *A Study of Capacity Loss: Electric Power Generating Stations* (Lafayette, Ind.: Purdue University, 1956), 3–5, 26.

10. The generation and transmission subsystems are often referred to as bulk electrical systems, or bulk power systems.

11. Richard L. Bean et al., *Transformers for the Electric Power Industry* (New York: McGraw-Hill Book Co., Inc., 1959), 8; Miller, 13, 143; and Fink and Beaty, 14-3. Electrical energy is transmitted at voltages ranging from 60,000 to 500,000 volts or more.

12. US Congress, Office of Technology Assessment, *Physical Vulnerability of Electric Systems to Natural Disasters and Sabotage*, OTA-E-453 (Washington, D.C.: Government Printing Office, June 1990), 4 (hereafter cited as OTA Report).

13. *Electricity Transfers and Reliability* (Princeton, N.J.: North American Electric Reliability Council, October 1989), 8.

14. OTA Report, 47.

15. OTA Report, 5. This report also notes that transporting the very large transformers is difficult because they must be moved on special railcars called Schanbel cars and currently there are only thirteen of these cars in the US and one in Canada, 55. While this may not be

predictive of the difficulty in other areas of the world in transporting transformers, it does reflect on the problems involved in repairing an electric system.

16. Theodore C. Perry, executive director, Planning, Allegheny Power System, telephone interview with author, 8 April 1993.

17. While my report concentrates on the consequences of conventional bombing there are now methods of attack available to interrupt power without destroying any transformers. One example is the use of carbon fibers reportedly used in Desert Storm, see David A. Fulghum, "Secret Carbon-Fiber Warheads Blinded Iraqi Air Defenses," *Aviation Week & Space Technology*, 27 April 1992, 18–20.

18. Herman L. Gilster and Robert E. M. Frady, *Linebacker II USAF Bombing Survey* (Headquarters Pacific Air Forces: April 1973), 12.

19. OTA Report, 31–33. Interestingly, during World War II the Luftwaffe decided that the transmission network was the most logical place to attack electric power. They developed a bomb, which carried a cable that, when dropped over power lines would produce a short circuit. This short circuit would result in a fire that would then cause the transmission poles to collapse. This "cable bomb" or "wire bomb" which was formally named the "S Bo 53" was never employed in combat because of the high risks involved with dropping it from low altitude. Paul Deichmann, *The System of Target Selection Applied by the German Air Force in World War II* (Karlsruhe, Germany: 1956), 247–251, USAF Historical Researech Agency (HRA) file K113.107-186; Richard Muller, *The German Air War in Russia* (Baltimore, Md.: The Nautical & Aviation Publishing Co. of America, 1992), 185; and Paul Deichmann, *Luftwaffe Methods in the Selection of Offensive Weapons*, USAF Historical Study 187 (Manhattan, Kans.: MA/AH Publishing, n.d.), 64–67.

20. Fink and Beaty, 18-2.

21. Ibid., 10-52, 53.

22. Ibid., 16-3-5.

23. Leyson, 47; and *Electricity Transfers*, 25–27.

24. Leyson, 45; and Fink and Beaty, 16-8.

25. Dominion Resources, Inc., *Annual Report 1992* (Richmond, Va.: 1992), 8. This report notes that Virginia Power, a subsidiary of Dominion Resources, which supplies power to eastern Virginia and northeastern North Carolina recently moved their control center from corporate headquarters in downtown Richmond to an industrial park in a Richmond suburb. In neither location was the control center located within a power plant.

26. *Power in Balance* (Princeton, N.J.: North American Electric Reliability Council, n.d.).

27. *Electricity Transfers*, 39.

28. Ibid., 22.

29. OTA Report, 33–34.

30. Ibid.

31. *Electricity Transfers*, 26.

32. Energy Information Administration, *Annual Energy Review 1991* (Washington, D.C.: US Department of Energy, June 1992), 14–14, 30–31, 206–207. According to this source the total amount of electricity consumed in the United States by end users was 9.41 quadrillion Btu. Using a standard conversion factor of 3,412 Btu per kilowatt-hour this equates to 2.8 trillion kilowatt-hours. DOD use was given as 120.6 trillion Btu or 3.5 billion kilowatt-hours, approximately 1.3 percent of the total amount of electricity consumed in the country. Maj James Mandziara, Material and Resource Management Policy directorate, Office of the Assistant Secretary of Defense (Production & Logistics), telephone interview with author, 4–5 May 1993.

33. Gosline interview; and Gilster and Frady, 12–14.

34. Robert R. Ploger, *U.S. Army Engineers, 1965–1970* (Washington, D.C.: Department of the Army, 1974), 194–95.

35. Headquarters Far Eastern Air Forces, "FEAF Report on the Korean War," draft, 15 February 1954, bk. 3 of 3, sec. 20, 13–14, HRA file K720.04D.

36. Ploger, 60, 194–95; John Schlight, *The War in South Vietnam: The Years of the Offensive, 1965–1968 (Washington, D.C.: Office of Air Force History, 1988), 171; and Richard*

Tregaskis, Southeast Asia: Building the Bases (Washington, D.C.: GPO, 1975), 209–10, 224, 250, 257, 284–85, 370.

37. Department of Defense, *Conduct of the Persian Gulf War: Final Report to Congress*, April 1992, 442–44. This report notes that the US Air Force maintains a bare base construction package, nicknamed Harvest Eagle, which contains its own power generation and distribution equipment. This equipment is capable of supporting 55,000 people and 750 aircraft at 14 different airfields.

38. OTA Report, 19. The impact of power interruptions in this report are largely from the 1965 Northeast and 1977 New York City blackouts.

39. OTA Report, 23–29.

Chapter 3

Electrical Power Targeting in the Past

Attacks in Total War

The first conceptual work in identifying specific strategic bombing targets in general, and electric power in particular, was done during the 1930s at the service school for airmen, the Air Corps Tactical School (ACTS). While the ideas developed at the school were not official doctrine in terms of being supported by the Army hierarchy and written into regulations, these concepts were the bedrock upon which the World War II strategic bombing campaigns were first designed.[1]

The bomber advocates at ACTS used meticulous logic in explaining how strategic bombardment could win wars through the attack of specific targets. This group, which included such future Air Force leaders and commanders as Harold George, Kenneth Walker, Donald Wilson, Haywood Hansell, Laurence Kuter, and Muir Fairchild, began their thinking with the premise that the will or morale of a country, and not the destruction of the field forces, was the true objective in war. This assumption was based in large part on the perception that Germany was defeated in World War I because the German people lost the will to continue the war, not because the army had been defeated.[2] Thus, the disintegration of the nation's civilian morale was the true objective in war.[3] Presumably, according to these instructors, if German morale could have been attacked in 1914 the war would have ended then.

The quickest and most efficient way to directly attack a nation's will, they felt, was by "paralyzing its economic structure and threatening its very existence" through precision bombardment.[4] Obviously though, there were too many potential targets in an economic structure to allow even a very large air force to hit every target. The strategic bombing advocates hypothesized, however, that because a modern nation was very specialized and interdependent—an industrial web in their terms—it would be vulnerable to interruption at certain pivotal points, which could be identified through a scientific analysis of the economic system.[5] The instructors demonstrated the validity of this concept in a lecture called the "National Economic Structure" which analyzed the United States. A second study offered a more in-depth analysis of New York City. This detailed study was taught to acquaint the students with how an air planner would, according to then Maj Muir S. Fairchild, "select the vital points, get some idea of their vulnerability to air attack, and estimate the effects that might be expected."[6] One of the targets most frequently cited for destruction in these lectures was the electrical power system.

Electric power was seen as a key target set in the entire industrial web theory, and in some respects, might be termed the "panacea target" of ACTS because of the promised success attacking this system would yield. An attack on electric power was attractive for several reasons: it would affect, simultaneously, the social and economic spheres of a nation; the targets were relatively easy to locate and were believed to be vulnerable to air attack; the generators and transformers were difficult to replace; and perhaps most importantly, this type of attack was economical, because a small amount of destruction would yield, in their minds, impressive results.[7] According to their calculations, 100 bombs would destroy three-quarters of the electric generating capacity in the Northeastern United States.[8] After first identifying the electric system as a potential target in 1933, the bombing theorists spent much of the rest of the decade refining their analysis of the components of the system and the effects of an attack on electric power.

By 1938, the New York City electric system was well known to these instructors, and they used a hypothetical attack on it to demonstrate the effectiveness of their theory.[9] They knew, for instance, that in the city there were 26 steam generating plants for general use, and eight steam generating plants solely for the transportation system. Although the city could be supplied by two outside sources of power in the event of disruption, these were routed through the normal generating plants for distribution. Therefore, the destruction of these plants would effectively eliminate the outside sources of power as well. Along with focusing on how to destroy the power system, the instructors also hypothesized about the effects of such an attack, especially the impact on civilians. They believed that the lack of power would stop almost any form of modern transportation—there would be no rapid transit and no elevators. Also the lack of power would cause difficulties in driving because of problems with traffic signals. Shipping would be disrupted because ships could not be unloaded at the port. Eliminating power would also cause water supply distribution problems and fire hazards.[10] The overall impact would be twofold: first, and most importantly, it would hurt the morale of the population "by making life under war conditions more intolerable to them than the acceptance of our terms of peace," and secondly, these attacks would destroy the enemy's capacity to wage war.[11] The presumed end result, though left unstated, was the immediate capitulation of the foe.

Because the ACTS instructors believed that victory in war depended on the civilian population's will to continue fighting, their target analysis emphasized civilian rather than military effects. This is evident in their justification for selecting electric power. Certainly they were aware that the results of these attacks would impact war production; however, their analysis of the attack of New York City, which highlighted the value of an attack on electric power, included no considerations about how this attack would effect war production—only manufacturing in general. For their strategy to succeed the bombing had to affect the morale of the civilian population enough to cause a change in government policy. This could be done most efficiently by collapsing the economic structure by destroying one of its linchpins—electric power.

These ideas about strategic attack developed at the Air Corps Tactical School became more than academic theories—they strongly influenced the target selection of the first air war plans for World War II. Therefore, it is no surprise to find that electric power was considered a priority target, primarily because of the potential civilian effects.

World War II— Germany

Targeting priorities during World War II underwent many changes, reflecting inputs from various boards, committees, and individuals all encumbered by their own facts, biases and assumptions about strategic targeting. As a result there is no definitive priority list for strategic bombing. Nevertheless, there are certain key targeting documents that give a sense of the relative priority of electric power in the bombing effort and provide evidence for why its priority changed. These documents include Air War Plans Division (AWPD)/1, AWPD/42, and the Combined Bomber Offensive target priority list. Each classified electric power as a potential target, but its ranking underwent a significant evolution, from one of the most important to being virtually ignored. This change in the priority of electric power not only reflected an increase in the planners' knowledge of the system, but also a shift in air strategy from the ACTS emphasis on civilian morale to one that focused on the effect of bombing on the fielded forces.

The first opportunity for air planners to present their ideas on strategic bombing outside of the Air Corps Tactical School came in 1941, when President Franklin D. Roosevelt requested that the Army and Navy submit plans for their production requirements.[12] The aircraft portion of the Army's request was formulated by the newly constituted AWPD in August 1941.[13] While this plan, christened AWPD/1, was technically only a production forecast and not an employment plan, the air planners used the opportunity to advocate their ideas on how the United States could defeat Nazi Germany through strategic bombardment.

The four primary planners for AWPD/1, Col Harold L. George, Lt Col Kenneth N. Walker, Maj Laurence S. Kuter, and Maj Haywood S. Hansell, Jr., had been students and then instructors at the ACTS. This common intellectual foundation gave them a strong belief in the efficacy of strategic bombardment and the importance of electric power as a target system.[14] They believed that victory was possible through strategic bombing by causing "the breakdown of the industrial and economic structure of Germany."[15] In order to fulfill this primary air mission, the planners selected targets that were essential to war production and to the civilian population, such as electric power, transportation and oil. Once these were struck and civilian morale began to break, they projected that area bombing of cities might be required to achieve the final capitulation.[16]

The team systematically analyzed the information available on the German electrical system to establish its value as a potential target. They found that there would be problems in attacking the system, such as destroying the hydroelectric dams, and hitting the small power and transformer stations. Countering these difficulties, however, was the vulnerability and scarcity of the electrical generating equipment. They believed that destroying 50 electrical power plants would eliminate approximately 40 percent of the German electric generating capacity.[17] They were confident that despite the small size of the targets (calculated as 500 feet by 300 feet for the entire plant) they would be easy to find in daylight and that "about 17 hits in that area will guarantee destruction of the plant."[18] Because of their belief that electric power was so important to both industry and society, they named the number one priority in AWPD/1 the "disruption of a major portion of the Electric Power System of Germany."[19] Attacking this system would be second only to what the planners called the "intermediate objective of overriding importance"—gaining air superiority.[20]

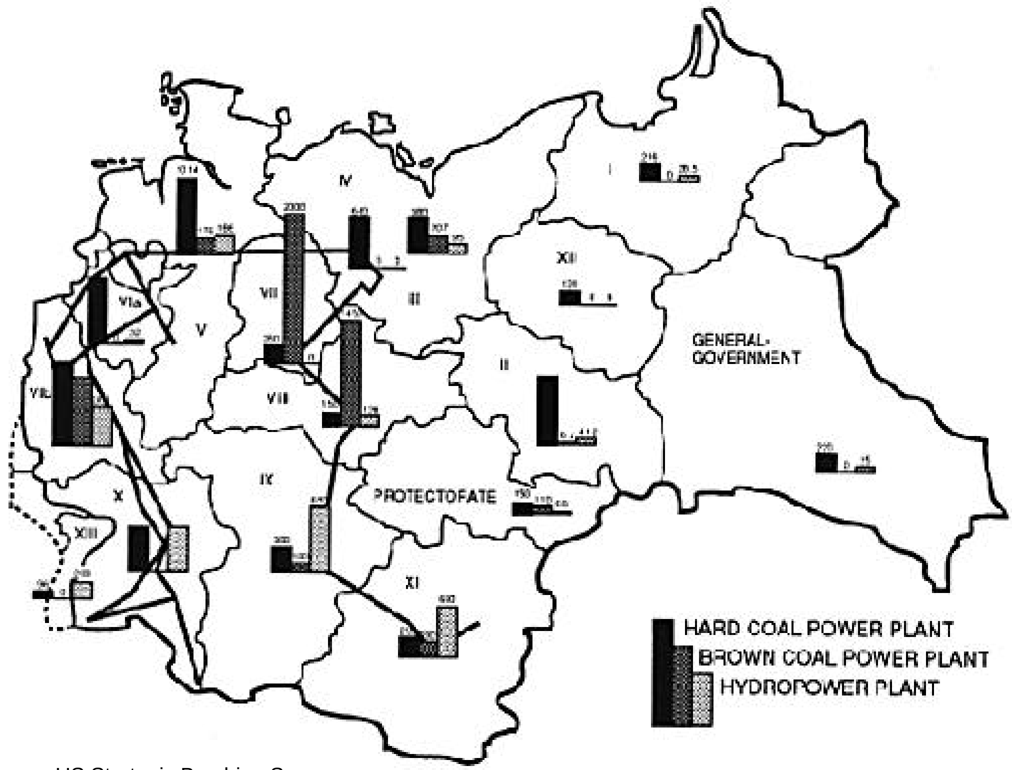
In identifying target priorities, the planners relied heavily on the targeting theory they had refined at the ACTS, which is one reason why electricity was chosen above other systems.[21] The effects they hoped for as a result of bombing electrical power were split between military production and civilian discomfort. Among the war industries listed in AWPD/1 as being dependent on electricity were aircraft and ship production, along with aluminum, synthetic rubber, and armaments production. The plan also identified areas that were primarily civilian, such as textile production, which was important to the planners because "of the shortage of wool and warm clothing in Germany."[22] Other civilian targets affected by a reduction in power were automobile production, the cold storage of food, and urban transportation—areas chosen for their impact on lowering civilian morale, rather than affecting military production or forces. As a faithful reproduction of the ACTS theory, the strategy in AWPD/1 relied heavily on affecting the will of the people. This, in turn, was reflected in their target selection, especially the high priority accorded to electric power.

The target priorities and air strategy of this first air plan were reviewed one year later, in August 1942, when President Roosevelt directed the services to prepare a new plan for the production requirements of aircraft in order to achieve "Air Ascendancy" in 1943.[23] In light of this new guidance, the new plan, called AWPD/42, revised the target priority list, displacing electrical power to fourth, preceded by the German air force, submarine construction, and transportation. While in AWPD/1 electric power was ranked second only to the German air force.[24] With the shift away from attempting to defeat Germany through air power alone to the need for attaining air superiority in preparation for a land invasion, the new air strategy focused less on affecting civilian morale and war production, and more on the impact of bombing on the fielded military forces of Germany. This put less emphasis on hitting economic targets like electricity and more on traditional military targets such as the transportation system.[25] AWPD/42 was issued on 9 September 1942 and became, according to the official historians, the "basis for all AAF [Army Air Forces] strategic planning prior to the Casablanca conference of January 1943."[26]

Even before the Casablanca conference, however, the targeting assumptions in AWPD/42 received intense scrutiny. The chief criticism of AWPD/42 was leveled by members of the Joint Intelligence Committee who objected to the assumptions involved in the target selection process.[27] This questioning led to the creation of an Army Air Force headquarters organization whose sole purpose was to perform an independent analysis of Germany and make target recommendations.[28] First known as the Bombing Advisory Committee and later as the Committee of Operations Analysts (COA), this committee was composed of civilian and military personnel instructed by Gen Henry H. ("Hap") Arnold, the commander of the Army Air Forces, to analyze the deterioration of the German economy through bombing and determine the "date when deterioration will have progressed to a point to permit a successful invasion of Western Europe."[29] This guidance marks an almost complete reversal from the objective of the initial air plan, which aimed at collapsing civilian morale, to an air strategy that focused on both ground and air forces.

The Committee of Operations Analysts began its target analysis by dividing into subcommittees to evaluate targets. The COA found that while there was considerable information about the supply of electric power, there was no analysis on the effects of an attack.[30] In addition, a review of the information about the production of electricity highlighted the fact that a successful attack on power might be more difficult than previously anticipated. According to the electric power subcommittee, the biggest difficulty in striking the German electrical system was the so-called grid system. This system, they believed, interconnected the entire country and allowed power to be quickly shifted from one region to another making anything less than a general attack on all German electrical power ineffective. Because of this assumption, the overall committee directed that specific regions, rather than all of Germany, be studied for possible attack.[31] (See fig. 2.)

The results of this regional approach identified two potential target areas, one in the Rhine-Ruhr industrial area and another south of Berlin.[32] Based on the information available and the operational capabilities at the time, the subcommittee decided to concentrate its work on the Rhine-Ruhr area. They identified 29 targets in that area which, if attacked, would reduce the overall generating capacity by 57 percent,[33] although the effects of a reduction in power would differ by industry. Because coal production was critical to the German economy, and steel production essential to war production, these industries would only be slightly affected by an attack on power facilities. Coal mining would continue virtually unaffected and iron and steel production would receive 63 percent of normal power. However, other industries, not so essential, would only receive a quarter of their usual amount and civilians would obtain only the minimum requirements.[34] The electrical subcommittee concluded that the effects of this type of attack "would be extremely worthwhile," not so much for the effects on production, but because of the morale problems that destroying this amount of electricity would cause the civilian population.[35]



Source: US Strategic Bombing Survey

Figure 2. Map of Germany Showing Breakdown of Electrical Utility Generating Capacity by Source of Power in Each of the Fourteen Power Districts (Conditions Shown Believed to Be for 1943) and Transmission Grid. [36]

Despite this endorsement by the subcommittee there were other factors that influenced the entire COA in its assessment of the German electrical system. The first was the belief that the German national power grid was highly flexible and could shift power quickly between regions. Because of this flexibility, the COA concluded that the German electrical system contained between 15 and 20 percent excess power which, they believed, constituted an "enormous reserve."[37] The COA also postulated that the poor results of the Luftwaffe bombing of British power plants demonstrated that "the vulnerability of electric power plants is debatable."[38] Finally, the shift in strategy from effecting production and morale to fielded forces played a role. They felt that targeting other systems such as ball bearings, petroleum, and steel production would have a more immediate impact on the military capability of Germany.[39] The net result was that, relative to other target systems, electric power did not appear to be a high priority, and in the formal COA report to General Arnold it was ranked thirteenth—eliminating it from any real consideration as a target.[40] Arnold forwarded this list to Eighth Air Force headquarters in England and it became, in effect, the target priorities for the Combined Bomber Offensive (CBO) Plan.[41]

The policy of a Combined Bomber Offensive between the Royal Air Force (RAF) and the United States Army Air Forces' Eighth Air Force, resulted from the Casablanca conference held in January 1943, between President Roosevelt, Prime Minister Winston Churchill, and the British and American chiefs of staff. The Allied leaders issued the directive with the hope of coordinating the night bombing efforts of the RAF with the daylight bombing raids of the Eighth Air Force. The objective of both efforts was, "The progressive destruction and dislocation of the German military, industrial, and economic system, and the undermining of the morale of the German people to a point where their capacity for armed resistence is fatally weakened."[42] Because the CBO directive was more a policy statement than an employment plan, it was not greatly concerned with target selection. However, within the overall objective of the bombing effort, it did prioritize the general order in which target systems should be attacked.

1. German submarine construction yards
2. The German aircraft industry
3. Transportation
4. Oil plants
5. Other targets of war industry.[43]

It should be remembered that this list constituted one part of a strategic plan, and these were not intended to be the only targets attacked. There were many changes to this list and ample opportunity for the air commanders to attack targets not on this list or to change the target priorities. The operational targeting plan which did specify targets was developed by representatives of Eighth Air Force and RAF Bomber Command who combined the Casablanca directive and the target list from the COA.

When the planning team received the suggested targets from the COA, they could have changed the ranking of the targets, but according to Haywood Hansell, a planner of AWPD/1 and a member of the CBO staff, they were "reluctant . . . to challenge the intelligence structure."[44] Thus, when the Combined Bomber Offensive officially began on 10 June 1943, electric power was a low priority target and regular attacks were never carried out against the system.[45]

At least one other American targeting organization in Europe addressed the possibility of attacking electrical power—the Enemy Objectives Unit (EOU). As part of the Economic Warfare Division in the US Embassy, this unit was assigned the task of formulating criteria for target selection and then applying them to different target systems. Such a process would, theoretically, produce the best targets to attack.[46] The methodology developed by the EOU was based on the premise that targets would be "chosen in light of an explicitly defined military aim, linked to the full context of war strategy." The members of the unit opposed attacks designed to weaken the economy or to affect morale,[47] and instead concentrated on the impact bombing would have on the German military capability.[48] The EOU *Handbook* specifically states, "The target systems in this Handbook have been selected on the basis of their direct military effects only."[49] While this organization operated autonomously from Eighth Air Force, much of the target analysis was used by the Eighth in its efforts to prioritize targets. Electric power was rejected on general principle by the EOU analysts because attacking it would not lead to "an early reduction in military strength disposable in the field."[50] Electric power was also rejected for three specific assumptions. Contrary to the COA, the EOU felt that the targets were dispersed in "extraordinarily small" units and they postulated that "23 [of the] largest stations produce only 20 percent of German output."[51] However, they agreed with the COA findings regarding the grid system's flexibility which minimized the effectiveness of any attack.[52] Finally, the EOU felt that "installations in power plants and switching stations are of such a kind as to require bombing of the highest concentration and precision,"[53] a level of precision they obviously felt was beyond the capability of Eighth Air Force.

There were two main factors that caused both the COA and the EOU to disagree with the ACTS instructors and early air planners that German electric power should be a key target. The belief that the interconnections within the German electrical system would allow power to be transferred and thus reduce the vulnerability of the system was the first element, but more important was the change in air strategy from one of affecting the will of the civilian population to one of support for a land invasion. As a result, the German power system was never systematically attacked during the war.

World War II— Japan

In contrast with the extensive planning for a strategic bombing campaign against Germany, the study of Japan did not seriously begin until early 1943 when General Arnold directed the COA to analyze the Japanese economy to determine appropriate strategy targets.[54] Prior to this time the "Germany first" strategy that the US and Great Britain had adopted dictated that the COA's targeting attention would initially be focused on Europe and only after that was complete would they need to consider targets in Japan. In addition, the Army Air Forces possessed little capability, even by 1943, to attack mainland Japan on a sustained basis.[55] Finally, and perhaps most importantly for target selection, there was a severe lack of intelligence on Japan.[56]

In October 1943, the COA began consolidating subcommittee reports prior to making targeting recommendations to General Arnold. The electrical power subcommittee noted that isolated attacks on the power system would be of "little more than nuisance value."[57] They felt that large-scale attacks on the system would be effective in weakening Japan, but only in the long term (estimated to be between six months to one year).[58] In addition, the committee discovered that the Japanese obtained the bulk of their power from a large number of small hydroelectric dams (fig. 3). Because of their location, number, and construction, these dams presented poor targets for strategic bombing.[59] The subcommittee's pessimism about the effectiveness of bombing electrical power resulted from the dispersion of the power plants, which lowered the vulnerability of the system and the delay in effecting the military capability of Japan. Based on this report, and perhaps the COA's ambivalence toward electric power based on their German targeting experience, they concluded that, while the electrical power system was vulnerable, it would not be a profitable target overall.[60] The net outcome was that the Japanese electrical system was not mentioned in the six target systems the COA recommended to General Arnold.[61]

The COA reexamined the possibility of bombing the Japanese electrical system in 1944 when General Arnold ordered a revised target study.[62] They, in turn, requested that Army intelligence study the system and offer their recommendations for attacking it. This intelligence analysis reemphasized the impression that electric power was not a vulnerable system based on the dispersion of power production, the number of standby facilities, and the interconnected grid system.[63] The report concluded that "electrical power is not an attractive system for strategic bombing."[64] Based on this information, and earlier reports, the net outcome was that the Japanese electrical power system was not isolated for attack during the strategic bombing of World War II.

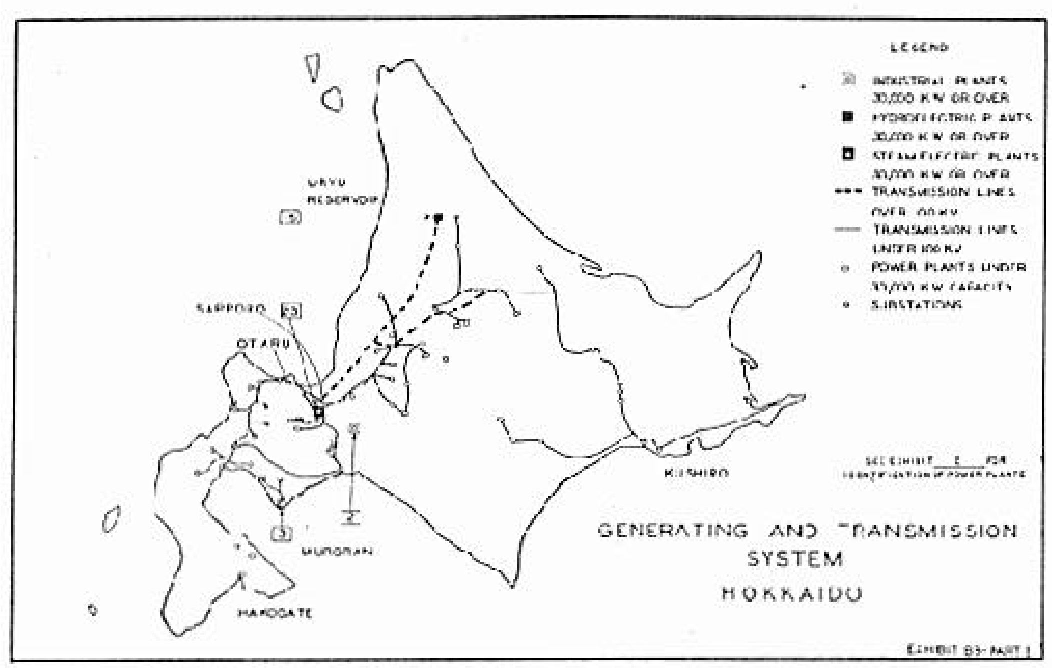
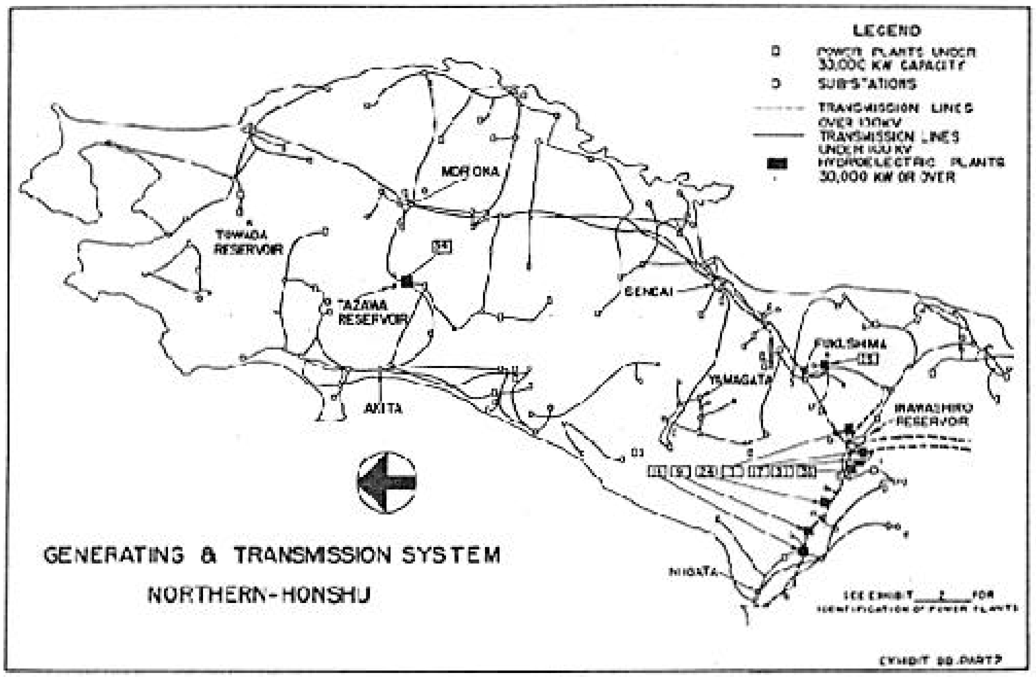
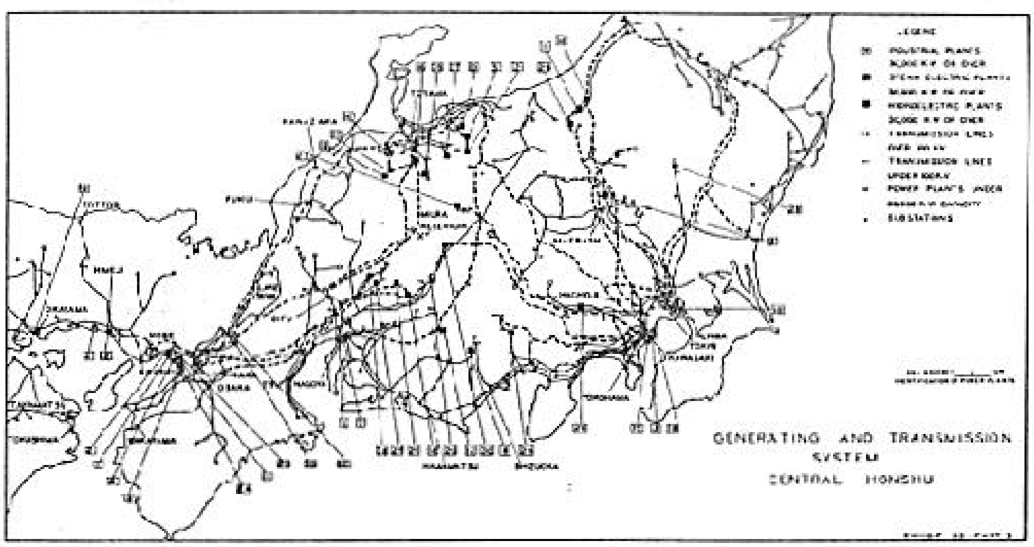


Figure 3. Generating and Transmission Systems.[65]

Figure 3—continued





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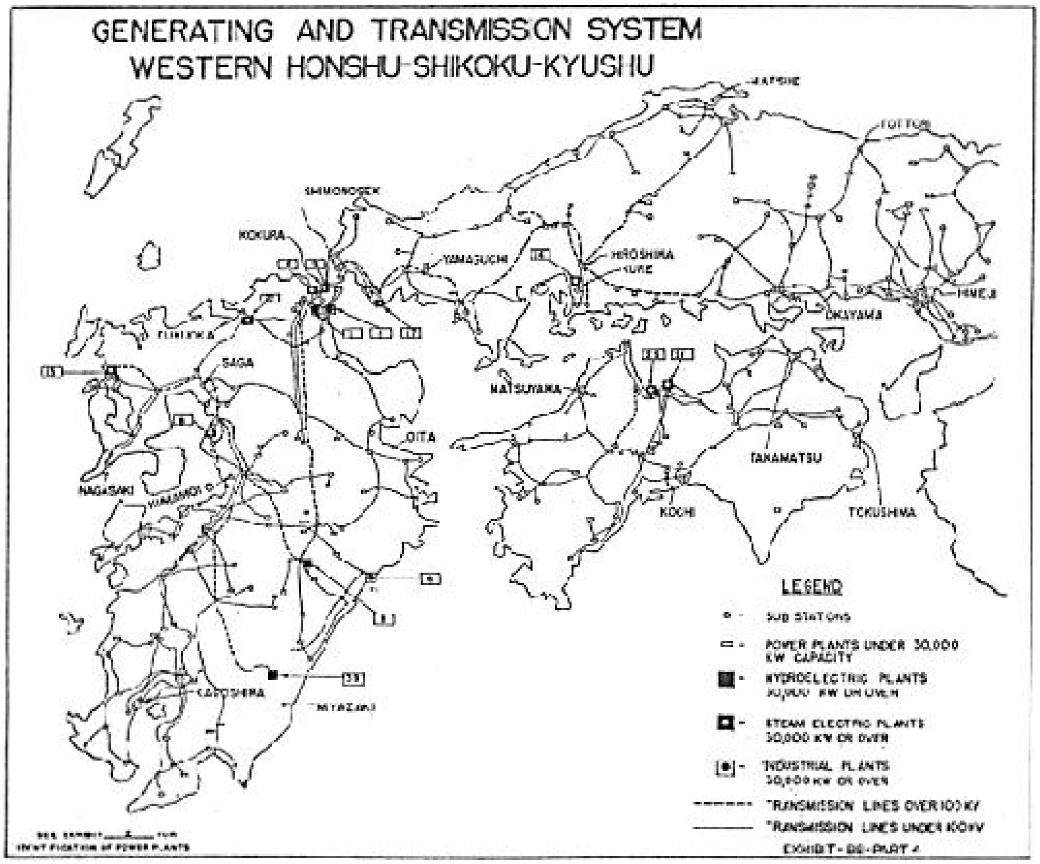


Source: *United States Strategic Bombing Survey (USSBS), Electric Power Industry of Japan* (Washington, D.C.: GPO, December 1945), 57–60.

United States Strategic Bombing Survey

During the war, members of the COA and the Army Air Forces recognized that one of the most difficult problems in air warfare was trying to relate the effectiveness of attacking particular targets with the overall objectives of the war. The only way to gauge if the correct targets had been selected against Germany and Japan was through a postwar survey of the results. This quest for feedback resulted in a high-level commission called the United States Strategic Bombing Survey (USSBS) which was formally implemented with an executive order from President Roosevelt in November 1944.[66]

The results of the survey's investigation of electric power offered some vindication of the ideas of the ACTS instructors and AWPD/1. The summary report of the USSBS declared, "Had electric generating plants and substations been made primary targets as soon as they could have been brought within range of Allied attacks, the evidence indicates that their destruction would have had serious effects on Germany's war production."[67] The survey members who investigated power felt that electricity would have been an excellent target for strategic bombing. They found that power production was concentrated into a few plants and that there was very little reserve capacity in the system. In addition, they found that the generation and transmission equipment were easily damaged through bombing.[68] The report points out two glaring errors in the wartime assessment of the power system, namely the lack of appreciation for how tight the supply of power was in Germany and the limited ability of the Germans to transfer power. As the electric team members wrote, "The German utility system was in a state of continuous tension, straining it almost to the breaking point."[69] In making their assessment of the value of attacks on electric power the team members concentrated on the vulnerability of the system to bombing and statements from German officials regarding their fear of attacks on the system. These comments range from those of Albert Speer to a German electrical engineer who claimed that the war would have ended two years sooner if the Allies had attacked electric power.[70]

While there can be little argument with the fact that electricity was a critical resource in Germany, it does not necessarily follow that attacking it would have resulted in an earlier victory for the Allies. As the USSBS report on the German economy noted, "It seems likely that the Germans overestimated the vulnerability of their power system."[71] This report notes that the supply of power was a problem and curtailments of electricity, which began in October of 1941, had by the winter of 1942, caused some temporary halts in production. Specifically, the report notes that in November 1943 there was a curtailment in power equivalent to 8 percent of the peak load. This resulted in synthetic nitrogen production falling by 12.5 percent, and steel production by 20 percent.[72] While these reductions may have been important, there is no evidence to show that they were. Stockpiled nitrogen and steel could have been used to maintain war production, with little resultant effect on the final production of goods, only a reduction of stockpiles.

Another problem in addressing the impact of a loss of power is that most German officials only considered the output of the national system. The data from 1939 points out that 58 percent of the generating capacity in Germany was in the public system. The remaining 42 percent was in large industrial factories, such as the aluminum plants and the Krupp ironworks, which generated their own electricity.[73] Because of the large amount of private capacity, a reduction of half of the public power production would have meant a loss of only one-quarter of the entire capacity. Given the small size of the electrical generating units in industrial plants, it is unlikely that they could have been hit without simultaneously destroying the factory.

One other factor that would have helped Germany substitute for a loss in power was a fuller mobilization of their economy. As the USSBS economic team reported, most German industry was on a single shift throughout the war, and in addition, they did not fully mobilize their manpower.[74] When most workers in a country are on one shift, this creates a demand for power at the same time, and if there is not enough power available, some curtailments will result. (This is similar to situations in some areas of the United States where the peak load during a summer afternoon exceeds the generating capacity, resulting in "brownouts.") By using three shifts, power demand could be spread out over a longer period of time allowing the same amount of electricity to be used with fewer curtailments. Power could have also been saved by substituting manual labor in place of machines. This would have allowed electricity to be conserved for more critical tasks. Even given all of these measures, however, it seems certain that a concentrated attack on power would have put a severe strain on German war production. What is unclear is how much this would have effected the timing of the Allied victory.

There is little evidence from German experience pertaining to the impact of the loss of electricity on public health. The lack of power did cause problems in some areas of Germany that relied on electrical pumping stations; however, these were isolated instances and in most places it was possible to get water either by means of gravity or through the emergency measures instituted by the government.[75] The loss of power to the sewage systems did cause some pollution of the water supply; however, in comparison to the widespread damage caused by bombing, such as ruptured water and sewer mains and the use of raw sewage to put out fires, the problems involved with the loss of electricity were minimal. Although the conditions were ripe for disease the USSBS health team noted an "amazingly low" incidence of disease caused by waterborne bacteria. The team found that the number of cases of dysentery, typhoid fever, and paratyphoid fever did not change significantly because of the conditions caused by bombing,[76] and the team credited the low rate of disease on personal health habits and a public health service that monitored the water supply and stressed health measures.[77] Overall, the impact of the loss of power on public health was small compared to other problems with the water supply in Germany.

While the USSBS European report offered some vindication for the ACTS theory, its report on bombing in Japan confirmed most of the assessments made of the Japanese electrical system. The biggest complaint of the Pacific report was the lack of adequate intelligence about the Japanese economy. Part of this was a result of poor American preparedness, but it was also partly because of a concerted effort on the part of the Japanese to withhold information from 1929 onwards.[78] Despite this lack of information, the USSBS agreed with the intelligence assessment of the Japanese power system. The postwar investigation showed that the analysis about Japanese reliance on hydroelectric power was correct. The report stated, "Japan's electric power system was properly rejected for specific attack because of the large number of small targets presented."[79]

The survey team did offer one criticism of the targeting work during the war. While there was sufficient information on the production of electricity and the location and size of the facilities, the team felt that there had been a lack of analysis on the relative importance of the installations. They based this observation on the fact that there had been little consideration given to bombing the thermal plants in Japan. In contrast to the hydroelectric plants, the thermal facilities were few in number and vulnerable to air attack. While the thermal plants only accounted for 17 percent of the overall generating capacity, during the dry season the Japanese relied on these facilities for 30 percent of the power generated. The USSBS report also noted that not every part of Japan was the same regarding the use of power—some portions were highly dependent on steam-generated electricity and would have been more affected by the bombing of these stations than other areas.[80]

The report on the health effects in Japan due to electrical outages revealed many of the same results as in Germany. The survey investigated the six largest cities in Japan to determine the death rates due to bombing and disease from 1941 to 1945. While the loss of power did impact some pumping stations and interrupt service to these areas, the overall effect on the water supply was small.[81]

The loss of electricity on sewage systems was also minor in comparison to the damage caused by bombing. Nonetheless, problems with the primary waterborne diseases were significantly greater in Japan than in Germany, and some diseases could be traced to problems with the water supply. There were several epidemics in Japan. Nagoya, in particular, suffered from a dysentery epidemic from July to October 1945, and the survey suspected that heavy bombing raids in May 1945 may have been responsible for an outbreak of typhoid and paratyphoid in August and September.[82] Even with these epidemics and a significantly higher rate of disease in Japan than in Germany, the survey found that despite bombing death rates for these diseases remained constant.[83]

In many ways the USSBS reports brought strategic thinking about air attacks on electric power full circle. The survey pointed out that electricity was, as the ACTS instructors predicted, an important target, especially in Germany. It is important to note, however, that the USSBS comments are solely in relation to the importance of electricity to war production, rather that the original objective of winning the war by collapsing civilian morale. In addition, while the USSBS did discuss the potential value of electricity in Nazi Germany, they made no recommendations regarding its value as a target in the future. Despite these important differences for air planners, the lesson was clear—hit electric power, regardless of the situation. This attitude prevailed despite the changes in the nature of war and in the enemies the United States faced in the post–World War II era, and is still the basis for current attitudes about the value of attacking electrical power.

Notes

1. Robert T. Finney, *History of the Air Corps Tactical School, 1920–1940*. USAF Historical Study, no. 100 (Maxwell AFB, Ala.: Air University, 1955), 5–7.

2. For a vivid example of this reasoning, see Giulio Douhet, *The Command of the Air*, eds. Richard H. Kohn and Joseph P. Harahan, reprint ed. (Washington, D.C.: Office of Air Force History, 1983), 126, 139–40.

3. "Air Force Objectives," lecture, ACTS, Maxwell AFB, Ala., 1934–1935, 1, in USAF Historical Reserach Agency (hereafter cited as HRA) file 248.2015A-12.

4. "General Air Force Principles," lecture, ACTS, Maxwell AFB, Ala., 1934–1935, 1, in HRA file 248.2016A-3.

5. "Air Force Objectives," lecture, 2.

6. Maj Muir S. Fairchild, "New York Industrial Area," lecture, ACTS, Maxwell AFB, Ala., 6 April 1939, in HRA file 248.2019A-12.

7. "Air Force Objectives," lecture, 2.

8. "The National Economic Structure," lecture, ACTS, Maxwell AFB, Ala., 1939–1940, 15, in HRA file 248.2021A-7. Their precision was a direct reflection of the amount of information they had on electric power in the United States. They could pinpoint the number of electric targets because they had obtained a listing of the major power plants in the United States through the McGraw Central Station Directory.

9. For example, the file containing the 1939–1940 lecture on the "National Economic Structure" also has a 59-page pamphlet, complete with overhead photography and floor diagrams, on the Hudson Avenue Generating Station in New York City.

10. Fairchild lecture.

11. Fairchild lecture, 2.

12. H. H. Arnold, *Global Mission* (New York: Harper & Brothers, 1949), 245.

13. James C. Gaston, *Planning the American Air War: Four Men and Nine Days in 1941* (Washington, D.C.: National Defense University Press, 1982), 14, 90; and Haywood S. Hansell, Jr., *The Air Plan That Defeated Hitler* (Atlanta: Higgins-McArthur/Longino & Porter, 1972), 60.

14. Hansell, 70.

15. Air War Plans Division (AWPD)/1, *Munitions Requirements of the Army Air Forces*, 26 August 1941, 2, in HRA file 145.82-1.

16. Ibid.

17. Ibid., 3–4.

18. Ibid., 3.

19. Hansell, 81; and AWPD/1, 2.

20. Quoted in Haywood S. Hansell, Jr., *The Strategic Air War Against Germany and Japan: A Memoir* (Washington, D.C.: Office of Air Force History, 1986), 34.

21. Hansell, *Strategic Air War*, 112–13.

22. AWPD/1, 3.

23. Robert Frank Futrell, *Ideas, Concepts, Doctrine: Basic Thinking in the United States Air Force 1907–1960* (Maxwell AFB, Ala.: Air University Press, 1989), 130.

24. Hansell, *Air Plan*, 163.

25. Futrell, 157. The additional year of war also played a role in the target priorities. At the time this plan was drafted, August 1942, there was considerable concern over the United States's ability to keep Great Britain resupplied with material. This problem forced the addition of submarine building yards and its concomitant high priority on the strategic bombing target list. For the dramatic successes of the German submarine campaign, see John Keegan, *The Price of Admiralty: The Evolution of Naval Warfare*, reprint ed. (New York: Penguin Books, 1990), 267–73. Keegan notes that because of their victories the U-boat captains called the period from December 1941 until June 1942 the "happy time."

26. Wesley Frank Craven and James L. Cate, *The Army Air Forces in World War II*, vol. 2, *Europe: Torch to Pointblank, August 1942 to December 1943* (Chicago: University of Chicago Press, 1948–1958), 277.

27. *History of the Committee of Operations Analysts,* 1, (hereafter cited as *COA History*) in HRA file 118.01; Futrell, 142; and David MacIsaac, *Strategic Bombing in World War Two* (New York: Garland Publishing, Inc., 1976), 24–25.

28. Hansell, *Air Plan*, 148; and Craven and Cate, 2: 349–50.

29. Lt Gen H. H. Arnold, commanding general, Army Air Forces, to assistant chief of Air Staff, management control, 9 December 1942, in HRA file 118.01; and Craven and Cate, 2: 353–54.

30. *COA History*, 13.

31. Ibid.; and Minutes, Meeting of the Advisory Committee on Bombardment, 21 December 1942, in HRA file 118.151-1. This recommendation was based heavily on information supplied by the British Ministry of Economic Warfare. They concluded that because of the efficient German grid system, "It is therefore probable that as long as the damage is not concentrated in a single area, Germany could bear the destruction of a substantial portion of the total generating capacity." Ministry of Economic Warfare, German Electricity Supplies, 4 January 1941, 83, in HRA file 512.4281.

32. *COA History*, 17.

33. Minutes, Meeting of the Advisory Committee on Bombardment, 31 December 1942, in HRA file 118.151-1.

34. USAAF Intelligence Service, "Air Estimate: Vulnerability of the Electrical System in the Rhine Ruhr Area, Germany," 18 January 1943, in HRA file 142.042-27.

35. Minutes, Advisory Committee on Bombardment, 31 December 1942.

36. Hansell, *Air Plan*, 234–35.

37. Minutes, Advisory Committee on Bombardment.

38. Memorandum, Committee of Operations Analysis, to General Arnold, subject: Economic Targets within the Western Axis, 8 March 1943, in HRA file 118.04A-1; and Craven and Cate, 2:362.

39. *COA History*, 16–19; and Hansell, *Air Plan*, 161.

40. Craven and Cate, 2:363; *COA History*, 44; and Hansell, *Air Plan*, 159. The target systems listed ahead of electric power included the German aircraft industry, especially fighter assembly plants and engine factories, ball bearings, petroleum, grinding wheels, nonferrous materials, synthetic rubber and tires, submarine construction yards and bases, military motor transportation, general transportation systems, coking plants, steel production, and machine tools.

41. *COA History*, 44; and Craven and Cate, 2:364–65.

42. Craven and Cate, 2:307; and quoted in Hansell, *Strategic Air War*, 72.

43. Hansell, *Air Plan*, 153.

44. Ibid., 162.

45. Craven and Cate, 2:308.

46. W. W. Rostow, *Pre-Invasion Bombing Strategy* (Austin, Tex.: University of Texas Press, 1981), 15.

47. Ibid., 23.

48. Enemy Objectives Unit (EOU), Economic Warfare Division, US Embassy, London, *Handbook of Target Information*, 24 May 1943, in HRA file 512.323, 1.

49. Ibid., 18. For a postwar analysis that supports the primacy of this approach for target selection, see Carl Kaysen, *Note on Some Historical Principles of Target Selection*, Rand Research Memorandum RM-189 (Santa Monica, Calif.: Rand Corp., 15 July 1949).

50. EOU *Handbook*, 107–8.

51. Ibid., 108. By way of contrast, the COA believed an attack on 29 targets in the Rhine-Ruhr area would disrupt 57 percent of the power in that region.

52. Ibid.

53. Ibid.

54. Craven and Cate, 5:17; and Futrell, 159.

55. United States Strategic Bombing Survey (USSBS), *Summary Report (Pacific War)* (Washington, D.C.: GPO, 1 July 1946), 6, 8–9. Bombing of mainland Japan did begin in the fall of 1943 with B-29 attacks from China. However, due to logistical problems these raids were sporadic and ineffective. Sustained attacks began in November 1944 when B-29s began flying to Japan from bases on the Mariana Islands.

56. Craven and Cate, 5:17; and *COA History*, 82. The *COA History* notes that an intelligence study in March 1943 of Japanese targets did not include electric power, 59.

57. Report to the Committee of Operations Analysts by subcommittee on Far Eastern Electrical Power, 30 October 1943, in HRA file 118.04F-1.

58. Ibid; and *COA History*, 82.

59. Ibid.

60. Memorandum, Committee of Operations Analysts, to General Arnold, chief Army Air Forces, subject: Report of Committee of Operations Analysts on Economic Objectives in the Far East, 11 November 1943, 4, 53, in HRA file 118.04D.

61. Craven and Cate, 5:93; and Futrell, 159. The six target systems they did endorse were antifriction bearings, the electronics industry, the aircraft industry, merchant shipping in harbors, urban areas, and coke and steel production.

62. Craven and Cate, 5:132–33.

63. Memorandum, Army G-2 to COA, 13 June 1944, 3, in HRA file 118.04A-11.

64. Ibid.

65. USSBS, *Electric Power Industry of Japan* (Washington, D.C.: GPO, December 1945), 57–60.

66. MacIsaac, 21–23; 154–56.

67. USSBS, *Summary Report (European War)* (Washington, D.C.: GPO, 30 September 1945), 14.

68. USSBS, *German Electric Utilities Industry Report* (Washington, D.C.: GPO, January 1947), 2.

69. Ibid., 18.

70. Ibid., 46–51.

71. USSBS, *The Effects of Strategic Bombing on the Germany War Economy* (Washington, D.C.: GPO, 31 October 1945), 126.

72. Ibid., 72, 121; and USSBS, *German Electric Utilities Report*, 40–45.

73. *Effects of Strategic Bombing on Germany War Economy*, 72, 114; and Alfred C. Mierzejewski, *The Collapse of the German War Economy, 1944–1945: Allied Air Power and the German National Railway* (Chapel Hill, N.C.: University of North Carolina Press, 1988), 32–33.

74. Mierzejewski, 8–9, 43.

75. USSBS, *The Effects of Bombing on Health and Medical Care in Germany* (Washington, D.C.: GPO, January 1947), 230–37.

76. Ibid., 262–63. The dysentery rate for the six sites surveyed by the health team was 13.42 per 100,000 per year in 1938 and 12.88 in 1944, 72.

77. Ibid., 81–82.

78. USSBS, *Summary Report (Pacific War)*, 31; USSBS, *The Effects of Strategic Bombing of Japan's War Economy* (Washington, D.C.: GPO, December 1946), 69–73.

79. USSBS, *Electric Power Industry of Japan*, 5–6, 17.

80. Ibid., 30–32, 35, 38. In fact, most of this information was known, at least in some parts of the US intelligence structure. A report by the Office of Strategic Services in May 1944 highlighted the very ideas that the USSBS brought up. Whether this report was ever seen by any air planners in time to influence operations is unknown. See Office of Strategic Services, Research and Analysis Branch, *Summary of Strategic Information: Far East Axis Economy Japan's Electric Power Position*, R and A no. 1823, 6 May 1944, in HRA file 187.2-39A.

81. USSBS, *The Effects of Bombing on Health and Medical Services in Japan* (Washington, D.C.: GPO, June 1947), 92–102.

82. Ibid., 164, 167.

83. Ibid., 120–21, 160–62, 178. The survey found that in the five years of the war, 1941–1945, the number of deaths per 100 due to dysentery ranged between 16.3 and 18.9 and typhoid and paratyphoid between 10.4 and 13.8, 178. The rates of the outbreaks of these diseases were found to be significantly higher in Japan than in Germany. The combined rates for dysentery in the German cities were from 13 to 27 per 100,000 per year, in Japan the rates were between 74 and 204. Typhoid rates in Germany varied from seven to 11, while in Japan they ranged from 72 to 185, 163.

Chapter 4

Electrical Power Targeting in the Past

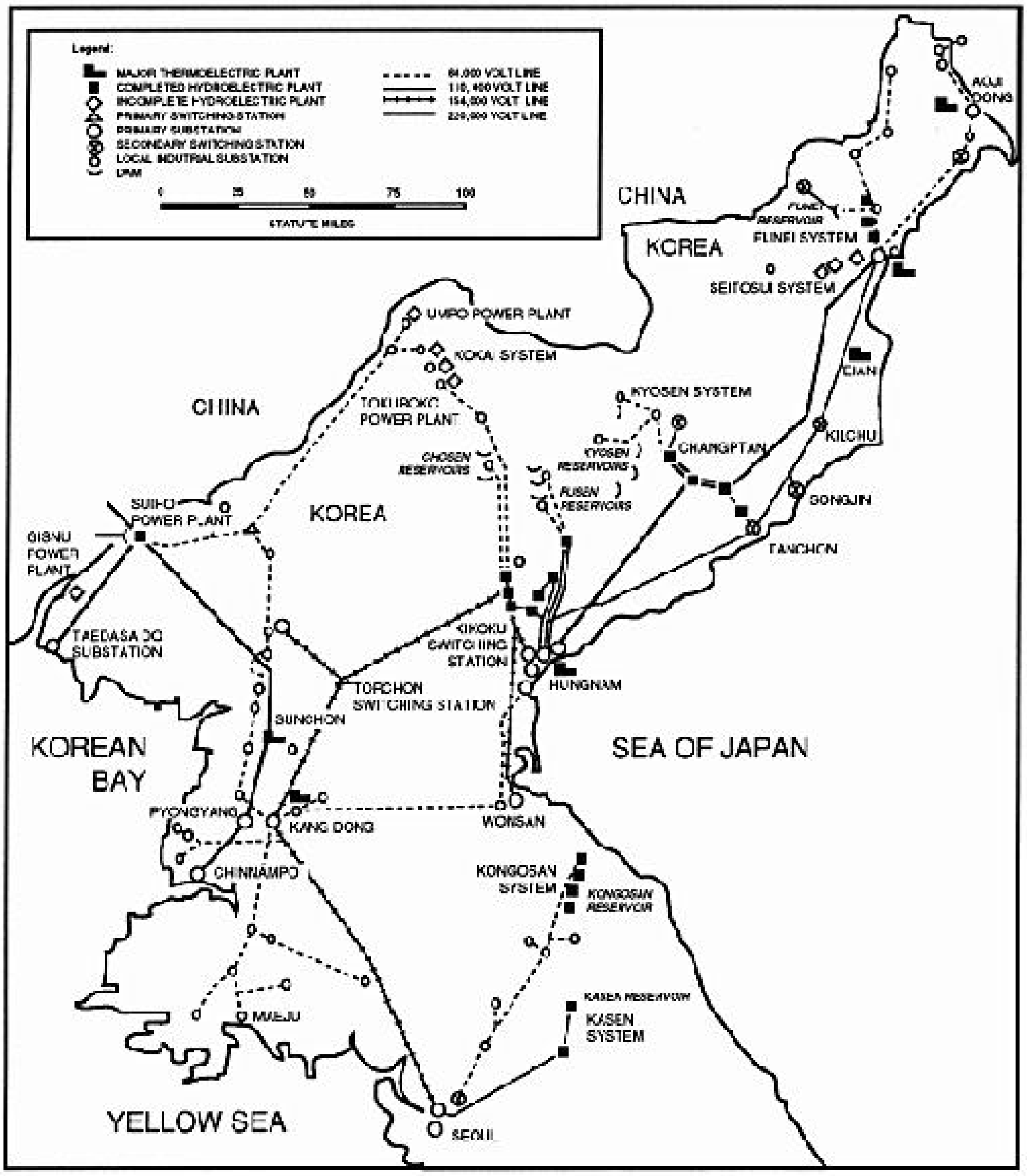
Attacks in Limited War

Korean War

When North Korean Communist forces launched their invasion on 25 June 1950, the US Air Force, like much of the rest of the world, was caught by surprise. Prior to the invasion, the Far Eastern Air Forces (the Air Force component responsible for air matters in Korea) had accomplished little contingency planning. Following World War II, the newly independent Air Force focused on nuclear warfare against the most likely enemy, the Soviet Union, and there was little planning or intelligence available for a limited war anywhere, especially Korea. It wasn't until 3 July that Strategic Air Command, which retained operational control of the bomber force, began looking for potential strategic targets.[1] This investigation identified five hydroelectric plants in eastern North Korea: Fusen, Choshin, Kyosen, Funei, Kongosan, and Suiho in western North Korea (the largest power plant in the Orient) as potential targets (fig. 4). Together these plants produced 90 percent of the power used in North Korea. Suiho was considered the most important because of its size and because it supplied electricity to Manchuria.[2]

The rationale at the beginning of the Korean War for attacking electrical power bore a striking resemblance to the strategy of AWPD/1. The objectives were spelled out in a memorandum to the Far Eastern Air Forces (FEAF) by Air Force headquarters in Washington, which stated, "Destruction of the plants was expected to lower North Korean morale by putting out lights, bring some electrically powered industry to a halt, and eliminate most of the surplus power being exported."[3] Based on this report, and other analysis, the Fusen plant was attacked on 25 September 1950, three months to the day after the war began. This mission, however, would be the first and last attack on electric power in the opening phase of the war.

The Joint Chiefs of Staff (JCS) had ordered the bombing north of the 38th parallel stopped when Gen Douglas MacArthur obtained permission to cross the 38th parallel.[4] The attacks were stopped for several reasons, based on the success of the ground advance north. The first reason was based on the length of time between attacking electrical power and the impact on the battlefield. In addition, if MacArthur did succeed in reuniting the peninsula, these attacks would result in the need for more reconstruction by the United States after the war. Lastly, there was also the fear that attacking the power facili-



Source: Robert F. Futrell, *The United States Air Force in Korea,* 1950–1953 (New York: Duell, Sloan and Pearce, 1961, rev. ed. Washington, D.C.: Office of Air Force History, 1983), 484.

Figure 4. North Korean Hydroelectric Plants and Power Transmission Grid

ties might provoke China into entering the war.[5] MacArthur's drive to reunite Korea, however, was halted near the Yalu river when the Chinese Communist army intervened in November 1950, forcing the United Nations (UN) command to retreat south. Following this attack the war stalemated near the 38th parallel and in July 1951, peace talks began. The UN ground forces' objective changed from the traditional aim of defeating the opposing army to a new objective of simply holding ground against any further territorial gains by the communist forces while minimizing UN casualties during the negotiation process. Air power became the primary military means available to directly influence the North Korean government.[6]

The initial attempt, through bombing, to compel the Communists to accept a cease-fire agreement was an interdiction campaign which began in September 1951, known as "Operation Strangle." This effort, aimed at both the North Korean rail and road systems, attempted to stop the flow of supplies from the rear areas to the front lines and to force a North Korean withdrawal and subsequent peace agreement.[7] This interdiction effort stopped 95 percent of the supplies going to the front lines, however, the remaining 5 percent "was still enough to permit the slow accumulation of communist stockpiles behind the static battle-line."[8] Although the interdiction campaign may have delayed or even prevented a ground offensive, it nonetheless fell short of its stated goal of "strangling" the enemy and forcing an armistice.[9] In addition, the effort was costly to the UN forces: from August 1951 to March of 1952, FEAF alone lost 236 aircraft on interdiction missions.[10] The lack of success in stopping the communist resupply effort coupled with the cost of the operation (both in terms of aircraft lost and in the loss of prestige to the newly independent Air Force) resulted in a search for alternative methods of employing air power to bring pressure on the enemy.

A new plan, based on a study commissioned early in 1952 by Maj Gen Jacob E. Smart, the FEAF deputy commander for operations, was written by Col Richard L. Randolph and Lt Col Ben I. Mayo, both Korean combat veterans and members of the FEAF staff.[11] They began their study with a review of the ongoing interdiction campaign and concluded that it was ineffective in applying pressure to the communist forces in North Korea because of the inability to completely stop the resupply process. They concluded that the most promising avenue to bring pressure on the North Korean government was to use air power to "destroy or damage enemy supplies, equipment, facilities and personnel."[12] They proposed that three criteria be used in selecting targets:

1. The importance and expense of the target to the enemy.
2. Our capability to destroy the target.
3. The cost to us.[13]

This plan, which they termed an *Air Pressure Strategy*, would include some of the interdiction targets that were already being attacked, but the aim of the new campaign would focus on destruction that would cause "a permanent loss to the enemy and produce an accumulative drain on his strength."[14] In addition to such targets as locomotives, vehicles, and supplies, they added electric power, which they considered "one of the most lucrative air targets remaining in North Korea."[15]

While the primary rationale for attacking electrical power may have been a desire to inflict costs on the North Korean leadership and convince them to stop the war, there were other reasons given for attacking the power generation facilities. The official explanation was based on curtailing war production. According to this rationale, previous bombing had largely eliminated North Korean industry, forcing them to take defensive measures by dispersing war production to small workshops and underground facilities which made the destruction of manufacturing by conventional bombing difficult at best. Hence, eliminating electric power at its source was deemed the most efficient and effective method of cutting North Korean production.[16]

The continued institutional perception about the value of electric power as a morale target was also a factor. In addition to stopping war production, eliminating electricity would cause an "adverse psychological effect on [the] civilian and military population."[17] An unwritten but nevertheless real reason for striking electrical power was to inflict costs on the Chinese, who were providing much of the support for the North Korean forces. Because North Korea exported surplus power from the Suiho plant to Manchuria, attacking this system would not only cost the Communists monetarily, both in terms of repair and lost production, but also inflict indirect damage on Manchuria, a sanctuary for communist forces.[18]

The effects of bombing the electrical power system were easy to judge from a tactical military viewpoint. In four days, beginning on 23 June 1952, US Air Force and Navy aircraft destroyed 11 of the 13 generating facilities, eliminating 90 percent of the power in North Korea.[19] The impact of these attacks was widespread. In North Korea there was a two-week blackout in the entire country, which stopped much of the war production going on in small factories and shops. The outage hampered vehicle and railcar repairs because of problems with electric welders,[20] and impeded agriculture by disabling the electric pumps used for irrigation and stopping the machines used for milling rice.[21] The damage to the Suiho facility resulted in a 23 percent loss of the electric power requirements of northeast China for 1952. As a result, 30 of 51 important industries in Manchuria did not make their production quotas for the year, and four were as much as 75 percent below their goal.[22]

Although the reports on the effectiveness of these attacks indicate that they were successful in crippling the supply of power, their real impact must be judged in light of their aim, which was to increase the costs to the North Korean, Chinese, and presumably Soviet leaders for continuing the war. The Soviet and Chinese leaders reacted by immediately sending technicians to repair the damaged facilities.[23] The North Koreans worked around the power interruptions by staggering shifts at workplaces to take advantage of the power available and buying small generators for mines and manufacturing plants.[24] However, because the North Koreans obtained most of their material from outside the country, primarily Russia and China, the elimination of electricity did little to effect military operations by hampering war production.[25]

Besides their minimal effect on the North Korean war effort, the attacks had a negative impact on allied leaders. The British press and Labor Party vehemently protested the attacks, out of fear that such attacks would cause the Communists to discontinue the peace talks. They were also indignant about the lack of consultation prior to the bombing.[26] American congressional leaders were also agitated, but for a different reason: Congress was dismayed that such important targets had not been bombed earlier.[27] These two widely disparate reactions probably presented mixed signals to the communist leaders about the allied intentions.

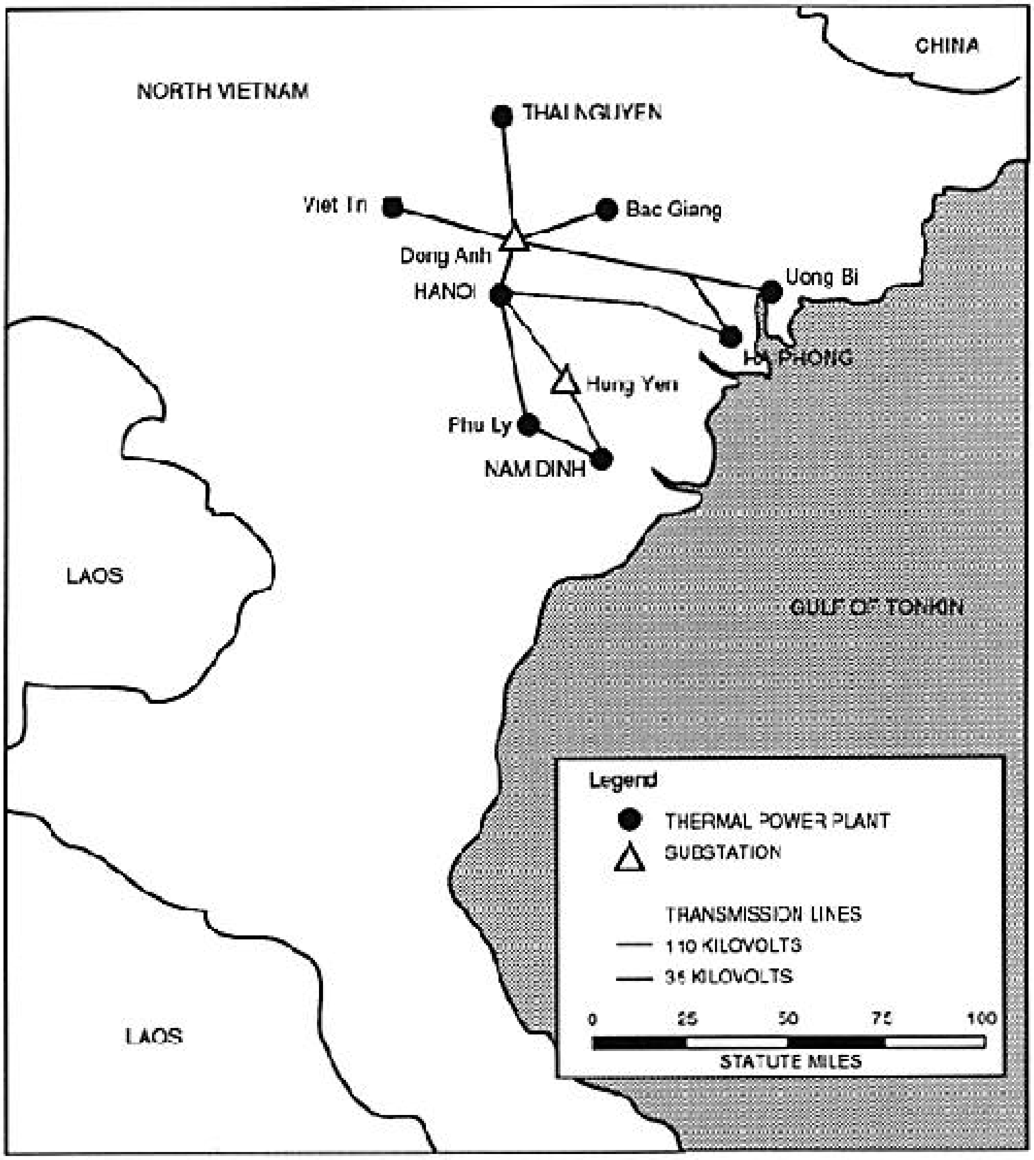
In the end, the attacks failed in their fundamental purpose of pressuring the North Koreans to sign a peace accord. Despite the increased costs caused by the virtual elimination of the national power system and the concomitant impact on production, the "Air Pressure Strategy," continued for over a year after these attacks.

Vietnam War

While attacks on electric power, and the strategy behind them, did not force an end to the Korean War, this failure did not diminish the high regard air planners placed on electric power as a target system. As a result, the North Vietnamese power grid was attacked during both the Rolling Thunder and Linebacker bombing efforts.

The Rolling Thunder air campaign was an attempt to fulfill a variety of political objectives through the bombardment of North Vietnam. At various times these objectives included boosting the morale of South Vietnam, demonstrating American resolve, interdicting the supplies used to support the insurgency in South Vietnam, and breaking the will of the Hanoi government to support the Vietcong insurgency.[28] While attacking the primitive electrical power system of North Vietnam may have had some small effect on morale and interdiction, the primary purpose in attacking it was to inflict costs on the North Vietnamese leadership and convince them not to support unrest in the south.[29]

Although Rolling Thunder began in March 1965, and there were occasional attacks on power plants, the electric system was not attacked systematically until the Spring of 1967. The JCS urged a concentrated attack of electric power in the fall of 1966, when the failure of the interdiction and oil campaigns became evident. In Rolling Thunder 52, eight major power plants were nominated to the president for attack (fig. 5). These attacks were designed to eliminate power in the Red River valley area, which would serve two purposes: one was to reduce production in the railway shops and the shipyard; the second was the hope that destroying these targets would disrupt normal life and affect the will of the people to support the war effort.[30] On 21 February 1967, President Lyndon B. Johnson approved attacks of all the North Vietnamese thermal power plants with the exception of those in Hanoi and Haiphong.[31] Authorization to attack the Haiphong thermal power plants was given on 22 March 1967, and they were struck on 20 April. An attack on the Hanoi central power station was authorized on 8 April and it was finally hit on 19 May. Attacks continued sporadically on all the plants throughout the rest of Rolling Thunder in an attempt to prevent repairs.[32]



Source: Deputy Chief of Staff for Intelligence, Headquarters Pacific Air Force, *The Effect of United States Air Operations in Southeast Asia,* 1968, 2 vols., I: 4–8, HRA file K7176094.

Figure 5. Major Power Grid

By the end of May 1967, 14 of the 22 electrical power targets, which included generating plants and transformer substations, had been attacked, virtually eliminating electrical power production in North Vietnam. The bombing destroyed 85 percent of the generating capacity of North Vietnam and heavily damaged the transmission network.[33] Despite these results, the overall impact of the attacks was minimal. The government asked residents to voluntarily cut consumption and requested that the foreign embassies in Hanoi turn off their air conditioners.[34]

The lack of electricity forced many factories to use manual tools rather than automatic machinery and compelled the government to disperse much of the production. Although one of the stated goals of the attacks was to stop or hinder work at the Haiphong shipyard, there was no evidence to suggest that the lack of power had any impact on the ability to off-load cargo. [35] One Air Force study felt that the reliance on generators increased demands on the government to supply petroleum, however, they could find no concrete evidence of this occurring.[36] Another intelligence study, completed shortly after the main power plants were struck in 1967, found that the North Vietnamese were concealing many of the effects of the bombing, but concluded that the "results [of the loss of power] will not be as far-reaching as originally expected."[37] Overall, according to a Central Intelligence Agency (CIA) report, the loss of the central power system did degrade the industrial production of North Vietnam, but it did not reduce their ability to continue the war.[38]

The North Vietnamese leadership reacted to the loss of power in several ways. The first was to ensure that the priority users still had electricity. They did this through the use of some 2,000 portable generators and five underground diesel generating stations.[39] The bombing of electricity did cause a decline in industrial capacity. They compensated for this by relying on increased support from the Soviet Union and China, which by 1968 amounted to $600 million in economic aid and $1 billion in military assistance. No doubt this aid was crucial in allowing the North Vietnamese to continue the war, although it did increase their dependency on these outside powers.[40] Although the social and economic costs inflicted on North Vietnam were quite severe, they were not enough to coerce the Hanoi government into accepting the American demands.

The attacks on electricity also had an effect on the American government, as support among policymakers for the bombing of North Vietnam waned after the strikes in early 1967. While some, like Walt Rostow, urged President Johnson to continue the bombing in order to impose more costs on the Hanoi government,[41] others like McGeorge Bundy urged a stop to the bombing. He wrote to the president in May 1967, "The lights have not stayed off in Haiphong, and even if they had, electric lights are in no sense essential to the Communist war effort." He felt that continued attacks would prove politically counterproductive at home and abroad and would distract from the more important ground war in South Vietnam.[42] As in Korea, the attacks on the North Vietnamese electrical power system did not prove decisive in achieving American policy goals.

Rolling Thunder ended in October of 1968, and strikes on the North Vietnamese power system did not take place again until April 1972 with the Linebacker I bombing campaign. This bombing effort was focused on interdiction, and the primary air tasks were reducing the flow of supplies into North Vietnam, destroying existing stockpiles in the north, and slowing the flow of supplies south.[43] The electric system was attacked as part of the effort to attack any target that supported the war effort.[44] One of the most dramatic attacks of this operation was on the Lang Chi hydroelectric power plant. This facility had been under construction during Rolling Thunder and was the largest known power plant in North Vietnam, supplying 75 percent of the power used by North Vietnamese industry.[45] However, because the generators sat on top of the dam, there was concern among US leaders of collateral damage if any of the bombs breached the dam. The introduction of laser guided bombs during Linebacker I made an attack on the facility possible with little risk of collateral damage. The attack was flown on 10 June 1972 with four F-4s carrying laser guided bombs. The aircrews reported that they had achieved direct hits on the generator facility and the transformer yard, but no bombs impacted the dam.[46]

The attack on Lang Chi and other bombing raids during Linebacker I eliminated 70 percent of the total power generating capacity in North Vietnam. What effect this had on stopping the invasion is uncertain—it is known that the North Vietnamese political leaders and military facilities were virtually unaffected by the loss of power because they were assured of electricity supplied by portable generators. President Richard M. Nixon ordered the bombing of North Vietnam stopped on 23 October 1972 because of progress in the peace negotiations with the North Vietnamese.[47]

The bombing of the North Vietnamese power system resumed on 18 December 1972, with the initiation of the Linebacker II bombing effort. The objectives of this campaign were purely psychological. President Nixon hoped to destroy the North's will to fight and force them to sign a peace agreement, while demonstrating US resolve to the South Vietnamese government through the use of air power.[48] In 11 days the USAF attacked six electrical power targets in North Vietnam with 166 bombing sorties (12 percent of the total).[49] Laser guided bombs were judged the most effective munitions for attacking electric power plants, and their use on the Hanoi facility put it out of operation for six months.[50]

Overall, the attacks on electric power reduced the amount of operational generating capacity from 115,000 kilowatts to 29,000. These attacks, coupled with the damage done during Linebacker I, eliminated almost 90 percent of the generating capacity in North Vietnam. Despite this impressive amount of damage there is little evidence that the bombing had much negative influence on daily life in the North. Certainly the people lost electricity in their homes and manufacturing stopped, but many of the government programs instituted during Rolling Thunder were still in place, and, if needed, previous methods could have been implemented, such as increasing imports, using manual machinery, and other substitutions for the loss of electricity. The lack of power had little impact on the functioning of the government or the military. As the official USAF bombing survey noted, "The limited amount of power available [through the national system and portable generators] was probably supplied only to priority users, such as the more important industrial installations, foreign embassies, and selected government buildings in Hanoi." [51] The best that can be said of the bombing of electric power during Linebacker II is that, while it had some effect, the level, intensity, and influence as far as the Hanoi government eventually signing a peace agreement are still unclear.

Desert Storm

Because most of the information from Operation Desert Storm is still classified, it is difficult to make definitive judgments about the impact of attacks on electrical power, but once again electric power was a high priority target. The primary purpose in bombing was not to stop production, but rather to induce strategic paralysis on the leadership in Baghdad.[52] The focus of these attacks was on the military, with the loss of power intended to affect military facilities such as radar sites and communication facilities.[53] In addition to the military effects, there was also the hope that because electricity touched all aspects of Iraqi society it might have a psychological impact as well.[54]

Prior to the Gulf War, Iraq had a very modern, concentrated electrical power system. The majority of power came from 19 generating stations which had a capacity of 9,500 megawatts. One unusual feature of the system was the large amount of reserve capacity available; in 1990 the peak load only accounted for slightly more than 50 percent of the available capacity.[55] During Desert Storm attacks on electric power accounted for 215 sorties, or about 1 percent of the total US sorties flown.[56] These attacks virtually eliminated any ability of the Iraqi national power system to generate or transfer power by reducing the generating capacity to less than 300 megawatts, and the transmission ability to one-quarter of the prewar capability.[57] Further, a Department of Defense study notes that "the synergistic effects of losing primary electrical power sources in the first few days of the war helped reduce Iraq's ability to respond to coalition attacks."[58]

Despite the destruction of Iraq's electrical power system, at least some high-priority users had access to electricity, as I personally observed. From 22 January to 4 March 1991, I was held as a prisoner-of-war in Baghdad. I stayed in four different prisons and was taken to a number of other locations for interrogations. While most places had no electricity, two locations did have electric power. The first was a building in Baghdad the prisoners referred to as the "Bunker," an underground facility known officially as the Directorate of Military Intelligence.[59] In this building there was power for ventilation, lighting, heating, and a kitchen. I was taken there several times over the course of two weeks for interrogations and there was never a lapse in electric power. The Iraqi Intelligence Service Regional Headquarters, known to the prisoners as the "Baghdad Biltmore," also had a constant source of power. I was moved to this prison late at night on 31 January 1991, and I can distinctly remember that the lights were on inside the prison and that I was taken down several floors to my cell in an elevator. This prison had a generator located outside the building which was turned on by the guards as needed. While the information I have is not definitive, it does offer some evidence that, as in Vietnam, the military and political leaders were well insulated from the loss of the national power grid.

There is little doubt, on the other hand, of the impact of the loss of power in Iraq on the civilian population. The civilian effects from the loss of power were quite severe, including the loss of power to hospitals, the breakdown of water purification systems, and damage to sewage systems, which then contaminated the water supply. One report attributed 70,000 deaths to this indirect collateral damage caused by a lack of electricity.[60] The negative political backlash of such reports is unquantifiable but nevertheless real, and must be considered in future air campaign planning.

Attacks on electric power have echoed some familiar themes. They have been attempted to affect production (Korea and Vietnam) and to directly impact the military forces (Iraq), in addition there has continued hope that somehow the loss of electric power will have a psychological impact on the target population. The evidence of these attacks, plus the experience of World War II provide the basis for the conclusions about when attacks against this system should be performed and the recurring failures of the Air Force in understanding attacks on this system.

Notes

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2. Air University Quarterly Review Staff, "The Attack on Electric Power in North Korea," *Air University Quarterly Review* 6, no. 2 (Summer 1953): 14; and Futrell, 184.

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Chapter 5

Targeting Electrical Power Systems

Despite the claims by air planners that electric power should always be attacked, the historical evidence suggests that there are specific conditions that must be evaluated before nominating this system as a strategic target. This chapter presents the conditions that define when an attack on the national power system will be successful. While electrical power systems are inherently vulnerable to attack, the application of air power against these systems, especially in a limited war, is usually ineffective in achieving strategic objectives, despite accomplishing the intermediate goals of diminishing electrical generating capacity, hindering war production, and causing civilian discomfort. Prior to discussing the strategies behind attacking this system it is important to note the recurring failures in understanding electric power as a target system that have plagued strategic air planners.

Failures

The two failures that stand out in the understanding of electric power as a target system are a lack of appropriate intelligence about the system and the repeated failure to assume a reactive foe.

Some problems in targeting electrical power are inherent in the nature of strategic air intelligence. The employment of air power demands more than just a knowledge of the number of enemy fighters, the types of missiles they fire, and how high they fly. Those facts are simply tactical or ground intelligence transferred to the air. In order to employ strategic air power it is necessary to have an understanding of the economic structure of a country. Attacking electrical systems demands information, not just on power production, but also on consumption, backup systems, and, most importantly, the projected effects of eliminating electricity. Unfortunately, this type of information is difficult to acquire and has rarely been available.[1]

The planning for World War II offers a good illustration of the problems involved with gathering appropriate intelligence. Prior to the war there was a severe organizational deficiency. General Arnold commented after the war that “looking back on it, I think one of the most wasteful weaknesses in our whole setup was our lack of a proper Air Intelligence Organization.” He continued, “Our target intelligence, the ultimate determinant, the compass on which all the priorities of our strategic bombardment campaign against Germany would depend, was set up only after we were actually at war."[2] Most of the information that was collected by the Air Intelligence section prior to the war was obtained through the New York banks, who had provided the capital for most of the equipment, and the British intelligence agencies.[3] Much of this intelligence, however, was on the supply side of the problem: data such as the number of power plants, electrical capacity available versus the amount used, and the flexibility of the German grid system. What the air planners lacked was information on the effects of the bombing of electric power and an analytical approach that justified attacking this system.[4] This created difficulties because, while the air planners shared common assumptions about how bombing electric power would lead to the capitulation of Germany, they were unable to either express or convince others of this vision.

Since World War II there has been little disagreement on bombing electrical power, especially within the Air Force, but not because of better information. In Korea the Air Force was forced to institute a "crash" program to look for strategic targets and naturally, electric power was an obvious choice.[5] Against both North Vietnam and Iraq, the attacks were undertaken more out of knowledge about the supply of power than because of information about the effects.

In addition to the lack of intelligence about effects, there has also been a lack of awareness of how the enemy will react to this type of attack. In target analysis, just as in science, it has been necessary to assume a static or linear system. But, as scientists are discovering, in the "real" world systems are not static; they are dynamic. This crucial difference means that the calculations and predications made for static conditions are not valid for predicting actual, dynamic events.[6] This dynamic quality is even more accurate when discussing war because, as Carl von Clausewitz noted, "War is not an exercise of the will directed at inanimate matter. . . . In war, the will is directed at an animate object that *reacts*."[7]

There are several ways that a nation can react to attacks on electric power. Given enough prior preparation, it is possible to reduce the vulnerability of the electrical system. This can be done by creating many small generating plants and by interconnecting the generating facilities in the system. These two methods usually take long lead times and are expensive; therefore, most systems will have these programs in place prior to any conflict.

There are other methods for protecting electrical facilities that have been undertaken during war. One is to harden the facilities which house the generators[8] or, as was done in both Germany and Japan during World War II, the use of blast walls around sensitive equipment.[9] Other ways of protecting facilities would include using camouflage or creating underground facilities. The USSBS found one such underground plant in Germany after the war, and there were reportedly five built in North Vietnam.[10] Operators can be trained to react to transfer power quickly; the purchase of spare equipment and a national means for allocating resources for the rebuilding of the system can speed recovery.[11]

All of the above methods are useful in trying to restore power in the national electrical system. But one of the characteristics of a power system that makes it attractive for strategic attack is the fact that it has no storage. How do nations function when power is not available? Part of the solution lies in the fact that while it is not practical to store large amounts of generated power in the same manner as oil or aluminum, there are methods of ensuring that power is maintained to priority users, assuming that some parts of the system are functioning or can be repaired.[12]

The first way of ensuring that electricity is available is to reduce the amount of reserve capacity. Power plants do not normally run at their maximum capacity; therefore, there is a reserve of electrical power available for use. In the United States most power plants typically operate at 60 percent of capacity. Maximum efficiency, which compares costs for operation and maintenance to income, is usually 75 percent of capacity.[13] As a result, there is at least 15 percent of reserve capacity available. Every country will vary as to the amount of reserve capacity available, but some reserve is normally available.

In addition to reserve capacity, power can also be "rationed."[14] One of the first steps a nation will take to ensure that power is available to the critical consumers is to centralize control of the system. For example, in 1939 both Germany and Japan created government ministries to prioritize power distribution and regulate use.[15] In Germany the Central Office of Electric Supply considered measures for saving electricity such as forcing business to operate on off-peak hours and days by using three full shifts. They also sent power saving engineers to plants, curtailed power to low-priority industries, and switched off entire areas. They attempted to voluntarily reduce personal consumption, but later instituted involuntary measures.[16]

In Japan, the Ministry of Commerce and Industry had responsibility for power use and developed programs similar to those in Germany, but much more restrictive. The ministry prohibited the use of certain items that used electricity such as signs, decorative lighting, or the use of elevators in buildings under five floors. They also mandated "electric holidays" among certain industries. In addition, they prioritized the major users of power and fixed quotas for the lower-priority users; any use above the monthly quota was subject to a large surcharge.[17]

Besides conserving electric power, nations can make substitutions for electricity just as with any other resource. Germany compensated by importing power from Switzerland until 3 February 1945.[18] The North Vietnamese, besides using numerous portable generators, also substituted by building hydrodynamic stations to power machinery directly from water flow.[19] In addition, the whole problem of not having power for production can be bypassed by increasing imports to make up for the manufacturing deficit of needed material. The ability to substitute for the loss of power makes it difficult to predict exactly how the enemy will react. As Carl Kaysen wrote in an article about his experiences in intelligence during World War II, "Many substitution possibilities are not discovered or known until necessity forces their discovery."[20]

There is nothing inherently new or different to how a nation will react to an attack on electric power, most of the methods have been done in the past. What is important to remember is that the enemy will react—possibly in the most unlikely way.[21]

When to Target Electric Power

Generation and transmission of electric power follow certain basic laws of physics that are the same the world over, yet systems are often constructed differently. Comparing Germany and Japan during World War II offers some idea of the disparity between national power systems (table 1).[22] At the beginning of the war both countries used about 90 percent of the power for industry and somewhat less than 10 percent for individual household use. Other than this fact, however, the systems were very different. Germany's generating capacity was almost evenly split between public and private facilities, 58 percent to 42 percent. By contrast, Japan had an overwhelming amount of public plants, 87 percent, as compared to 13 percent private. However, production of electricity was greater in Germany, 86-billion kilowatt-hours versus 38.4 billion in Japan.[23]

Geography and national resources played a key role in the design of the two nations' power systems. Germany's greatest resource was coal, thus it is no surprise to find out that 80 percent of German power plants were fueled by coal. In contrast, Japan's topography and lack of natural fossil fuels dictated a dependency on hydroelectric power. The Japanese used both traditional

Table 1

Comparison of German and Japanese Electric Systems

	Germany (1939)	Japan (1943)
Production in kilowatt-hours	86 billion	38.4 billion
Generating Capacity	57.9% public 42.1% private	87% public 13% private
Fuel source	80.2% coal 20% hydroelectric	18% coal 82% hydroelectric
Consumption	92% industry 6.4% households, buildings	92% industry 8% households, lighting

hydroelectric dams and stream-flow plants which harnessed the power of a river directly.

Although Japan did have most of the capacity in this hydroelectric capability during certain parts of the year, mainly the dry season of January, February, and March, the system was heavily dependent on the thermal plants to supplement the loss in power due to the reduced flow in the rivers. Thus, an attack on the thermal plants would have had a much greater impact on the Japanese economy in February than in August.

Another difference in the Japanese system that surprised the USSBS inspectors was the amount of spare equipment available. The team members noted, "The entire Japanese utility system is over equipped by American standards, with spare generating, transforming, and instrument units" and there was a "much higher availability of replacement [parts] than would be expected on the basis of American or European practice."[24] Examining the differences in the German and Japanese power systems underlines the differences that can exist between power systems and the problem with assuming that because the physical characteristics are similar the cultural ones will be also.

In assessing a nation's vulnerability to losing power, the dispersion of the generating facilities and the interconnections within the country must be analyzed. Simply put, the more dispersed the generating facilities, the harder it is to attack the electrical power system. The greater the number of plants, the less power each one contributes to the system, and eliminating a few plants does little to affect the total output. The dispersion of the Japanese power system was a key reason why it was not attacked. Likewise, the EOU analysis, although mistaken, rejected the German power system in part because they thought it was very dispersed. Determining the dispersion of a nation's electric power grid is relatively simple and extremely important. Many nations have highly concentrated electrical systems—for instance, eliminating 25 plants might destroy 75 percent of the national power system, or in a large country, 50 of the biggest facilities may supply half of the national power. Other systems are more widely dispersed—for example, in China, an attack on 100 of the biggest plants would affect only one-quarter of the power capacity.[25] Determining how a country's system is interconnected is not so easy.

As mentioned earlier, power facilities are primarily interconnected for reliability—to allow power to be transferred from areas with a surplus to areas that are experiencing difficulties.[26] If only a portion of a country's generating capacity is eliminated, it would still be possible to get power to the affected area from undamaged facilities further afield, as long as the transmission system is working. Thus, interconnections of the national power grid allow each generating plant to serve as an emergency power center for every other area. The assumption by the Committee of Operations Analysts and the Enemy Objectives Unit during World War II that Germany had a very interconnected system was a key reason for their not recommending the German power system as a priority target.

More fundamental than deciding the vulnerability of the system, however, is knowing the strategy behind the attacks because this determines when striking these facilities is likely to be effective in achieving the goals of the air campaign. There have been four basic strategies used, either separately or in combination, to justify attacks on electric power: to influence the will of the people; to raise the costs to the leaders; to produce direct military effects; and to impact war production (table 2). Highlighting each strategy provides insight into when it should be attacked in the future.

Table 2

Case Studies

Case	Amount Destroyed	Effects	Actual Impact
Air Corps Tactical School	100% (planned)	Morale—high Cost to leaders—low Forces—low Production—medium	Theory Only
WW II—Germany	Not attempted	Morale—high Costs to leaders—low Forces—low Production—medium	Not attempted
WW II—Japan	Not attempted	Morale—medium Costs to leaders—low Forces—low Production—high	Not attempted
Korea	90%	Morale—medium Costs to leaders—high Forces—low Production—medium	Little—support from outside countries, increase in imports. Did not pressure North Korea into peace.
Vietnam	85–90%	Morale—medium Costs to leaders—high Forces—low Production—medium	Little—increase in foreign aid; substitution efforts. Did not stop NVN support of Vietcong.
Iraq	Over 90%	Morale—medium Costs to leaders—medium Forces—high Production—low	Not known; perhaps temporary confusion, but no paralysis.

Legend:

HIGH: Primary effects sought by air planners in attacking electricity and its impact on ending the war.
MEDIUM: Other "bonus" effects anticipated by air planners.
LOW: Either not anticipated or inconsequential.

Attacks on Morale

One of the most persistent assumptions among air planners has been the belief that depriving civilians of electricity will lead to a change in a nation's policy. This notion drove the ACTS strategic targeting policy and has been an enduring thought in the justification for bombing electricity in every war since. The belief in electric power as the panacea target for affecting civilian morale stems in part from the ubiquitous nature of electricity in American society. The United States accounts for 35 percent of the generating capacity in the world. In addition, our per-capita usage is among the highest in the world—double the consumption of other industrialized countries, such as Germany, Japan, and the United Kingdom.[27] Although daily life without electricity is almost unthinkable for an American, the problem is that in other areas of the world where electricity is not used as much, its loss would not be as catastrophic as in America. Oliver Todd, a journalist who visited Hanoi during the Vietnam War, summed it up best when he observed that "to a Western, so-called developed society, cutting our electricity means something. It doesn't mean very much in Vietnam. The Vietnamese for years and years have been used to living by candlelight or oil lamps."[28] Cutting electricity will not always have the same disastrous effect in other countries as in America.

There is still a more basic problem with attacking morale—it rarely succeeds in achieving the overall objective. While bombing attacks can lower morale in terms of attitude, causing populations to become apathetic, these changes do not influence behavior. For example, bombing in World War II did lower morale. Moreover, this decline was in direct proportion to the amount of civilian deprivation, caused in large part by the loss of electricity.[29]

Despite the decrease in civilian morale, studies after World War II showed that active opposition to the current government policy was infrequent and that bombing electrical power to produce a change in civilian morale did not bring about a change in government policy.[30] Ultimately then, air planners must decide if eliminating electricity will have any impact on lowering civilian morale, and if so, if it will actually influence the political leadership toward the desired objectives.

Attacks to Influence Leaders

Attempts to influence the political leaders of a country by depriving the civilians of electricity or by destroying the costly equipment in a power plant is usually associated with a strategy of increasing costs on the leadership to force a change in policy. This was the justification for attacking electric power in Vietnam and Korea, and in neither case was it successful, nor is it likely to be successful in the future.

There are several reasons why this strategy fails. The first is nationalism and the high resolve most nations have in any conflict, which tends to undermine the usual calculus of cost versus benefits that may seem applicable to nations outside of the conflict. If the area or issue in question is of high national interest, then the damage inflicted on electric power will not likely exceed the costs that the leaders of a country are willing to pay.[31] In addition, once national leaders become committed to a course of action, they are reluctant to change. Such a change could mean the loss of prestige and political power, which they may fear more than "losing" the war. Rather than admit certain defeat in domestic politics, they would rather continue the present course of action despite the bombing.[32]

A more practical consideration is that political leaders are generally well insulated from the loss of the national power system. As the official USAF bombing survey from Linebacker II noted, "An air campaign against the electrical power system of a country should not have as an objective the total cutoff of power. All critical elements of military and government agencies have alternate means of generating electric power."[33]

The loss of electric power is not likely to exceed the cost the political leadership is willing to pay. Coupled with government and military insulation from the loss, it seems unlikely that national political leaders will be convinced to change their policy because of an attack on electric power.

Attacks for Military Effects

An attack on electricity to directly affect the military forces of a country is a new phenomenon, having been used for the first time in the war against Iraq. This is primarily a reflection of how much more dependent the military is on electricity to perform activities, such as powering air defense radars and communications, than in the past. In contrast, during World War II attacks on electric power for military effects were specifically rejected because of the length of time between an attack and the impact on military operations.

While striking electrical power plants might be useful as a tactical measure to create temporary confusion, such attacks will have only a minimal long-term impact, because the military, as a priority user, will have access to whatever power is available in the national grid and will also likely have emergency power systems. Even in Baghdad, where the lights went out minutes after H-hour, it is not clear if that was a direct result of the attacks on the electric system or an Iraqi defensive reaction, and what, if any, long-term impact it had on military operations. No doubt the attacks against the Iraqi power system did cause some confusion in the Iraqi military, but exactly how well that advanced the goal of strategic paralysis on the Iraqi leadership is still not clearly known.[34]

William C. Arkin of Greenpeace International investigated the bomb damage in Iraq after the war and believes that the strategic bombing of Iraq made little difference to the outcome.[35] According to Arkin, "The air war was clean on a strategic level, but irrelevant to the defeat of the Iraqi army."[36] The attack on electric power and the indirect collateral damage inflicted has caused others to question the target selection plan of the Gulf War as well. In *The Gulf Conflict and the New World Order*, Lawrence Freedman and Efraim Karsh state, "The aspects of its [USAF] campaign most directed against Iraq's economic and political structure (i.e., electric power) seems to have been the least relevant to the ultimate victory."[37]

Attacks on Production

The strongest argument for attacking electrical power is to stop or slow down war production. The industries that make war goods are usually very dependent on electric power, and many processes are simply not possible without this resource. In most countries, the majority of the electricity generated is used in the manufacturing process.

The USSBS analysis after World War II recommended attacks on electric power, but only in the context of affecting war production, which can be an important factor in winning a war, over the long term, against a country that cannot import.[38] Therefore, bombing electrical power to affect war production is most effective in a total war of attrition against a major power. Likewise, in a war of short duration, where the enemy has stockpiled war material, stopping war production will have minimal impact on winning the war. In a limited war, against a small nation with outside support, attacking electrical power to halt war production will not have much impact because of the ability of the nation to substitute for the loss of power by increasing imports and dispersing manufacturing, as North Korea and North Vietnam demonstrated when their power systems were eliminated.

Conclusions and Implications

Strategic attacks on national electrical power systems can be useful in fulfilling national security aims, but only under specific conditions. First, the target country's power system should be vulnerable to destruction by being very concentrated with very few interconnections. Second, the strategy behind the attacks should be focused on stopping war production over the long term. To strike electric power to affect civilian morale, increase costs to the leadership, or impact the military will waste missions and could prove counterproductive to the political aims of the war.

The problem with attacks on electric power is the potential negative political impact of causing indirect collateral damage to the civilian population. There are some actions in attacking electrical power such as breaching a hydroelectric dam or bombing a nuclear generator that would be successful at interrupting power, but would not be considered because of the negative political impact generated. Although dams have been attacked in the past, in the current political climate and with the limited nature of modern war, it seems unlikely that these attacks would be considered as a means of eliminating electrical power.

Similarly, the indirect effects to civilians in Iraq as a result of the bombing of electric power have raised questions at home and abroad. The official response is that although the attacks were more thorough than planned, they were nonetheless necessary and the postwar suffering of the Iraqi people is the fault of Saddam Hussein.[39] Certainly this is true from the legalistic point of view, for the defender and the attacker both bear an equal responsibility for the protection of civilians; but the practical fact is that the negative impact of these attacks on world opinion far outweighed the military benefits accrued by bombing electrical power in Iraq.[40] The implication is clear—national electrical systems are not a viable target. If the wars of the near future will be limited wars and not total wars of attrition, then attacks on electric power should not be considered. Although national power systems are vulnerable to air attack, the military is largely insulated from a loss of power, and civilian discomfort has not been shown to influence government policy. If the true aim of eliminating electricity is to affect other systems, such as communications or computers, then the time and effort would be better spent concentrating on the intelligence and methods for attacking these systems. In future strategic air operations, the targeting of national power systems has little utility.

Notes

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21. Beyerchen, 72–75.

22. These statistics are drawn from two USSBS reports, *The Effects of Strategic Bombing on the German War Economy* and *The Electric Power Industry of Japan, Electric Power Division*.

23. The German figures for power production are from 1944 while the Japanese figures are 1943 statistics. The main difference is that Germany produced a much greater amount of electricity than Japan.

24. USSBS, *Electric Power Industry of Japan*, 29.

25. Richard I. Brody, *Regional Conventional Deterrence and TLAM* (Unpublished paper, Strategic Policy Analysis Group, Center for Naval Analysis, 31 July 1992).

26. Eugene Gorzelnik, North American Electric Reliability Council, telephone interview with author, 14 April 1993; and *Electricity Transfers and Reliability* (Princeton, N.J.: North American Electric Reliability Council, October 1989).

27. Donald G. Fink and H. Wayne Beaty, eds., *Standard Handbook for Electrical Engineers*, 12th ed. (New York: McGraw-Hill, Inc., 1987), 16-2, 16-3. The only two nations with a higher per-capita number of kilowatt-hours are Canada and Sweden. In the case of Canada, at least, much of the power that is produced there is exported to the United States.

28. Mark Clodfelter, *The Limits of Air Power: The American Bombing of North Vietnam* (New York: Free Press, 1989), 136.

29. Irving L. Janis, *Air War and Emotional Stress*, Rand series, reprint ed. (Westport, Conn.: Greenwood Press, Publishers, 1976), 145–46.

30. Ibid., 147–49, 151–52.

31. Robert A. Pape, Jr., "Coercion and Military Strategy: Why Denial Works and Punishment Doesn't," *The Journal of Strategic Studies* 15, no. 4 (December 1992): 432–33.

31. Ernest May, *Lessons of the Past* (Oxford, England: Oxford University Press, 1976), 125–42.

33. Herman L. Gilster and Robert E. M. Frady, *Linebacker II USAF Bombing Survey* (Headquarters Pacific Air Forces: April 1973), 12.

34. Gosline interview; and Col John A. Warden interview with author, Air Command and Staff College, 7 December 1992.

35. "Tactical Bombing of Iraqi Forces Outstripped Value of Strategic Hits, Analyst Contends," *Aviation Week & Space Technology* 136, no. 4 (27 January 1992): 62–63.

36. Ibid.

37. Lawrence Freedman and Efraim Karsh, *The Gulf Conflict and the New World Order* (Princeton, N.J.: Princeton University Press, 1993), 437.

38. USSBS, *Summary*, 14; and USSBS, *German Electric Industry*, 3, 46–51.

39. "Strategic Campaign Focused on Targets and Cut Casualties, Pentagon Maintains," *Aviation Week & Space Technology* 136, no. 4 (27 January 1992): 64–65.

40. I am not arguing that the number of postwar casualties is correct; in fact, I believe they are well above the number actually caused by the loss of electricity. These numbers are based on a survery of 9,034 households and not the actual number of cases in hospitals. This methodology is in International Study Team, *Health and Welfare in Iraq*. This study also did not take into account the restoration of electricity, which—according to the *Gulf War Airpower Survey*—occurred despite the UN sanctions by the summer of 1991. The numbers also seem exaggerated in comparison with the figures from World War II. For example, in Japan during 1944 approximately 4,600 people died of dysentery and typhoid (based on a population of 13 million, and death rates per 100,000 per year, of 14.3 and 20.8), in the same year there were a total of 33,000 cases of dysentery and typhoid, see USSBS, *Health and Medical Services in Japan*, 159–64. Based on an Iraqi population of 18 million, 70,000 deaths would equal a death rate of 388 per 100,000—almost 20 times that of Japan in 1944. Regardless of the accuracy of the figures from the Gulf War, the fact remains that the perception among many people is that these deaths were preventable.

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