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POLAND: AN ENERGY AND ENVIRONMENTAL OVERVIEW

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SECTION 1:

OVERVIEW

1 ENVIRONMENTAL AND ENERGY HIGHLIGHTS

1.1 STATEMENT OF THE PROBLEM

Poland's reliance on coal as its primary source of energy imposes heavy environmental costs on its economy and population. Specifically, many of Poland's air and water pollution problems can be traced to the high energy intensity of Polish industrial production. Substantial costs are imposed on the economy as a whole because of losses in productivity and work time associated with ill health and the rapid deterioration of buildings and capital equipment that results from the effects of acid rain and acid-rain precursors, saline water, and airborne particulates.

The coal-mining industry discharges large quantities of untreated saline water into the two main river basins, the Vistula (Wisla) and the Odra, and the burning of coal leads to very poor levels of ambient air quality in major population centers. Upper Silesia in southern Poland, which is the center of the mining industry as well as the location for major industrial plants, is one of the most polluted regions in Europe.

Eastern European nations that burn large volumes of coal and lignite do virtually nothing to control pollution. It should be possible (and, of course, very desirable) to reduce the extent of pollution by managing existing coal-burning plants better, installing flue-gas scrubbing equipment (which admittedly could be expensive), applying coal-beneficiation techniques, and/or introducing the clean coal technologies (CCTs) that are being developed in the United States and abroad to reduce emissions from power plants. Moreover, significant environmental and economic improvements might be achieved by promoting greater energy efficiency and modifying patterns of fuel use; to achieve these improvements, a reduction in the use of domestic coal and electricity, combined with an increase in the consumption of imported gas and perhaps petroleum products, is implied.

Coal and lignite production and consumption appear to be the most significant sources of sulfur dioxide (SO_2) emissions, contaminated water effluent, and airborne particulates. However, to date, the energy sector is unable to reduce these emissions because it lacks three items:

- Incremental energy supplies for its highly energy-intensive industries,
- Investment funds to increase energy exports, and
- Capital and operating funds to implement environmental protection and energy conservation.

1.2 CURRENT SITUATION IN POLAND

As these two quotes exemplify, a variety of issues make the current situation in Poland more than an interesting topic of study.

> Over the mountains, where the borders of Poland, GDR, and Czechoslovakia meet, and across the valley hangs a thick grey mist shrouding the hilltops. Mile after mile of stunted birch trees and brown conifers suggest that the mist is an acid-rain smog (Kratochvil 1990).

> Pollution's threats to health are ubiquitous. A young woman, university-educated, worries about feeding her son vegetables grown in her parents' garden, ten miles from Warsaw. Last year, poisonous gas escaped from the local chemical plant. "Nobody has said whether it is safe to eat them again. But vegetables are so hard to come by these days" (Economist 1990).

The first five issues stated below relate to energy.

1. The country exhibits a high dependence on domestic coal production -- for primary energy consumption and for employment purposes.

2. Poland remains dependent on the Soviet Union for *all* its imported oil and gas supplies.

3. Plans for nuclear power plant construction and operation had been postponed and recently have been cancelled altogether.

4. Electric power generation and heavy-industry power consumption continue to demonstrate an extremely inefficient use of energy; in addition, desulfurization equipment in power plants is virtually unknown.

5. The Polish government has recently introduced a number of steps to establish a market-based economic system. Given that the public sector has demonstrated a lack of resources to rationalize the power sector, this introduction could open the door to private participation in the power sector.

The next three issues are associated with the environment.

6. Poland continues to experience a steady deterioration in air quality with frequent smog episodes -- the highest SO_2 emissions have been recorded in the vicinities of Krakow, Katowice, and Warsaw.

7. Contamination of its ground and surface waters (flowing from the southern cities northward to the Baltic Sea) increases daily from the dumping of untreated human sewage and industrial wastes.

8. Over the years, Poland's soil has become laden with excessive levels of heavy metals, especially lead and cadmium, contributing to contaminated crops (especially in Silesia) and pervasive forest damage (especially along the southern and southwestern borders).

Two other areas of concern are related to human health and materials.

9. Medical investigations continue to link an increasing volume and variety of industry-related human illnesses (e.g., cancer and circulatory and respiratory illnesses) to the environmental situation in Poland, contributing to decreasing life expectancy.

10. Damage to cultural resources and buildings from airborne emissions and particulates, especially in southern Poland, has been noted. For example, 95% of the historical buildings in the Old Town of Krakow are deteriorating, and railroad tracks near Katowice are so corroded that trains must not exceed 25 miles per hour.

In January 1990, Poland published a list of its 80 worst polluters, most of them in the mining-industrial area of Upper Silesia. The government is expected to publish a schedule for cleanup by these polluters within a four-year time frame (JAWMA 1990).

Dr. Bronislaw Kaminski, Poland's Minister for Environmental Protection, Natural Resources, and Forestry, recently visited the United States to meet with the administrator of the U.S. Environmental Protection Agency (EPA) and officials of the U.S. Agency for International Development (A.I.D.) to discuss a proposed loan from the World Bank for $20 million to improve Poland's environmental management practices. He told a U.S. press conference in March 1990 that cleanup of his country's environment would cost $20 billion* -- a tremendous sum for any economy -- and would require 15 years. He projected that Poland will rely on market forces to begin to drive its environmental protection, and stated that it has set targets for a 25% drop in energy consumption, a 50% drop in water consumption, and a 50% drop in sulfur emissions. These targets may be unattainable, however, given Poland's economic status (JAWMA 1990).

According to Minister Kaminski, pledges from foreign governments to aid in Poland's environmental cleanup have now reached $200 million, including $65 million from 24 Organization for Economic Cooperation and Development (OECD) countries, $45 million from Sweden, $35 million from the United States (A.I.D.), and $30 million from the Netherlands. Japan has sent environmental missions to Poland to study flue-gas desulfurization, desalinization of mining-waste waters, a national environmental monitoring system, and upgrading of Poland's steel works, but it has made no financial pledge (JAWMA 1990).

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*All costs mentioned in this report are in U.S. dollars unless stated otherwise.

1.3 REPORT FOCUS AND ORGANIZATION

This report provides an overview of the environmental situation being experienced by Poland, particularly with respect to air quality. Section 2 (Chaps. 3-8) presents Poland's energy picture, discussing resources, production, trade, consumption, electricity generation, and sectoral end use. Section 3 (Chaps. 9-20) presents the main topic of the report. It describes Poland's air pollution status, focusing on trends in emissions of SO_2, nitrogen oxides (NO_x), and carbon dioxide (CO_2). Section 4 (Chaps. 21-28) provides some strategies for consideration in ameliorating the environmental problems discussed. The appendix provides detailed data on Poland's public power stations.

However, before these significant environmental issues are introduced and developed, the next chapter (Chap. 2) lists a number of items that would affect research and development (R&D) activities in Eastern Europe. These items relate to ongoing efforts and new U.S. legislation. They address the application of new energy technology in Poland and transboundary pollution in the region. These items are presented before the energy picture and the environmental status are discussed in order to demonstrate that positive activities are under way.

2 WESTERN INVOLVEMENT IN TECHNOLOGY AND RESEARCH ACTIVITIES

The reader should be aware of a number of items in a recent piece of U.S. legislation -- the SEED Act of 1989 -- that affect technology and research activities in Eastern Europe.

1. Under congressional legislation already enacted (Public Law 101-179, Nov. 28, 1989), the U.S. Secretary of Energy is authorized/instructed "to cooperate with Polish officials and experts to retrofit a coal-fired commercial power plant in Krakow with advanced clean coal technology that has been successfully demonstrated at a comparably scaled power plant in the United States" (U.S. Congress 1989).

   Congress has appropriated $10 million for the project this year. Under an agreement signed with Poland in March 1990, the U.S. Department of Energy (DOE) is expected to issue a competitive solicitation for proposals to install advanced retrofit pollution-control technology on a 50-MW coal-fired boiler at the Skawina power plant near Krakow. "The technology should be capable of reducing SO_2 emissions by at least 70%, should be broadly applicable throughout Poland, and should have been successfully demonstrated at a comparable scale" (Inside Energy 1990). The purpose of this project is to produce a prototype retrofit for applications throughout Poland (CWI 1990b).

2. Under that same legislation, the U.S. Secretary of Energy is instructed to assist "officials of Poland and Hungary in improving the efficiency of their energy use, through emphasis on such measures as efficient motors, lights, gears, and appliances and improvements in building insulation and design."

3. Furthermore, the U.S. Secretary of Energy is instructed "to cooperate with Polish officials and experts and companies within the United States to assess and develop the capability within Poland to manufacture or modify boilers, furnaces, smelters, or other equipment that will enable industrial facilities within Poland to use fossil fuels cleanly."

4. In recognition of "the severe pollution problems affecting Poland and Hungary and the serious health problems which ensue from such pollution," the U.S. EPA administrator "is authorized to undertake such educational, policy training, research, and technical and financial assistance, monitoring, coordinating, and other activities . . . as appropriate, either alone or in cooperation with other U.S. or foreign agencies, governments, or public or private institutions, in protecting the environment in Poland and Hungary."

5. The U.S. EPA administrator is instructed to "cooperate with Polish officials and experts to:

   a. Establish an air quality monitoring network in the Krakow metropolitan area as a part of Poland's national air monitoring network and

   b. Improve both water quality and the availability of drinking water in the Krakow metropolitan area."

6. Moreover, the U.S. EPA administrator is instructed to "work with other U.S. and Hungarian officials and private parties to establish and support a regional center in Budapest for facilitating cooperative environmental activities between governmental experts and public and private organizations from the United States and Eastern and Western Europe."

More recent U.S. legislation -- the Fiscal Year 1991 Appropriations Act for Foreign Operations, Export Financing, and Related Programs -- has authorized a total of $320 million for assistance to Eastern Europe to carry out the provisions specified in the 1989 SEED Act (U.S. Senate 1990; U.S. House 1990a, 1990b). A number of the items in this appropriations bill have special relevance to the energy and environmental situation in Poland and include the following:

1. The provision of $75 million for environmental and energy activities, with emphasis on policies encouraging end-use energy efficiency, least-cost energy planning, conservation, and renewable energy resources. No more than 50% of this amount can go to any single country in Eastern Europe.

2. The allocation of $72.5 million for the Polish-American and Hungarian-American Enterprise Funds to be administered by the U.S. A.I.D.

3. The appropriation of $65 million for other private enterprise activities.

4. The stipulation that A.I.D. should continue to give high priority to activities to combat global warming, particularly through end-use energy efficiency initiatives in Poland and through assistance in the development of its national energy conservation program. The legislation states that the A.I.D. Office of Energy is best suited to carry out such a program and provides not less than $30 million to A.I.D. to support the "Global Warming Initiative." Not less than $20 million is earmarked for the A.I.D. Office of Energy.

5. The allocation of $1.5 million for a renewable energy prefeasibility study fund for Eastern Europe and other regions to be conducted by A.I.D.'s Office of Energy in conjunction with other agencies.

Some other items also affect technology and research activities in Eastern Europe.

1. Applied Energy Services (AES) Transpower (an affiliate of the AES Corp.) has been awarded a feasibility grant by the U.S. A.I.D. Office of Energy to cofund an examination of the potential for refurbishment and modernization of the Zeran Thermal Power Project in Warsaw.

2. A Swedish firm, ABB Carbon, which is an Asea Brown Boveri affiliate specializing in pressurized fluidized-bed combustion technology, is considering the potential penetration of Poland with respect to the combined heat-and-power (CHP) cogeneration sector. ABB Carbon signed a letter of intent with Poland's Joint Power and Lignite Board to equip a proposed cogeneration plant with 130-MWe and 120-MWt generating capacity (CWI 1990c).

3. Bilateral-support programs are being established, such as the Foundation for Environmental Contact between Poland and the Netherlands, which is for information exchange, and the Swedish-Polish Environmental Federation (SPM), which is providing funds for monitoring the Vistula, fuel switching in historical dwellings in Krakow, and air pollution monitoring in Krakow, as well as information exchange. In addition, Sweden has committed significant financial resources toward the installation of flue-gas desulfurization equipment at Polish coal-fired power plants.

4. Several U.S. utilities have recently considered the prospect of joining together as partners with the North American Energy Corp. of Maryland to form the North American Energy Partners (NAEP). This partnership would then attempt various U.S./Polish joint ventures, in which NAEP would hold a majority interest. Projects under investigation include the installation of pollution-control equipment on existing plants, expansion of electricity generation, construction of a coal-preparation plant, and addition of district heating capacity.

SECTION 2:

ENERGY RESOURCES, PRODUCTION, AND USE

3 COAL RESOURCES*

3.1 RESERVES

Located on the North European Plain between the Baltic Sea and the Carpathian Mountains, Poland has substantial reserves of both hard coal and lignite (brown coal). According to the U.S. DOE/Energy Information Administration (EIA), Poland ranks seventh in the world in coal reserves, with recoverable hard-coal reserves of 42.6 billion tonnes (Gt) (Table 3.1). Estimated hard-coal reserves total about 164 billion tonnes, with proven (measured) hard-coal reserves of 63 billion tonnes (DOE 1989).

Hard coal is found primarily in the Upper Silesian Basin in southern Poland (Fig. 3.1), but some resources are also found in the Lower Silesian Basin (southwest Poland) and the Lublin Basin (southeast Poland). In Upper Silesia, more than 55 billion tonnes (World Bank 1987b) of hard coal are considered by the Poles to be technically and economically extractable (proven) from six mining areas; of that volume, more than 36.5 billion tonnes (66%) possess steam-coal characteristics, while about 19 billion tonnes (34%) are considered to be of metallurgical quality (Table 3.2). Nearly 7 billion tonnes of proven hard-coal reserves, characterized predominantly (85%) as steam coal, can be found in the Lublin Basin, Poland's most recently developed region; only 410 million tonnes of proven reserves are located in Lower Silesia, a region in which reserves are being depleted. On the basis of these reserves, Poland is expected to be able to produce hard coal for at least 200 years. Thus, given its very limited oil and gas resources, it is not surprising that Poland is primarily a coal-fueled nation.

TABLE 3.1 Coal Resources in Poland (Gt)

Resource	Estimated Reserves	Proven/ Measured Reserves	Recoverable Reserves[a]
Hard coal	164	63	42.6
Lignite	30	12	3.0

[a]Recoverable refers to reserves that are recoverable by existing mining techniques and are of commercial quality.

Sources: DOE 1989; World Bank 1987a.

*In this report, metric tons are referred to as tonnes or by the appropriate abbreviation: t for tonnes, kt for thousand tonnes or kilotons, Mt for million tonnes or megatons, or Gt for billion tons or gigatons. An "oe" after the abbreviation means oil equivalent; "ce" means coal equivalent defined at 12,600 Btu/lb.

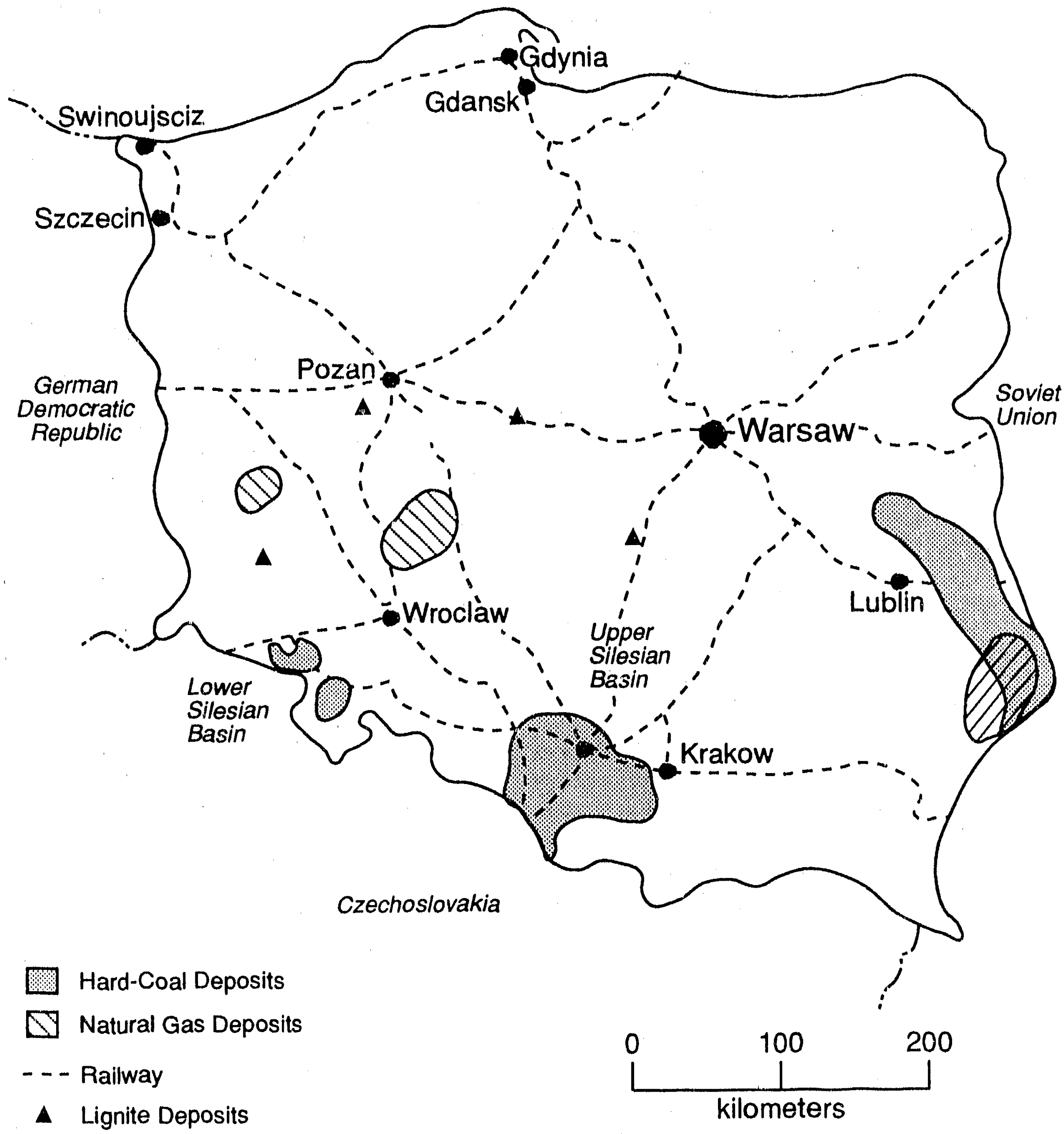

FIGURE 3.1 Location of Main Coal Mines, Natural Gas Fields, and Railways in Poland [Sources: Doyle (1989); Encyclopedia Britannica (1979)]

TABLE 3.2 Proven Coal Reserves in Poland (Gt)

Coal Type and Source	Metal-lurgical	Steam	Total	%
Proven hard coal				
Upper Silesia	19.040	36.539	55.579	88.3
Lower Silesia	0.228	0.182	0.410	0.7
Lublin	1.023	5.904	6.927	11.0
Total proven			62.916	100.0
Lignite (brown coal)				
Recoverable				
Belchatow/Szczercow			1.780	58.4
Adamow			0.152	5.0
Konin			0.408	13.4
Turow			0.704	23.1
Sieniawa			0.005	0.2
Total recoverable			3.049	100.0
Other resources				
Under exploration			1.460	
Prospective			7.909	
Total other			9.369	
Total proven			12.418	

Source: World Bank 1987a.

Existing hard-coal reserves are associated with geological conditions that make mining difficult. The coal is mined deep underground; no hard-coal deposits are considered suitable for open-pit mining, as are lignite deposits. These hard coals are high-volatile bituminous in rank, with sulfur contents of about 1%. The average calorific value for steam-coal production is 5,300-5,600 kcal/kg (9,540-10,080 Btu/lb). Lublin coal is especially deep, hard to mine, and high in sulfur.

Substantial reserves of lignite, about 30 billion tonnes (Table 3.1), are scattered throughout central and western Poland (near Poznan and Legnica), with 12 billion tonnes measured. Recoverable lignite reserves of 3 billion tonnes that are considered economically mineable are located in operating mines or adjoining areas. Most lignite is currently being mined in the central region, the Belchatow/Szczercow area, where approximately 1.8 billion tonnes of recoverable reserves are estimated to reside (Table 3.2) This volume represents about 58% of Poland's 3.0 billion tonnes of recoverable lignite. About 1.2 billion tonnes of lignite reserves are located at four other mining areas, representing about 53 small lignite deposits (not in table). These lignite deposits are surface mined and are characterized by relatively low calorific values of

1,900-2,100 kcal/kg (3,420-3,780 Btu/lb), moisture contents of about 50%, ash contents of 10-15%, and sulfur contents of 0.2-1%. Surface mining of lignite is in direct competition with agricultural production in some areas.

3.2 PRODUCTION CAPACITY

Poland is the fourth largest producer of hard coal in the world, after the People's Republic of China (PRC), the United States, and the Soviet Union (DOE 1989). Recent hard-coal production capacity has exceeded 190 million tonnes per year (Mt/yr), with 186 Mt/yr from the Upper Silesian Basin (Table 3.3). Less than 3 Mt/yr is mined in Lower Silesia and less than 1 Mt/yr in the Lublin area. All mines are highly mechanized; longwall mining predominates. Of the seven mines under construction, five are located in Upper Silesia and two are located in the Lublin area.

Lignite production stands at approximately 80 Mt/yr (Table 3.3). Lignite is used solely for domestic consumption, primarily at mine-mouth power stations. Belchatow production has increased from 24 Mt/yr to more than 38 Mt/yr in the last few years, because mine expansion continues to produce coal to be burned in twelve (360-MW) mine-mouth power plants.

From 1976 through 1985, the average annual growth rate for domestic hard-coal consumption was 2.1%. Hard-coal production, after peaking at 201 million tonnes in 1979, declined and apparently stabilized near 185-190 Mt/yr. However, production in 1989 attained only 177.4 million tonnes because of the uncertainty of the fledgling free-market economy, the miners' lack of interest in Saturday overtime, the failure of mine management to invest in new machinery, and ever-decreasing mine-seam thicknesses (ICR 1990a). Polish coal production in the first quarter of 1990 totaled 42.2 million tonnes, compared with 47.5 million tonnes for the same period in 1989. Four mines switched to a four-day work week, and the Jaworzno mine recently reduced its work force from 8,300 to 4,000 (Energy Economist 1990).

According to ICR (1990a), any disruption in production, such as that experienced in 1980 and 1981, would probably be largely absorbed by a decline in exports. Exports in 1989 totaled 28.2 million tonnes, a decrease of 4 million tonnes from 1988. If output were to slump to 157.5 million tonnes (a figure reported by the Communist paper *Trybana Ludu*), exports to Eastern Bloc countries would probably fall to 5 million tonnes, and deliveries to the West would cease. The cost to the trade balance would be $700 million (ICR 1990a).

3.3 EXPORTS

Poland is the fifth largest coal exporter in the world, behind Australia, the United States, South Africa, and Canada (DOE 1989). During the last four decades, an average of 20% of the hard coal produced in Poland -- approximately 35 Mt/yr -- was shipped abroad, providing 10-15% of Poland's income in foreign exchange, a prime source of foreign currency (Imielski 1989).

TABLE 3.3 Coal Production Capacities in Poland (Mt/yr)

Coal Type and Source	Mining Area	Current Production Capacity	Capacity under Construction
Hard coal			
Upper Silesia	Jaworznicki/Mikolowskie	39.0	
	Dabrowskie	23.5	
	Katowickie	28.5	
	Bytomsko/Rudzkie	29.0	
	Zasbrzanskie	29.0	
	Rybnicko/Jastrzebski	37.0	
	Czeczott		7.2
	Budryk		6.0
	Krupinski		2.4
	Morcinek		1.8
	Warsowice		3.6
Lower Silesia	Dolnoslaskie	2.7	
Lublin	Lubelski/Chelmskie	0.7	
	Bogdanka		2.4
	Stefanow		3.0
Total hard		189.4	26.4
Lignite	Belchatow	38.5	
	Turow	24.0	
	Konin	13.5	
	Adamow	4.5	
	Signiawa	0.2	
Total lignite		80.7	

Source: World Bank 1987a.

In recent years, neighboring Eastern Bloc countries have received 45-50% of Poland's exports, and 40-45% of the exports have gone to Western Europe (Imielski 1989). In 1988, the Soviet Union imported 11.7 million tonnes of Polish coal, predominantly steam coal for the Baltic and Moldavian power stations and factories; Czechoslovakia received 1.7 million tonnes and Romania 1.3 million tonnes, with lesser quantities going to the German Democratic Republic (GDR, East Germany)* and Hungary (ICR 1990c). As domestic demand increases, however, exports will probably decrease, since hard-coal production is constrained (and has been declining), unless interfuel competition from oil or gas imports is allowed to occur.

Volumes of export coal fell from a record 43 million tonnes in 1984 to 36 million tonnes in 1985 (Petroleum Economist 1987) and to 32 million tonnes in 1988 (ICR 1990a). In 1989, 28 million tonnes were exported, as a result of a mild winter, which allowed power stations to reduce consumption, and reduced domestic consumption because of a sevenfold increase in the price of coal (ICR 1990b). Only 15-22 million tonnes of coal are expected to be exported in 1990, honoring 14 million tonnes in commitments to Eastern Bloc countries and 6 million tonnes of long-term contracts to Western buyers (ICR 1990a).

3.4 IMPORTS

Currently, no significant coal imports occur except for cross-border exchanges estimated at 1.0-1.2 Mt/yr. This coal is metallurgical coal imported from the Soviet Union for the huge Soviet-built steelworks at Nowa Huta (ICR 1990c).

3.5 INDUSTRY STRUCTURE

Recently, the Polish coal-mining industry was reorganized, giving the mines more independence as state enterprises. Previously, under the Wegiel Polski organization, mines had been organized into groups, with 10-14 mines per group. On December 12, 1989, a government decree liquidated coal-mine groupings, allowing independent mines to act primarily on their own financial resources, even though some subsidies will be maintained. As a result of reorganization, increases in domestic coal prices were expected, leading to higher electricity prices (CWI 1989).

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*This report was written before German unification.

4 NONCOAL RESOURCES

4.1 ENERGY RESOURCES

Poland's total oil and gas reserves are estimated at 772 million tonnes oil equivalent (Mtoe) or 1,096 million tonnes coal equivalent (Mtce) (Table 4.1). Less than half of these reserves, 351 Mtoe (499 Mtce), is considered proven. Less than 165 Mtoe is considered recoverable.

Most of these reserves consist of nonassociated gas and are concentrated in the Midlands [91 billion cubic meters (Gm^3)] and the South East Basin (62 Gm^3). The Midlands reserves manifest a high nitrogen content and a calorific value of 5,200 $kcal/m^3$ (22 MJ/m^3); the South East Basin reserves exhibit a high methane content and a calorific value of 8,200 $kcal/m^3$ (34 MJ/m^3), similar to gas imported from the Soviet Union. In 1985, these two regions produced 4.2 and 1.8 Gm^3 of gas, respectively (World Bank 1987b).

Gas production and reserves are highly dispersed, spread over about 40 producing fields. Of the nonproducing proven reserves, about 25% are estimated to be uneconomical because of excessive reservoir pressures (too high for the drilling equipment currently available in Poland) and high sulfur content. The largest producing field contains 30 Gm^3, but, in general, producing fields are in the 0.1- to 5-Gm^3 range.

Proven recoverable oil reserves are only about 2 million tonnes, dispersed over about 60 small fields. Production in 1985 was less than 200,000 tonnes. Natural gas and oil are imported exclusively from the Soviet Union, as is discussed in Secs. 6.2 and 6.3, respectively. Poland also has considerable untapped reserves of coal-bed methane, which could provide an additional source of energy.

TABLE 4.1 Noncoal Resources in Poland

	Estimated Reserves		Proven/Measured Reserves		Recoverable Reserves	
Fuel	Mtoe	Mtce	Mtoe	Mtce	Mtoe	Mtce
Oil	107	152	33	47	2.2	3.1
Gas[a]	665	944	318	452	162.7	231.0
Total	772	1,096	351	499	164.9	234.1

[a]1000 m^3 and 42 GJ per tonne oil equivalent.

Sources: World Bank 1987a; Craig 1990.

Hydroelectric resources are very limited and are not a significant factor in the current (about 1% of total electricity generation) or future energy picture. Pumped storage plants, which derive their ability to generate from pumping energy supplied by thermal plants, are considered as potential future contributors and are already used to a limited degree. Hydroelectric potential is estimated at 12 terawatt hours per year (TWh/yr), of which about one-third has been developed to date in the Carpathian Mountains, the Sudeten Region, and the Brda and Vistula rivers (Encyclopedia Britannica 1988).

Nuclear power is in the planning and construction stages; the first nuclear power plant at Zarnowiec was scheduled to start up in the early 1990s, followed by a second plant at Klepicz. However, recent reports and personal communications suggest that this program has been deferred indefinitely because of financial reasons, technical difficulties, and environmental concerns (Nuclear News 1990).

4.2 NONENERGY RESOURCES

Some nonenergy resources also contribute to Poland's air-pollution problems. After coal and lignite, sulfur is Poland's second most important mineral, with reserves among the largest in the world. Other important nonmetallic minerals include borite, salt, kaolin, limestone, gypsum, and marble (Encyclopedia Britannica 1988). Among metallic minerals, copper and zinc are the most important. Reserves of zinc and lead ores are believed to be among the largest in the world. Iron ore is mined in small quantities, although Poland's steelworks import ore directly from the Soviet Union. Nickel, vanadium, cobalt, and silver are also produced (Encyclopedia Britannica 1988).

5 ELECTRICITY SUPPLY

5.1 GENERATION CAPACITY

Electricity-generation capacity in Poland is almost entirely coal fired. Total installed capacity in the public-supply system was 28.9 billion watts (GW) in 1988, of which 17.8 GW (62%) was fired with hard coal and 9.1 GW (31%) with lignite (Table 5.1). The remaining 2.0 GW (7%) was hydrogeneration capacity, associated primarily with pumped storage (used to meet peak loads). An additional 3.1 GW of self-producer capacity was available for industry self-generation of electricity.

Between 1980 and 1988, public-supply hard-coal capacity increased by only 1.6 GW, lignite capacity increased by 4.3 GW, and hydro capacity increased by 0.7 GW. Self-producer generation capacity remained nearly constant at 3.0-3.1 GW. The total electricity-generation capacity increased by 6.8 GW between 1980 and 1988, from 25.3 GW to 32.1 GW, at an average annual increase of 3.0%.

In the 1980s, the average capacity of a thermal power station increased from 360 million watts (MW) in 1980 to 500 MW in 1988, whereas the average hydro station's capacity increased only slightly from 11 MW to 17 MW. The highest capacity for a thermal power station increased from 2,600 MW in 1980 to 4,320 MW in 1988, with the commencement of the full complement of lignite-fired units at Belchatow (12 × 360 MW). (Thus, Belchatow accounted for approximately 13% of the total installed capacity in 1988.)

A list of both fossil-fueled (electric only and CHP) and non-fossil-fueled public power stations in Poland as of December 1986 appears in Table A.1 of the appendix. These stations accounted for 28.4 GW of generating capacity in the public supply system -- 26.4 GW of thermal and 2.0 GW of hydro/pumped storage. This list represents 64 sites with 282 single generating units. In 1986, these units generated 122 TWh (10^9 kWh) of electricity at an average capacity factor of 49%. Three additional lignite-fired units at Belchatow were commissioned after December 1986, adding 1.1 GW of electric capacity. The locations of major power plants are depicted in Fig. 5.1.

Table A.2, a subset of Table A.1, lists only the public fossil-fueled electricity-generation stations in Poland as of December 1986. These stations accounted for 22.2 GW of generating capacity, representing 23 sites with 139 single generating units that each averaged 160 MW. In 1986, these units generated 105 TWh, the bulk of Poland's electricity, at an average capacity factor of 54%.

Table A.3, another subset of Table A.1, lists only the public fossil-fueled CHP stations in Poland as of December 1986. These stations accounted for only 4.2 GW of generating capacity, representing 35 sites with 119 single generating units that each average only 35 MW. In 1986, these CHP stations generated only 13.4 TWh of electricity at an average capacity factor of 37%.

TABLE 5.1 Electricity Statistics in Poland (GW, unless denoted otherwise)

Source	1980 Installed Capacity	1980 %	1985 Installed Capacity	1985 %	1988 Installed Capacity	1988 %	1986+ Incremental Capacity	2000 Forecast Capacity
Public supply								
Hard coal	16.153	63.9	17.678	58.7	17.798	55.5	2.560	20.316
Hard coal, CHP							2.350	2.350
Lignite	4.784	18.9	7.303	24.3	9.103	28.4	3.240	11.263
Hydro/pumped	1.327	5.2	2.005	6.7	2.005	6.3	0.750	2.755
Nuclear							6.860	6.860[a]
Subtotal							15.760	43.544
Retirements							-4.000	-4.000
Total public	22.264	88.0	26.986	89.7	28.906	90.2	11.760	39.544
Self producers	3.028	12.0	3.121	10.3	3.150	9.8		3.000
Total	25.292	100.0	30.107	100.0	32.056	100.0		42.544

[a]The nuclear projections are no longer appropriate for the year 2000 because the nuclear program has recently been canceled.

Sources: World Bank 1987b; Computer Centre of Power Systems 1989.

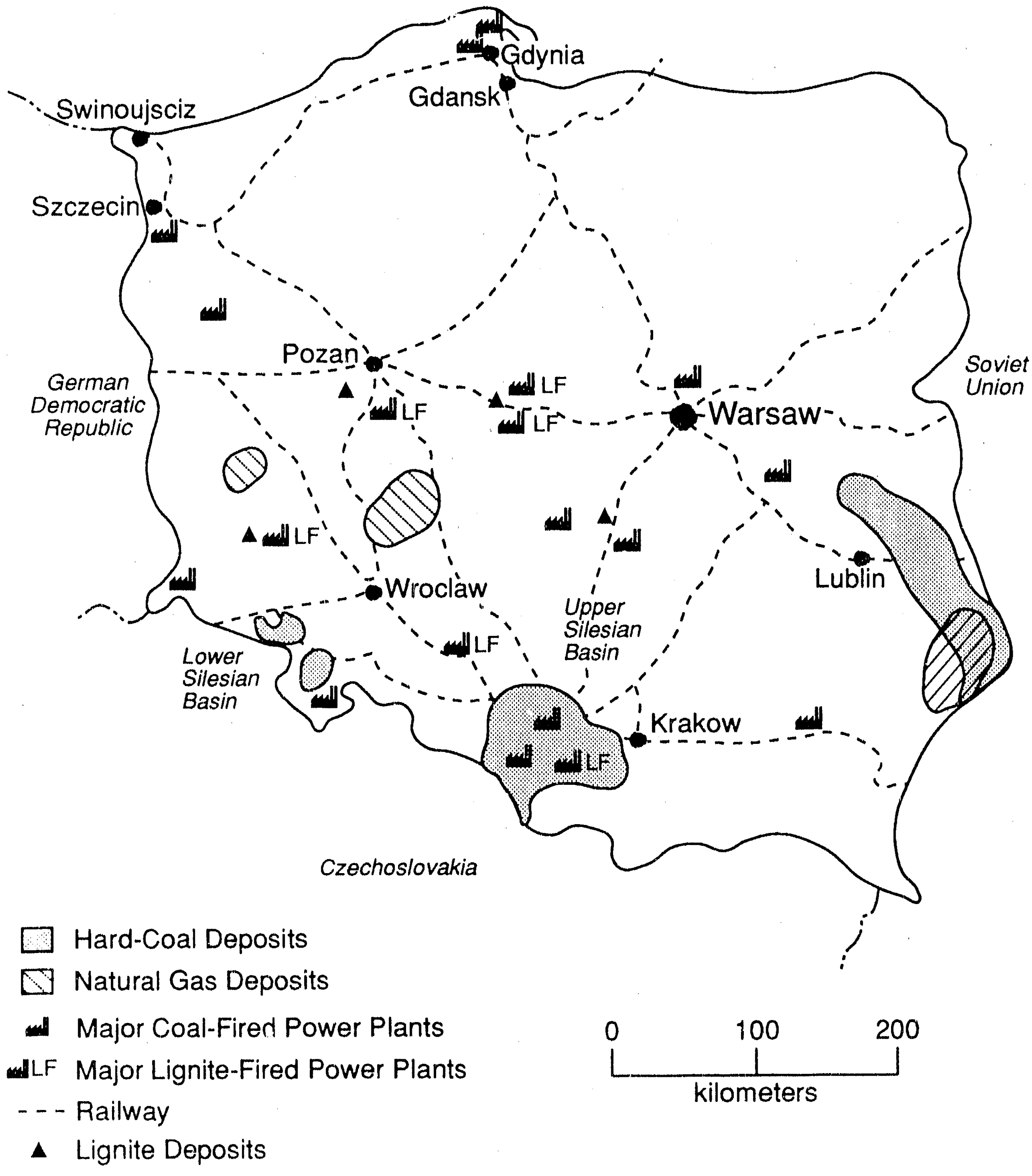

FIGURE 5.1 **Location of Main Coal Mines, Natural Gas Fields, and Major Power Plants in Poland [Sources: Doyle (1989); Cofala and Bojarski (1987); Buehring (1987); Encyclopedia Britannica (1979)]**

On the basis of 1986 capacity, the Poles had anticipated that approximately 15.8 GW (Table 5.1) of new capacity would be commissioned in the public supply system by the year 2000. At that time, the largest planned increment (7 GW) was expected to occur as a result of the introduction of nuclear-fueled electricity generation to Poland's power-generation system (perhaps an unattainable feat for the near term for a variety of reasons, primarily nontechnical). Another 8 GW was expected to be derived from some combination of hard coal, lignite, and combined CHP units, a more probable scenario. Hydro increments of 0.8 GW were planned. About 4 GW of primarily coal-fired capacity was expected to be retired. In this scenario, at an average annual growth rate of 2.4%, generating capacity by the year 2000 would total 42.5 GW. If the nuclear component is not achievable, as now seems likely, the balance is likely to be taken up by coal.

5.2 PRODUCTION

In 1988, the public supply system produced 135.9 TWh of electricity, of which 131.7 TWh was from coal and lignite thermal units and 4.2 TWh was from hydro/pumped storage (Table 5.2). Only 8.4 TWh was generated by self producers. Imports exceeded exports by 4.5 TWh, yielding a total gross electricity supply for Poland of 148.8 TWh.

From 1980 to 1988, capacity factors* decreased from 59.0% to 55.9% for thermal units, from 28.2% to 23.9% for hydro/pumped storage, and from 39.0% to 30.5% for self producers. The overall capacity factor was 51.4% in 1988, down significantly from 55.0% in 1980.

In 1980, 33.7 million tonnes of lignite (equivalent to 9.0 Mtce) and nearly 59 million tonnes of hard coal (37.8 Mtce) were consumed in public power plants (Table 5.3) to generate 108.2 TWh of electricity. In 1988, more than double that amount of lignite was burned -- 70.5 million tonnes (19.2 Mtce) -- whereas hard-coal consumption dropped slightly to 58 million tonnes (36 Mtce), partially because of poorer coal quality, to generate 131.7 TWh of electricity. The oil/gas contribution to fuel consumption for electricity generation was minimal, at less than 3% of the total calories consumed in 1980, dropping to about 1% in 1988. No electricity was generated by nuclear power.

Power shortages have been common since the 1970s (Encyclopedia Britannica 1988), implying that production has not been able to keep up with demand. An informed estimate places suppressed electricity demand at 5% per year (Filipczak 1989).

5.3 CHARACTERIZATION OF POWER STATIONS BY REGION

Power plant capacity can be considered and characterized on a regional basis. The lists of public power stations in the appendix are given by region.

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*Capacity factor = GWh of electricity generated/(GW of electricity capacity × 24 hours × 365 days).

TABLE 5.2 **Electricity Production in Poland**

Source	1980 Production (TWh)	1980 Capacity Factor (%)	1985 Production (TWh)	1985 Capacity Factor (%)	1988 Production (TWh)	1988 Capacity Factor (%)
Public supply						
Thermal	108.252	59.0	124.997	57.1	131.733	55.9
Hydro/pumped	3.279	28.2	3.894	22.2	4.200	23.9
Total public	111.531		128.891		135.933	
Self producers	10.340	39.0	8.817	32.2	8.407	30.5
Subtotal	121.871	55.0	137.708	52.2	144.340	51.4
Imports	4.161		5.456		12.456	
Exports	-4.396		-7.568		-7.980	
Total supply	121.636		135.596		148.816	

Sources: World Bank 1987b; Computer Centre of Power Systems 1989.

TABLE 5.3 Fuel Consumption in Public Power Plants in Poland

	1980		1985		1988	
Fuel	kt	Mtce	kt	Mtce	kt	Mtce
Hard coal	58,986	37.86	60,411	38.48	57,988	36.05
Lignite	33,686	8.98	55,836	15.01	70,501	19.22
Oil	990	1.36	508	0.32	489	0.68
Gas	a	0.02	a	0.02	a	0.01
Total		48.22		53.84		55.96

[a]Gas is reported as 28 million Nm^3 (1980 and 1985) and 17 million Nm^3 (1988).

Sources: World Bank 1987b; Computer Center of Power Systems 1989.

5.3.1 Northern Region

In the Northern Region, all of the generating capacity, 623 MW, is of the CHP type, fueled by hard coal. The largest site comprises four units totaling 187 MW and is located at Gdansk. The region contains five 55-MW units, one 50-MW unit, and 21 smaller units between 1 and 32.5 MW. The 50- to 55-MW units were commissioned in the 1970s, with most of the smaller units (<25 MW) commissioned before 1957. Eleven operating units are of pre-World War II vintage, with two operating units having been commissioned in 1895! The region produced only 1,900 GWh of electricity in 19[illegible] at an average capacity factor of only 35%. The largest regional producer -- Bydgoszcz-2 -- produced 684 GWh at a capacity factor of 46% with an efficiency of 76%. The smallest regional producer -- Bydgoszcz-1 -- produced only 31 GWh at a capacity factor of 25% with an efficiency of 53%.

5.3.2 Central Region

In the Central Region, 1,700 MW of the generating capacity is of the hard-coal CHP type. A single, three-unit, coal-fired electricity-generating plant at Ostroleka can generate 600 MW, and 4,300 MW (3,240 MW as of December 1986, plus 1,080 MW subsequently) comes from a single, 12-unit, lignite-fired, electricity-generating plant at Belchatow. The region has twelve 360-MW units (Belchatow), three 200-MW units (Ostroleka), four 120- to 125-MW units, eight 50- to 63-MW units, and 33 smaller units between 2 and 40.5 MW.

The first Belchatow unit was commissioned in 1981; the last in 1989. The Ostroleka units were commissioned in 1972, and two other 55-MW units were commissioned at Lodz in 1977. In the postwar period 1954-1968, 36 operating units totaling 1,500 GW were commissioned. Seven units between 2 and 32 MW, totaling 115 MW, are still being used, having been commissioned between 1904 and 1914! The region produced about 25,000 GWh of electricity in 1986, at an average capacity factor of 51%. The largest regional electricity producer -- Belchatow -- produced 17,500 GWh at a capacity factor of 62% with a respectable efficiency of 33%. The seven pre-World War I plants produced only 188 GWh at an average capacity factor of only 19%.

5.3.3 Southern Region

In the Southern Region, all of the generating capacity, 8,240 MW, is fueled by hard coal; 1,200 MW is of the CHP type and 7,000 MW generates electricity only. Of the electricity type, there are three megaplants: 1,600 MW at Rybnik, 1,300 MW at Jaworzno-3, and 1,000 MW at Laziska. In the 600- to 1000-MW class, there are two plants -- Lagirza (840 MW) and Siersza (740 MW); in the 300- to 600-MW class, there are three plants totaling 1,400 MW; and in the 100- to 300-MW class, there are five plants totalling 823 MW. Three smaller plants generate a total of 216 MW. In the region, there are six individual units at 215 MW; twelve at 200 MW; one at 150 MW; two at 130 MW; sixteen at 120 MW; four at 100 MW; and forty-four units at less than 100 MW.

Three plants (3,400 MW) were commissioned in the 1970s, four (1,900 MW) in the 1960s, five (1,600 MW) in the 1950s, three (1,200 MW) in the 1913-1921 period, and two plants (198 MW) in 1898! The region produced 36,000 GWh of electricity in 1986 at an average capacity factor of 50%.

The largest regional electricity producer -- Rybnik -- produced 9,800 GWh at a capacity factor of 70% (the highest in Poland in 1986) with an efficiency of 32%. The smallest regional producer -- Szombierki -- produced only 87 GWh at a capacity factor of 14% with an efficiency of only 22%.

5.3.4 Western Region

In the Western Region, electricity generation predominates: 2,000 MW from hard coal, 4,400 MW from lignite, and 400 MW from oil (although the oil plant did not operate in 1986). Only 568 MW of capacity is of the hard-coal CHP type. There are three large plants: 2,000 MW at Turow, 1,900 MW at Dolna Odra, and 1,200 MW at Palnow-1. One plant is 600 MW; two (743 MW) are in the 300- to 400-MW range; four (694 MW) are in the 100- to 300-MW class; and six (234 MW) are less than 100 MW. In the region, there are eight individual units at 235 MW; eighteen at 200 MW; one at 125 MW; seven at 120 MW, and twenty-nine units at less than 100 MW.

One large plant (1,880 MW) and two small plants (60 MW) were commissioned in the 1970s; two large lignite plants (2,000 MW and 1,100 MW) and four other plants (1,100 MW) in the 1960s; three (574 MW) in the 1950s; and four (85 MW CHP and 400 MW oil) in the 1929-1947 period. The region produced 35,000 GWh of electricity in 1986, at an average capacity factor of 55%, the highest capacity factor for any region in Poland.

The largest regional electricity producer -- Turow -- produced 12,000 GWh at a capacity factor of 68% (almost as high as Rybnik in the Southern Region) with an efficiency of only 29%. (This plant's efficiency may be indicative of its status as a good repowering candidate for an appropriate U.S. clean coal technology.) Palnow-1 produced 7,200 GWh at a capacity factor of 69% with an efficiency of 33%. Dolna Odra, on Poland's northwest coast, appeared to be underutilized in 1986, at a capacity factor of only 46% despite a good efficiency of 34%. A Swedish firm has been looking at Dolna Odra as a possible source for electricity to replace the Swedish nuclear plants scheduled for decommissioning in the near term.

5.3.5 Eastern Region

In the Eastern Region, all of the 4,600-MW generating capacity is of the electric type, fueled by hard coal. There are two large plants that can generate 2,600 MW and 1,600 MW each, and one medium-sized plant of 385 MW. Two units generate 500 MW; sixteen generate 200 MW; two generate 120 MW; and five generate less than 100 MW. The large plants were commissioned in the 1970s; the medium one is pre-World War II. The region produced 20,000 GWh of electricity in 1986 at an average capacity factor of 49%.

The largest regional electricity producer -- Kozjenice -- produced 10,000 GWh and is apparently underutilized at a 44% capacity factor with an efficiency of 34%. Polaniec produced 8,000 GWh at a capacity factor of 59% with an efficiency of 33%.

5.3.6 Non-Fossil-Fuel Stations

Of the non-fossil-fuel power stations in Poland, there are three pumped storage plants of 680, 500, and 150 MW, commissioned in 1982, 1979, and 1970, respectively. There are three hydro plants of 163, 136, and 79 MW, commissioned in 1969, 1968, and 1936, respectively. Numerous other plants total 302 MW. Individual unit sizes as listed range from 50 to 170 MW for pumped storage and 21 to 47 MW for hydro. Hydro/pumped storage plants produced 3,700 GWh of electricity in 1986 at an average capacity factor of 21%. The largest pumped storage producer -- Zarnowiec -- produced 1,200 GWh at a capacity factor of 20%.

5.4 TRANSMISSION AND DISTRIBUTION LOSSES

Losses in electricity transmission and distribution in Poland are among the highest in Europe (Table 5.4) (World Bank 1987b). In 1985, losses in Poland accounted for about 10.8% of the electricity delivered from the public supply system, compared with an average of 8.2% in Europe. Because of the significantly high proportion of electricity sold to Polish industry at a high voltage, one would expect the losses to be much lower. However, the losses at lower voltage levels may be responsible for increasing the average transmission and distribution losses, with lower voltage losses estimated to be as high as 13%. Losses are inherently higher to low-voltage residential consumers, and the increasing level of supply failures that result from distribution outages contributes to transmission and distribution losses. If transmission and distribution system losses could be lowered to 8.5%, a target actually achieved by Poland in 1968, fuel savings of approximately 1 Mtce/yr might be possible (World Bank 1987b).

5.5 THERMAL EFFICIENCY

In recent years, the average thermal efficiency for public-supply electricity generation has been somewhat comparable with that in the West, at 34-35%, with an average hard-coal generation efficiency increasing from 34.5% in 1980 to 35.7% in 1985. Since 1975, however, the efficiency of lignite power plants has steadily declined, without any apparent significant deterioration in lignite quality, from 33.6% in 1975 to 32.7% in 1985. This decrease is said to represent a fuel loss estimated at approximately 350 ktce/yr (World Bank 1987b).

Efficiency for fossil-fueled electricity generation in 1986 is highlighted by plant in Table A.2 of the appendix. Only one plant -- Stalowa Wola -- averages an efficiency of 36%. Surprisingly, this plant is of 1938 vintage. Two plants commissioned in the 1970s -- Dolna Odra and Kozjenice -- average an efficiency of 34%. Three plants average 33% efficiency: Belchatow (lignite, 1980s), Palnow-1 (lignite, 1960s), and Polaniec (1979). Six plants average 30-32% efficiency, seven plants average only 25-29%

TABLE 5.4 Electricity Network Losses in Selected Countries in 1985

Rank	Country	Losses (%)	Rank	Country	Losses (%)
1	Netherlands	4.2	15	Denmark	8.1
2	GDR	4.7	16	Soviet Union	8.3
3	Belgium	5.7	17	Sweden	8.7
4	Romania	5.7	18	Italy	8.7
5	Finland	5.8	19	Yugoslavia	8.9
6	Cyprus	6.3	20	Bulgaria	9.0
7	Austria	6.8	21	Norway	9.9
8	France	7.4	22	Hungary	10.0
9	Czechoslovakia	7.6	23	Spain	10.1
10	FRG	7.8	24	Ireland	10.8
11	Switzerland	7.8	25	**POLAND**	**10.8**
12	Greece	7.9	26	Iceland	11.0
13	Canada	8.1	27	Turkey	11.4
14	United Kingdom	8.1	28	Portugal	11.6
Average		8.3			

Source: World Bank 1987b.

efficiency, and three plants average less than 25% efficiency. Clearly, there is much room for improvement in efficiency.

Efficiency for fossil-fueled CHP stations varies widely from 22 to 80%, as highlighted in Table A.3 of the appendix. These CHP plants deliver both thermal and electrical energy to users. In some plants, production of thermal energy is the primary function, and electricity is generated as a by-product and is delivered to the electrical grid. In such cases, the efficiency associated with the electrical generation can be as high as 80%. Some CHP plants can operate in the condensing mode without useful heat production. Operating CHP plants in the condensing mode results in thermal efficiencies that are similar to those of conventional electricity-generation plants.

5.6 POWER STATION CONSUMPTION

Self consumption in public power stations is approximately 7.2% in Poland. If internal consumption were reduced to 6.5%, comparable with similar power systems elsewhere, Poland could potentially save about 350 ktce/yr of fuel (World Bank 1987b).

5.7 POWER INDUSTRY BOILER CHARACTERISTICS

The Polish power industry uses hard coals and lignites that have relatively low calorific values and high ash contents (often above 25%), which serve to lower the combustion temperature required. The boilers used are the dry-bottom type (which are also used in industrial power generation). Because of the slagging properties of Polish coals, the Polish furnaces typically have lower heat loads than analagous foreign designs, which tends to favor lower NO_x emissions. Most of the large power boilers have tangential-type furnaces, characterized by relatively low emission coefficients. Stream burners with top and bottom air flow are commonly used, similar to those operating on over-fire air principles (Cofala and Bojarski 1988).

5.8 PRIVATE POWER PROJECTS

5.8.1 AES Transpower

The U.S. A.I.D.'s Office of Energy awarded a feasibility grant to AES Transpower, an affiliate of AES Corp., a major U.S. independent power project developer, to cofund an investigation of the potential for refurbishment and modernization of the Zeran Thermal Power Project in northern Warsaw. The Zeran facility is a CHP plant with a rated electric output of 290 MW and an additional thermal rating equivalent to 1,300 MW. The plant is currently under the jurisdiction of the Polish Power and Brown Coal Board, an agency of the Polish Ministry of Industry.

The Zeran facility consists of 10 units of 1950s vintage. Presently, unscrubbed boiler flue gases are released into the atmosphere. The feasibility study will investigate options for improving particulate collection systems, reducing SO_2 and NO_x emissions, improving boiler performance, automating turbine and boiler operations, automating water treatment systems, and installing more efficient electricity generation schemes. The facility is fueled primarily by coal from surrounding mines. All necessary infrastructures such as water, power, roads, railroads, and transmission are in place.

AES Transpower proposes to conduct a comprehensive refurbishment and modernization of the Zeran facility and then operate the plant under a long-term power/steam sales agreement. The study will also include an economic analysis of viable commercial terms of both build-own-operate and build-own-lease financial arrangements.

5.8.2 Asea Brown Boveri

A private power project is also being considered by a Swedish firm, Asea Brown Boveri. It involves building a pulverized-coal-fired utility plant, a coal-beneficiation plant, and exporting Polish coal by wire as electricity to customers in Sweden, via a direct-current transmission line across the Baltic Sea (Christofides 1990). Swedish environmental concerns and policies, especially with respect to air and water, are expected to weigh heavily in any such scheme, when and if actually proposed formally. At that time, a prefeasibility study would be required. Hard currency, increased local employment, and privatization with accompanying efficiency increments for Poland are the expected benefits. Sweden gains the ability to turn off its nuclear reactors and maintain electricity growth and its way of life.

5.8.3 North American Energy Partners

Reportedly, several U.S. utilities are considering becoming involved as partners with North American Energy Corp. of Maryland in a joint-venture project called North American Energy Partners. That partnership then intends to hold a majority interest in a U.S./Polish joint venture. The project may include the installation of pollution-control equipment on existing plants, new construction of 500 MW of electricity generation, the addition of 1,000 MWt for district heating, and construction of a coal-preparation plant. Organizers would also like to add a U.S. coal company and an engineering/construction company to the business arrangement to complement and focus its full-service expertise. Only Poland's debt situation and amount of available capital might preclude government participation in such a joint venture (Electric Utility Week 1990).

Initially, the Polish government would participate in partnership with North American Energy Partners. Then the share of the state-owned portion of the facilities would probably be sold to employees and managers of the utilities and, subsequently, to the general public. This privatization concept is likely to occur slowly, if it occurs at all, because of the need to establish a workable support system for business, including a stock market (nonexistent), a banking system (nonfunctioning), and better telecommunications (inadequate and intermittent). The transfer of individual power generating stations to private sector consortia, in which the government and/or the workers have ownership representation, is a more likely approach to improve conditions in the short term. The Poles appear to have significant expertise in siting power plants, securing fuel, and constructing transmission and distribution systems. But assistance in market-oriented financial and business transactions appears warranted.

6 ENERGY PRODUCTION, TRADE, AND USE

Poland's economy is highly energy intensive, with a level of per-capita energy consumption in 1987 similar to that of Japan, but with its per-capita income less than one-sixth that of Japan. Of countries that are highly dependent on the production and use of coal, only South Africa consumes a higher share of coal in primary energy use (Craig 1990). These two characteristics are directly linked to Poland's natural resource endowments and disproportionate reliance upon heavy industry.

6.1 COAL

Poland is unusually dependent on coal as its primary source of domestic energy. With a supply-oriented bias, the Poles have "made coal the mainstay of the nation's energy base and its most important export commodity. Supplies were believed to be forthcoming with hardly a problem and exuberant projections placed output at 250 and even 300 million tonnes (per year) by the end of the century" (Dienes and Merken 1985). Until recently, this situation was reflected in low prices for both coal and electricity (generated almost entirely from coal and lignite), although domestic coal prices have very recently increased by 400-600%, to $20.84 per tonne (CWI 1990a). On a hard-coal equivalent basis, nearly 97% of Poland's total energy production (180 Mtce in 1987) is coal and lignite (Table 6.1). Almost 99% of Poland's fuel input for public electricity production is coal and lignite (Table 5.3).

TABLE 6.1 Primary Energy Production and Trade in Poland

Fuel and Economic Activity	1985 Mtce	1985 %	1987 Mtce	1987 %	1985 Mtoe	1987 Mtoe
Coal and lignite	169.0	96.4	174.3	96.6	118.3	122.0
Oil	0.3	0.2	0.3	0.2	0.2	0.2
Gas	5.5	3.1	5.4	3.0	3.9	3.8
Hydro	0.5	0.3	0.5	0.3	0.3	0.3
Total production	175.3	100.0	180.5	100.0	122.7	126.3
Imports	31.5		34.8		22.0	24.3
Exports	-32.0		-27.7		-22.4	-19.4
Stock changes	3.3		-0.9		2.3	-0.7
Statistical error	-5.7		-5.2		-3.9	-3.4
Total	172.4		181.5		120.7	127.1

Source: UN 1989.

Coal's share of primary energy consumption in Poland, which is in excess of 80% (Table 6.2), is considered to be a rational response to the availability of cheap, domestically produced coal. However, in comparison with the market economies of the West, its coal share is very high. For example, coal's share of primary energy use is less than 25% in most OECD countries. Even Australia, which exports more than three times as much coal as Poland, depends on coal for less than 50% of its domestic energy consumption (IEA 1988).

Government coal policy calls for the stabilization of domestic coal production, targeted at 195 Mt/yr of hard coal (Gorst 1987) and more than 80 Mt/yr of lignite in 1990. Yet increased hard-coal production requires considerable outlays of capital investment, which are simply not available. Thus, there has been an incremental increase in the extraction of lignite from open-pit mines rather than hard coal from deep underground mines in Poland.

Of the hard coal produced in Poland, more than 160 Mt/yr is consumed domestically (Table 6.3). More than 55% of the hard coal is consumed in electricity generation and for CHP use (Table 6.4). About 20% is consumed directly in the residential/commercial sector, and about 15% is consumed in steel production. Of the Polish lignite produced, more than 95% is burned in public power plants for electricity generation (Tables 6.5 and 6.6).

6.2 NATURAL GAS

Poland's current supply of natural gas does not cover current demand. Domestic annual production is about 5-6 Gm^3 (160 PJ or petajoules) (Table 6.7), less than 50% of domestic consumption. Imports of natural gas are about 8 Gm^3 (250 PJ) and are projected to increase to 10-12 Gm^3 in the 1990s to fill the widening gap between demand and local production. However, this gas can only be obtained by Poland from the Soviet

TABLE 6.2 Energy Consumption in Poland

Fuel	1985 Mtce	1985 %	1987 Mtce	1987 %	1985 Mtoe	1987 Mtoe
Coal/lignite	142.3	82.5	148.2	81.7	99.6	103.8
Oil	17.5	10.2	18.6	10.2	12.2	13.0
Gas	12.4	7.2	14.0	7.7	8.7	9.8
Hydro	0.2	0.1	0.7	0.4	0.2	0.5
Total	172.4	100.0	181.5	100.0	120.7	127.1

Source: UN 1989.

TABLE 6.3 Hard-Coal Production, Trade, and Consumption in Poland (Mt)

Economic Activity	1980	1985	1987
Production	193.1	191.6	193.0
Imports	1.0	1.1	1.1
Exports	-31.1	-36.2	-31.0
Stock changes	-4.0	3.3	-0.7
Statistical error	0.0	0.2	1.4
Consumption	159.0	160.0	163.8

Source: UN 1988.

TABLE 6.4 Hard-Coal Consumption by Sector in Poland

Sector	1980		1985		1987	
	Mt	%	Mt	%	Mt	%
Electricity						
Public	59.0	37.1	60.4	37.8	60.7	37.1
Self	18.5	11.6	16.9	10.6	17.0	10.4
CHP	11.4	7.2	14.4	9.0	15.3	9.3
Steel	29.4	18.5	21.8	13.6	23.8	14.5
Industrial	10.2	6.4	10.3	6.4	11.8	7.2
Res./Comm.	25.8	16.2	32.0	20.0	31.1	19.0
Transport.	2.8	1.8	2.4	1.5	2.0	1.2
Agriculture	1.9	1.2	1.8	1.1	2.1	1.3
Total	159.0	100.0	160.0	100.0	163.8	100.0

Source: UN 1988.

TABLE 6.5 Lignite Production, Trade, and Consumption in Poland (Mt)

Economic Activity	1980	1985	1987
Production	36.9	57.3	73.2
Exports	-1.6	-0.2	0.0
Stock changes	-0.1	0.0	0.3
Consumption	35.2	57.1	73.5

Source: UN 1988.

TABLE 6.6 Lignite Consumption by Sector in Poland

	1980		1985		1987	
Sector	Mt	%	Mt	%	Mt	%
Electricity						
Public	33.7	95.7	55.8	97.7	69.8	95.0
Self	0.1	0.3	0.2	0.4	0.3	0.4
CHP	0.5	1.4	0.0	0.0	0.0	0.0
Steel	0.0	0.0	0.0	0.0	0.0	0.0
Industrial	0.1	0.3	0.2	0.4	0.8	1.1
Res./Comm.	0.8	2.3	0.9	1.5	2.6	3.5
Transport.	0.0	0.0	0.0	0.0	0.0	0.0
Agriculture	0.0	0.0	0.0	0.0	0.0	0.0
Total	35.2	100.0	57.1	100.0	73.5	100.0

Source: UN 1988.

Union by participating in the development and transmission costs that occur in the Soviet Union. An agreement between these countries calls for Poland to supply labor and equipment, which will entitle Poland to a total supply of 45 Gm^3 of Soviet gas for 20 years at the initial rate of 2.5 Gm^3/yr (Gorst 1987).

To date, the level of gas (and oil) imports to Poland from the Soviet Union has been low, since all of these imports must be paid for by Polish coal exported there. Investments in pipelines to enable importation of gas from the West have not occurred. [Central Europe already receives 37 Gm^3/yr of gas from the Soviet Union, most of which is delivered through the Soyuz pipeline from the Orenburg fields to the west of the Ural Mountains (Gorst 1987).]

Gas is used primarily in the industrial sector (about 75%) and residential/commercial sector (about 25%); none is used for electricity generation. (Pumped storage is considered cheaper than gas turbines for meeting peak loads in the electricity sector; however, gas use in the electricity sector may be reexamined in the future.)

TABLE 6.7 Gas Production, Trade, and Consumption in Poland (PJ)

Economic Activity	1985	1987
Production	162.4	157.8
Imports	203.2	253.7
Stock changes	-2.4	-2.6
Consumption	363.2	408.9

Source: UN 1989.

6.3 OIL

Crude oil production was about 190,000 tonnes in 1985 and about 100,000 tonnes in 1987, due, in part, to limited reserves (Table 6.8). Thus, virtually all of Poland's oil is imported from the Soviet Union. Oil use constitutes about 10% of Poland's primary energy consumption. There are nine oil refineries in Poland. The largest -- Plock -- has an annual throughput of 12.5 million tonnes, accounting for about 80% of the total refining output. Fuel oil is used in Poland in industry as an auxiliary boiler fuel or as a furnace fuel. It is nearly exclusively heavy fuel oil. Fuel oil is not used in the residential sector in Poland. Amounts of light fuel oil used in agriculture for heating and drying are negligible (Cofala and Bojarski 1988).

TABLE 6.8 Crude Oil Production, Trade, and Consumption in Poland (Mt)

Economic Activity	1985	1987
Production	0.2	0.1
Imports	13.7	14.2
Stock changes	0.1	-0.1
Consumption	14.0	14.2

Source: UN 1989.

6.4 NUCLEAR FUEL

Poland has considered nuclear power to be its most important long-term electricity-generation option. Limitations on other energy options generally seem to leave nuclear power as the best future option by default. However, recent financial problems and technical difficulties (Gorst 1987), together with increased public concern about Chernobyl, have caused an indefinite delay in construction.

6.5 ELECTRICITY USE

Of the 135.6 TWh of electricity supplied (produced and imported) in 1985 (Table 5.2), 122.6 TWh was available for consumption. (The former figure compares with 148.8 TWh of electricity supplied in 1988, as noted in Chap. 5.) Of the electricity consumed in 1985 (122.6 TWh), about 62% was consumed by industry, 25% by the residential/commercial sector, and about 5% by the transportation sector. This compares with 67%, 21%, and 5%, respectively, in 1980 (of 111.1 TWh) (World Bank 1987a). No figures are yet available for 1988.

Analysts have estimated that electricity demand will be suppressed on the order of 5%/yr (Filipczak 1989). This estimate was based on the electricity supply and demand picture before Poland began its shift from a centrally planned to a market-driven economy. Electricity prices have increased 400% in the last several months, so it may be inappropriate to maintain this suppressed electricity-demand figure at 5%/yr. Nevertheless, with increased need for commercial services and consumer desire to improve living conditions, the demand for power for commercial and household purposes will probably grow, thus increasing the demand for electricity, despite the recent electricity-price market transition rise.

6.6 SECTORAL END USE

After one takes into account energy production and imports, adjusts for exports and changes in stock, and further adjusts for transformation and production use and conversion losses, the energy available for final consumption by end-use sectors remains. This level of energy use is usually labeled "final energy demand" or "final energy consumption." The text that follows focuses on three sectors -- the industrial, residential/commercial, and transportation sectors. In 1987, total final energy demand was 90.0 Mtoe (128.6 Mtce) (Table 6.9). Of this volume, 39% was consumed by the industrial sector, 55% was consumed by the residential/commercial sector, and only 6% was consumed by the transportation sector. By 1990, growth in final energy demand is expected to increase slightly to 92 Mtoe (131 Mtce); by the year 2000, at a 1.5%/yr growth, final energy demand would reach 107 Mtoe (152 Mtce) (World Bank 1987a; Polish National Committee 1989).

6.6.1 Industrial Sector

In 1987, about 36% of industry energy emanated from district heat (Table 6.10). About 31% of industrial energy was derived from gas and oil, most of which was imported. About 20% of industrial energy was generated directly from hard coal, generally for steel production. Only 13% came from electricity. Yet, of the electricity consumed in Poland, well over 50% is consumed in the industrial sector (World Bank 1987a).

TABLE 6.9 Final Energy Consumption by Sector in Poland (Mtoe)

Sector	1980[a]	1985[a]	1987[a]	1990[b]	2000[b]
Industrial[c]	38.9	34.2	35.3	33.5	28.8
Res./comm.[d]	41.7	43.6	49.7	52.3	70.9
Transport.[e]	6.5	5.2	5.0	6.0	7.2
Total	87.1	83.0	90.0	91.8	106.9

[a]Polish National Committee 1989.

[b]World Bank 1987a.

[c]Includes construction.

[d]Includes agriculture and forestry.

[e]Includes communications.

TABLE 6.10 Final Energy Consumption by Sector and Source in Poland in 1987 (Mtoe)

Fuel	Industry[a]	Res./Comm.[b]	Transport[c]	Total
Solid fuels	7.1	25.2	0.9	33.2
Refined petroleum products	2.5	9.3	3.3	15.1
Gas	8.4	3.3	0.0	11.7
Electricity	4.5	3.8	0.6	8.9
District heat, other	12.7	8.2	0.2	21.1
Total	35.2	49.8	5.0	90.0

[a]Includes construction.

[b]Includes agriculture and forestry.

[c]Includes communications.

Source: Polish National Committee 1989.

6.6.2 Residential/Commercial Sector

More than 50% of this sector's energy is derived directly from coal and lignite; more than 25% comes from gas and refined petroleum products; and about 16% emanates from district heating. Only about 8% comes from electricity, although this sector accounts for about 45% of electricity consumption.

About 75% of the sector's energy is derived either indirectly or directly from coal. Coal burning for residential use takes two forms. In the first, large coal-fired boilers that serve apartment buildings or groups of such buildings produce hot water for direct use or space heating. For the second, small boilers or open fires are used to provide heat and hot water for individual dwellings. Gas and liquid fuels account for less than 10% of total energy consumption in the residential sector.

6.6.3 Transportation Sector

Surprisingly, energy demand in this sector appears to have decreased in the 1980s, from 6.5 Mtoe in 1980 to 5.0 Mtoe in 1987 (Table 6.9). In 1987, this sector was fueled primarily by refined petroleum products (66%) (Polish National Committee 1989), while 18% came from coal and 12% from electricity. A significant change has taken place since 1980; direct coal firing (for steam locomotives) appears to have decreased from 2.4 to 0.9 Mtoe. Moreover, despite the fact they have increased in share, refined petroleum products have actually decreased in volume from 3.5 to 3.3 Mtoe.

6.7 DISTRICT HEATING

Poland's climatic conditions affected the significant development of district-heating supply by combined electric-power plants. In 1987, the heat produced by centralized sources amounted to about 920 PJ (equivalent to 22.1 Mtoe or 31.4 Mtce), or about 17% of the primary energy supply. About two-thirds of the heat from such sources was produced by public power plants, of which about 60% was cogenerated (Polish National Committee 1989).

More than 20% of final energy use in Poland consists of steam and hot water, much of which is piped from central heating stations. Government plans call for an increase in the amount of heat supplied from the joint production of electricity, by effectively recovering more of the thermodynamic losses inherent in electricity production. Consumers are charged a flat rate proportional to their floor area. Metering consumers could provide an incentive for conservation of this energy source.

6.8 FUEL CHOICES

At the heart of the Polish system is the assumption that coal will or should be used unless there are overwhelming technical reasons for substituting other fuels. Thus, gas is used for high-temperature processes, as it is in other industrial countries, but steam raising and space heating invariably depend on coal even when gas might be more economical, convenient, or environmentally desirable. There are specific internal constraints in Poland, such as a number of regulations that prohibit the use of specific fuels for particular purposes. For example, natural gas may not be used as a boiler fuel except in special circumstances.

Some sectors of the economy would prefer to use a higher quality of coal than they are able to obtain under the present system of central allocation. In the case of the electricity sector, a shift to higher quality (i.e., higher calorific value) coal would enable some power stations to improve their conversion efficiencies quite substantially, thus leading to a fuel savings of about 10%. Because the electricity sector alone accounts for about 55% of the hard-coal consumption in Poland, any shift in the composition of its demand would have an immediate impact on the balance between supply and demand for different grades of coal. On the supply side, however, many mines might not be able to operate profitably if the structure of coal prices were too heavily weighted against low-grade coals.

In Poland, increasing the fuel supply, especially lignite, is considered to be an appropriate and less difficult solution to meeting energy demand than investing in more energy efficiency, energy conservation, or interfuel substitution. Consumption of lignite and poor-quality hard coal is very high. At about 99%, coal's contribution to electricity generation is more than 25 percentage points higher in Poland than it is in its nearest rival in the free-market economies (the U.K.), which has 71% of its fuel input used for electricity generation (IEA 1988).

Beneficiation of coal is considered a controversial matter in Poland, partly because of Polish institutional arrangements. From the miners' perspective, beneficiation would just add an incremental cost to production, resulting in the loss of product. From the power plants' perspective, beneficiation would result in lower total costs for electricity generation, especially when the results would be a higher level of plant efficiency and lower cleanup costs (with respect to effluent and solid-waste generation and disposal). It is estimated that up to 50% of the sulfur in many coals could be removed by precombustion cleaning at the mine.

More importantly, the very high share of coal production and use in Poland creates a situation where:

- A shortage in available capital exists because of the highly capital-intensive nature of the coal-producing industry;

- A relatively high energy-intensive economy persists, especially when linked to Poland's disproportionate reliance upon heavy industry;

- An overload of the transportation network, especially the railways, makes the electricity generation sector very susceptible to climate and weather conditions; and

- A high level of environmental pollution results.

A high level of dependence on coal in primary energy consumption appears to be the result of autarchic trading policies, in which the high priority placed on using domestic energy sources prohibits recognizing the possible benefits of exporting one fuel in order to import other fuels that might be more efficient in specific end-user applications.

Moreover, for decades, Poland has relied substantially upon exports of hard coal to finance imports. Any increase in domestic consumption reduces the supply available for export. Thus, one could make a strong case for exporting high-quality coal and importing gas and/or crude oil in order to achieve a more appropriate combination of fuel use in the industrial and residential/commercial sectors and especially the agricultural segment (World Bank 1987a).

7 TRANSPORTATION

The transportation sector's utilization of fossil fuels is responsible for significant quantities of air pollutants in industrialized countries. This sector is usually analyzed for SO_2, NO_x, and hydrocarbon (HC) emissions from vehicles, which potentially can transform into other compounds in the atmosphere. Even though there are fewer vehicles in Eastern Europe than in the West, the inefficiencies of locally produced vehicles add to the levels of urban air pollution. As numbers of vehicles increase and congestion worsens, transportation-related problems can be expected to increase, unless more efficient vehicles or tighter emission standards can compensate.

7.1 VEHICLE POPULATION

Available statistics for 1985 show that the number of passenger cars is quite low (3.7 million) in Poland compared with the number (26 million) in the Federal Republic of Germany (FRG, West Germany) or 98 cars per 1,000 individuals in Poland compared with 427 cars per 1,000 individuals in the FRG (World Bank 1987c; Larssen 1989). Moreover, the number of passenger cars per 1,000 persons in Poland is the lowest among its European neighbors -- Hungary, 135; Czechoslovakia, 170; and GDR, 181 (Table 7.1). These figures are indicative of a lifestyle that does not incorporate passenger car ownership into daily living but considers it a luxury.

Poland has more trucks for movement of commodities (780,000) than each of its three neighbors, but it has about half as many as does the FRG (1.5 million). Per 1,000 persons, however, Poland is the lowest at 21 trucks (except for Hungary at 14), but it is roughly equivalent to the FRG at 25, Czechoslovakia at 27, and the GDR at 29.

Poland has fewer buses (23,000) but more tractors (919,000) than its neighbors, which is indicative of its agrarian society. (A comparative figure for tractors in the FRG is not available.) Poland also has more motorcycles (1.6 million) than its neighbors.

A cursory observation of these statistics for Poland indicates that very little energy conservation could be expected from this arena and that the transportation sector's current contribution to air pollution is less than industrial sources. However, a significant growth in passenger car ownership might be anticipated as a result of the changing economic, social, and political climate, especially with automobile companies racing to set up joint manufacturing ventures (Arndt 1990). Although at the national level, car ownership is not high, in major urban areas where most of the air-quality problems are present, passenger car ownership is much higher and is growing fast. In Krakow, for example, there are approximately 150 cars per 1,000 persons, and the number is increasing steadily (Carter 1987). If passenger car ownership increases, air quality could become a much more significant problem in the long term.

TABLE 7.1 Eastern and Central European Vehicle Population in 1985

	Poland		Hungary		Czechoslovakia		GDR		FRG	
Vehicle	1,000	per 1,000 persons	1,000	per 1,000 persons	1,000	per 1,000 persons	1,000	per 1,000 persons	1,000	per 1,000 persons
Passenger cars	3,671	98	1,436	135	2,640	170	3,020	181	26,100	427
Trucks	780	21	151	14	413	27	491	29	1,508	25
Buses	23	0.6	25	2	32	2	53	3	69	1
Tractors	919	25	55	5	193	12	516	31	NA[a]	NA
Motorcycles	1,624	44	630	59	670	43	1,300	78	876	14
Total	7,017		2,297		3,948		5,380		28,553	
Total vehicles minus tractors		164		210		242		291		468

[a]NA = not available.

Sources: Larssen 1989; World Bank 1987c.

7.2 ROAD TRAFFIC ACTIVITY

With respect to the highway system, the densest network of roadways existed at the turn of the century on lands belonging to Germany, and the least dense network existed on lands belonging to the Soviet Union. An attempt to remedy this situation was made between 1918 and 1938 and again, but more intensively, after 1945. Modern multilane highways adapted to mass traffic requirements have been built in Warsaw, and projects have been undertaken to link Warsaw to provincial centers (Encyclopedia Britannica 1988).

Estimated traffic activity in Poland for passenger cars is 20 billion km/yr -- lower than for Czechoslovakia, the GDR, and the Soviet Union, and far lower than for the FRG (Table 7.2), which is indicative of a lifestyle in Poland that does not incorporate passenger car ownership and use into its daily living. Truck activity here is higher than it is in its neighboring Eastern Bloc countries (19 billion km/yr), which is indicative of a significant movement of farm commodities (principally potatoes, sugar beets, and rye grain) and coal. However, this truck activity is lower than that of the FRG and the Soviet Union because of the greater distances for commodity movement in these two countries. Bus activity is higher in Poland than in its neighboring countries, because there are fewer cars; however, bus activity is higher in the Soviet Union. Motorcycle activity is roughly the same as it is in neighboring countries.

Passenger cars travel an average distance of 5,500 km/yr in Poland, compared with 10,000 km/yr in the GDR and 13,600 km/yr in the FRG (Table 7.3). Trucks travel an average distance of 24,000 km/yr in Poland, compared with 35,200 km/yr in Czechoslovakia and 23,700 km/yr in the FRG. Buses travel an average distance of 57,000 km/yr, about the same as in the FRG.

TABLE 7.2 Estimated Traffic Activity in Eastern Europe, the Soviet Union, and the Federal Republic of Germany in 1985 (billion km/yr)

Country	Passenger Cars	Trucks	Buses	Motorcycles
Poland	20.2	18.7	4.7	4.1
Hungary	14.4	2.9	0.9	1.6
Czechoslovakia	24.8	9.2	1.3	3.9
GDR	33.0	5.3	1.0	4.6
Total	92.4	36.1	7.9	14.2
FRG	313.0	37.4	3.3	5.7
Soviet Union	82.5	86.4	15.6	NA[a]

[a]NA = not available.

Source: Larssen 1989.

TABLE 7.3 Estimated Average Distance Driven in Eastern Europe and the Federal Republic of Germany in 1985 (km/yr)

Country	Passenger Cars	Trucks	Buses
Poland	5,500	24,000	57,000
Czechoslovakia	NA[a]	35,200	NA
GDR	10,000	NA	NA
FRG	13,600	23,700	53,300

[a]NA = not available.

Source: Larssen 1989.

7.3 FREIGHT AND PASSENGER TRANSPORT

7.3.1 Railways

The communications system in Poland developed in the nineteenth and early twentieth centuries when the country was divided among Russia, Germany, and Austria. The three areas thus developed under different economic and political conditions, and the main railway lines were centered on the capital cities of the three empires. Hence, the density of the railway networks in the three sectors was uneven.

In 1918, independent Poland acquired the system and began to redesign and rebuild it according to the standard European gauge. Among the most important railway lines built after that date were those linking Warsaw with Poznan and Krakow, and a coal-trunk line linking Upper Silesia with the newly built seaport of Gdynia.

After the devastation of World War II, the railway system was reconstructed, with the most traversed lines being converted to electricity. Because of Poland's location, its railway lines are important in transporting freight between the Soviet Union and the GDR and between Czechoslovakia and the Polish ports (Encyclopedia Britannica 1988).

Significant amounts of freight are transported via railroad in Poland, with more than 1 billion tonnes of freight transported in 1985 (Table 7.4). This volume compares with 323 million tonnes in the GDR, 289 million tonnes in Czechoslovakia, 127 million tonnes in Hungary, and 318 million tonnes in the FRG.

7.3.2 Inland Waterways

Inland navigation is considered to be of little importance in Poland. Less than 1% of Polish freight is carried via rivers and canals. Shipping by sea is well developed, however; there are three large ports -- Szczecin, Gdynia, and Gdansk -- as well as smaller fishing and coastal navigation ports.

Although the Vistula is the main Polish river, it remains unregulated and is of less importance as a waterway than the smaller Odra. The Odra is linked by the modern Gliwice Canal to the Upper Silesian industrial region and carries some coal to the port of Szczecin. The Odra Basin is also linked to the lower Vistula by the Bydgoszcz Canal (Encyclopedia Britannica 1988). Freight transported via internal waterways in Poland appears comparable to that of Czechoslovakia and the GDR, at 17 and 11 million tonnes, respectively, but it totals far less than it does in the FRG, at 222 million tonnes for 1985 (Table 7.5).

TABLE 7.4 Freight Transport via Rail in Eastern Europe and the Federal Republic of Germany in 1985

Country	million tonnes	billion tonnes/km
Poland	1,114	48
Hungary	127	23
Czechoslovakia	289	72
GDR	323	54
FRG	318	59

Source: Larssen 1989

7.4 FUEL CONSUMPTION

In the early 1980s, Poland restricted energy consumption by private automobiles via direct rationing of gasoline. Substantial price hikes also lessened consumption (Dienes and Merkin 1985). These restrictions produced the following effects.

In 1985, about 2.8 million tonnes of gasoline (Table 7.6) were consumed by approximately 3.3 million cars in Poland [90% of the passenger car population (Table 7.1)], at a rate of 0.8 tonnes per vehicle. These figures compare with 23.4 million tonnes of gasoline consumed in the FRG by approximately 23.5 million cars at a rate of 1.0 tonne per vehicle in that same year. Rates of consumption were comparable for Hungary, Czechoslovakia, and the GDR, at 0.7-1.0 tonne per vehicle.

Total diesel consumption in 1985 was 5.5 million tonnes in Poland, compared with 52 million tonnes in the FRG and 90 million tonnes in the Soviet Union (Table 7.7). Diesel consumption by Polish buses was 13.6 tonnes per vehicle in 1985, compared with 10-11 tonnes per vehicle in Hungary and Czechoslovakia and only 4 tonnes per vehicle in the GDR.

TABLE 7.5 Freight Transport via Internal Waterways in Eastern Europe and the Federal Republic of Germany in 1985

Country	million tonnes	billion tonnes/km
Poland	16.6	1.9
Hungary	4.2	7.9
Czechoslovakia	11.4	3.8
GDR	16.8	2.3
FRG	222.0	49.4

Source: Larssen 1989.

TABLE 7.6 Transportation-Sector Gasoline Consumption in Eastern Europe and the Federal Republic of Germany in 1985

Country	kt	tonnes per vehicle per yr
Poland	2,783	0.8
Hungary	1,271	1.0
Czechoslovakia	1,778	0.7
GDR	2,475	0.9
FRG	23,430	1.0

Source: Larssen 1989.

TABLE 7.7 Transportation-Sector Diesel Consumption in Eastern Europe, the Soviet Union, and the Federal Republic of Germany in 1985 (kt)

Country	Total	Pass Cars	Trucks	Buses	Agri-culture	Rail	Stationary/ Other
Poland	5,568	209	1,945	314	1,476	546	1,078
Hungary	3,638	64	639	251	700	280	1,704
Czechoslovakia	3,138	89	1,732	366	700	859	-608
GDR	5,313	0	640	218	650	705	3,100
FRG	51,890	NA[a]	NA	NA	NA	NA	NA
Soviet Union	90,100	3,400	4,125	4,130	27,800	9,200	41,445

[a]NA = not available.

Source: Larssen 1989.

8 FORECASTS OF FUTURE ENERGY CONSUMPTION IN POLAND

The significant amount of uncertainty that exists with respect to future economic development makes it difficult to predict energy consumption and demand; however, some decisions should be made now with respect to energy development measures. The measures should be chosen according to probability, but independently from the pace of economic processes. The results and measures presented in this chapter, which were discussed with staff of Poland's Department of Energy Problems, were made with the use of the energy environment model SPSEK-E (Cofala, Parczewski, and Umer 1990). These results were accepted by the government to use as a basis for creating an energy policy in Poland.

8.1 MACROECONOMIC GROWTH SCENARIOS

The macroeconomic assumptions given below are the result of discussions with the representatives of the Ministry of Industry and the Central Office of Planning as well as internal discussions by the authors of this report. No formalized mathematical model was applied because it was assumed that this would imply a greater degree of precision than actually exists. The uncertainty is caused by considerable changes in prices and production shortfalls of more than 20%, which render all assumptions of macroeconomic model coefficients based on conclusions from trends or dependencies to be imprecise. To present the assumptions, only simple spreadsheet-type procedures were used in order to enable proper summing of assumed exogenous values.

It is assumed that production (national income) will decline 25% in 1990 relative to 1989. It is also assumed that decline will be worse in the electromachinery, mining, construction, and transportation sectors.

Three scenarios of future economic development were considered:

1. Low (L) -- with an average growth rate from 1991 to 2010 of 3% per year,

2. Middle (M) -- with an average growth rate from 1991 to 2010 of 5% per year, and

3. High (H) -- with an average growth rate from 1991 to 2000 of 8% per year, and from 2001 to 2010 of 5% per year.

The next group of assumptions, which would significantly affect Poland's final energy demand, concerns new housing construction. In scenario L, the very low level of housing construction in 1990 is assumed to continue throughout 1991-1995 (about 125,000 flats per year), with some improvement in later years (i.e., 175,000 flats per year in 2000, 210,000 flats in 2005, and 215,000 flats in 2010). This near-term stagnation and long-term slow improvement is assumed to apply mainly to apartment blocks in cities.

In scenario M, in the period 1991-1995, it is assumed that 170,000 flats per year will be constructed (this is the average level that occurred from 1986 to 1990, taking into account the building of 100,000 flats in 1990). The next three five-year periods assume 200,000, 230,000, and 260,000 flats per year, respectively.

In scenario H, the systematic and high rate of housing construction of the 1970s is assumed. In the period 1991-1995, 205,000 flats are assumed to be built per year; the next three five-year periods assume the construction of 260,000, 285,000, and 310,000 flats per year, respectively.

The initial calculations show that the H scenario generates an energy demand of about 210 Mtce in 2010. Demands for electricity are expected to be about 210 TWh in 2000 and 280 TWh in 2010. It is impossible to fulfill such demands, especially until 2000, because of the lack of investment funds and also because of logistical reasons associated with the lack of construction time and new energy supply systems. In addition, the fast development rate results in bottlenecks, and -- under the new conditions -- may also lead to the replication of the former economic structure, which the new government wants to avoid. For these reasons, scenario H is not described further because it is basically unrealistic. Nevertheless, the results for this scenario are presented in the tables.

Assumptions about the main macroeconomic indicators for scenarios L, M, and H are presented in Table 8.1. Table 8.2 illustrates the assumed changes associated with the contributions of selected branches of the economy to the national income. In all variants, relatively great structural changes are evident, as manifested in the decrease of the contribution from energy-intensive sectors (iron and steel industries, building materials, chemical raw materials) and the increase in the contribution from the sectors producing goods that incorporate a higher degree of manufacturing (electromachinery, "light" chemical products, other branches of industry including the food industry, light industry, etc.).

8.2 POTENTIAL DEMAND FOR FUELS AND ENERGY

Table 8.3 shows the final demand for fuels and energy expected in the considered scenarios. It is estimated that this demand will be about 16% lower in 1990 than it was in 1988. In scenario M, this demand will exceed the level reached in 1988 only after 1995. In scenario L, this level will not be reached until at least 2005. In 2010, the demand increases by 12% in scenario L and by 33% in scenario M.

In all the scenarios, the necessity of limiting SO_2 emissions according to the program of the Ministry of Environmental Protection, Natural Resources, and Forestry (described in greater detail in Chaps. 25 and 26) is assumed. These emissions should be reduced by 30% in 2000 and by 50% in 2010 according to this program. It is assumed that all new power plants will be equipped with flue-gas desulfurization (FGD) installations and low-NO_x burners. For existing plants, it is assumed that primary measures for the reduction of NO_x emissions (low emission burners, the modification of combustion processes) as well as the installation of FGD units will be applied to the extent necessary to attain the permissible level of SO_2 emissions. The possibility of coal beneficiation

TABLE 8.1 Main Macroeconomic Indicators for Analyzed Scenarios (in billions of zlotys)[a]

Specification	1985	1990	Scenario L		Scenario M		Scenario H	
			2000	2010	2000	2010	2000	2010
Net material product generated	7,902	6,320	8,810	11,400	10,400	16,770	13,650	22,2[illegible]0
Net material product used	7,806	6,120	8,510	10,970	10,100	19,320	13,250	21,680
Export-import balance	96	200	300	450	300	450	400	550
Accumulation	2,393	1,780	2,740	3,030	3,550	6,700	6,380	10,070
Consumption	5,413	4,340	5,780	7,940	6,550	9,630	6,870	11,600
Investment outlays in material product sphere	1,155	860	1,320	1,460	1,710	3,230	3,080	4,860

[a]Based on 1984 prices.

TABLE 8.2 Shares of Selected Sectors in Economic National Mean Product Formation for Analyzed Scenarios in 1985-2010 (% unless indicated)[a]

Sector	1985 (billion zloty)	1985	1990	L		M		H	
				2000	2010	2000	2010	2000	2010
Fuel energy	468	5.9	6.4	5.9	5.6	5.2	4.7	4.6	4.4
Ferrous metallurgy	105	1.3	1.2	0.9	0.8	0.8	0.6	0.7	0.5
Nonferrous metal.	68	0.9	0.9	0.8	0.7	0.7	0.6	0.7	0.7
Equipment goods	1,041	13.2	12.7	12.7	11.9	12.7	14.0	13.8	14.4
Chemicals	236	3.0	2.8	2.9	3.4	2.9	3.6	3.0	3.4
Minerals	143	1.8	1.6	1.3	1.3	1.3	1.3	1.5	1.4
Other industries	1,780	22.4	24.1	24.4	26.7	26.5	30.0	25.1	26.7
Construction	891	11.3	9.2	9.6	10.8	9.6	9.7	10.5	9.9
Agriculture	1,229	15.6	16.2	15.2	14.1	14.5	11.2	12.8	11.0
Transportation	402	5.1	4.1	4.6	4.8	4.8	4.5	4.6	4.6
Other sectors	1,538	19.5	20.8	21.7	19.9	21.0	19.8	22.7	23.0
Total	7,902	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

[a]Based on 1984 prices.

TABLE 8.3 Final Energy Demand for Analyzed Scenarios by Sector and Fuel Type in 1985–2010

Demand by Sector and Fuel Type	1985	1988	1990	1995 L	1995 M	1995 H	2000 L	2000 M	2000 H	2010 L	2010 M	2010 H
Demand (PJ)												
By sector												
Industry	1,410	1,400	1,120	1,140	1,190	1,290	1,220	1,400	1,570	1,410	1,960	1,930
Construction	70	60	50	60	60	70	70	80	100	100	120	120
Agriculture	100	80	70	80	90	90	100	110	120	110	130	150
Transport	220	210	160	180	190	210	210	230	270	270	290	380
Households	1,600	1,780	1,560	1,740	1,770	1,810	1,820	1,900	1,980	2,050	2,190	2,400
By fuel type												
Solid fuels	1,210	1,310	1,010	1,070	1,080	1,090	950	970	990	800	870	940
Gaseous fuels	380	440	330	370	370	400	460	480	550	630	680	780
Liquid fuels	470	490	390	430	460	490	520	590	650	700	820	900
Electricity	350	380	330	370	390	420	430	480	570	530	680	780
Heat	880	840	810	870	910	970	970	1,110	1,180	1,190	1,540	1,470
Other fuels	110	70	90	90	90	100	90	90	100	90	100	110
Total	3,400	3,530	2,960	3,200	3,300	3,470	3,420	3,720	4,040	3,940	4,690	4,980
Demand (%)												
By sector												
Industry	41.4	39.7	37.9	35.7	36.2	37.2	35.8	37.8	38.8	35.7	41.7	38.9
Construction	2.0	1.7	1.7	1.8	1.8	2.1	2.0	2.2	2.4	2.5	2.6	2.5
Agriculture	3.0	2.3	2.5	2.4	2.6	2.6	2.8	2.9	2.9	2.9	2.8	3.0
Transport	6.6	5.9	5.4	5.8	5.7	5.9	6.1	6.1	6.8	6.8	6.2	7.6
Households	47.0	50.4	52.5	54.3	53.7	52.2	53.3	51.0	49.1	52.1	46.7	48.0
By fuel type												
Solid fuels	35.8	37.1	34.2	33.4	32.7	31.4	27.8	26.2	24.6	20.3	18.5	18.9
Gaseous fuels	11.3	12.4	11.3	11.7	11.2	11.4	13.5	12.8	13.6	16.0	14.6	15.6
Liquid fuels	13.7	14.0	12.9	13.3	14.0	14.2	15.1	15.8	16.1	17.8	17.4	18.1
Electricity	10.2	10.8	11.0	11.6	11.7	12.1	12.6	13.0	14.0	13.4	14.5	15.6
Heat	25.8	23.8	27.5	27.1	27.6	28.1	28.4	29.7	29.3	30.2	32.9	29.6
Other fuels	3.2	1.9	3.1	2.9	2.8	2.8	2.6	2.5	2.4	2.3	2.1	2.2

according to the Hard-Coal Board's Program is taken into consideration. On the basis of the original assumptions of that program, it is assumed that coal losses in the cleaning process will be reduced up to 50%. However, according to the estimates of independent specialists, the losses assumed in this program are too high. This assumption must be verified on the basis of the results of operation of pilot plants.

Table 8.4 presents data on the primary energy demand for the analyzed scenarios. It is estimated that this demand might be 156 Mtce in 1990, which is about 16% less than it was in 1988. In 2000, this demand is expected to increase to 178 Mtce in scenario L and 191 Mtce in scenario M (in 2010, 200 Mtce and 239 Mtce, respectively). The decrease in demand in 1990 involves all energy forms, even those that were in deficit recently (i.e., electricity, gas, and liquid fuels). The decrease in the demand for gas in 1990 may cause a drastic fall in the level of domestic supplies if renegotiation of contractual arrangements with the Soviet Union does not occur or is not possible.

Table 8.5 presents data on fuel production, exports and imports. After 1995, in scenarios L and M, the demand for natural gas increases. Taking into account domestic production, gas import demands reach 10-15 Gm^3 in 2000 and 16-21 Gm^3 in 2010, depending on the scenario. Therefore, it will be necessary to negotiate for additional gas imports to Poland. For security of supplies, the imported gas will have to be from countries other than the Soviet Union. Poland's heavy dependence on gas supplies from the Soviet Union means that there is danger that an economic catastrophe would occur if they were suspended. Poland's domestic production is not sufficient to meet the requirements of its customers other than those in the industrial sector. Dependence on gas from the Soviet Union forces Poland to receive a constant flow of gas despite changes in demand. Importing considerable amounts (several billion cubic meters) of gas from other suppliers (e.g., Norway, Algeria) would reinforce Poland's negotiating position in talks with the Soviet Union, who nevertheless will probably still remain Poland's main partner for a long time. It will also be necessary for Poland to considerably increase its use of liquid fuels and, as a result, increase the capacities of its refineries (Table 8.4). Even in scenario L, it will be necessary to build a large refinery by 1995.

Table 8.6 presents data on the investment outlays required to develop the fuel-energy industry from 1990 to 2010 as well as the value of the foreign currency balance in exports and imports of fuel. Investment requirements are about 7 billion zlotys (zl) in scenario L and 9.5 billion zl in scenario M. These funds represent approximately 4% of the national income produced during 1990-2010.

TABLE 8.4 Primary Energy Demand for Analyzed Scenarios in 1988-2010

			L		M		H	
Primary Energy Form	1988	1990	2000	2010	2000	2010	2000	2010
Demand (PJ)								
Hard coal	3,606	2,930	3,123	3,267	3,214	3,759	3,334	3,876
Lignite	592	589	545	442	545	551	560	700
Natural gas	406	308	577	779	715	946	894	1,105
Liquid fuels	740	621	832	1,011	1,002	1,228	1,134	1,301
Nuclear fuel	0	0	0	231	0	375	0	375
Other primary energy	102	135	135	135	135	135	135	135
Total	5,447	4,583	5,212	5,865	5,611	6,994	6,057	7,492
Total (10^6 tce)	186	156	178	200	191	239	207	256
Energy intensity of national mean product (1985 = 100)	94	111	90	80	82	64	68	52
Demand (%)								
Hard coal	66.2	63.9	59.9	55.7	57.3	53.7	55.0	51.7
Lignite	10.9	12.9	10.5	7.5	9.7	7.9	9.3	9.3
Natural gas	7.4	6.7	11.1	13.3	12.7	13.5	14.8	14.8
Liquid fuels	13.6	13.6	15.9	17.2	17.8	17.6	18.7	17.4
Nuclear fuel	0.0	0.0	0.0	3.9	0.0	5.4	0.0	5.0
Other primary energy	1.9	2.9	2.6	2.3	2.4	1.9	2.2	1.8

TABLE 8.5 Production, Exports, and Imports of Selected Energy Forms for Analyzed Scenarios

			Scenario					
			L		M		H	
Energy Form	1988	1990	2000	2010	2000	2010	2000	2010
Production								
Hard coal (Mt)	193	163	145	145	144	154	144	158
Lignite (Mt)	73.5	73	68	55	68	69	70	88
Natural gas[a] (Gm^3)	4.6	1.4[b]	6.3	6.9	6.3	6.8	6.3	6.8
Electricity (TWh)	144	125	160	191	176	244	203	279
Heat (PJ)	901	891	1,049	1,272	1,184	1,632	1,263	1,559
Exports								
Hard coal[c] (Mt)	31.2	28.6	2.2	-4.2	-0.9	-13.2	-2.5	-15.9
Coke (Mt)	2.9	3.2	3.2	3.2	2.9	2.3	0.0	3.2
Imports								
Liquid fuels[d] (Mt)	17.9	15.4	21.0	25.4	25.0	30.6	28.1	32.3
Natural gas[a] (Gm^3)	7.4	7.8	10.5	15.9	14.5	20.9	19.8	25.5
Nuclear fuel (PJ)	0	0	0	232	0	375	0	375
Electricity[c] (TWh)	4.5	4.0	4.0	4.0	4.0	4.0	4.0	4.0

[a]High methane gas equivalent (34 MJ/m^3).

[b]Necessary production decrease (no demand) in the case of gas quantities contracted from the Soviet Union.

[c]Import minus export balance.

[d]Crude oil plus (import minus export balance of liquid fuels).

TABLE 8.6 Investment Outlays in Fuel-Energy Industry and Net Spending for Fuel Imports in 1990-2010

Outlay or Net Spending by Year	Scenario		
	L	M	H
Investment outlays in fuel-energy industry (10^{12} zl)	6.86	8.80	9.42
Export-import balance in fuel trade (10^9 \$)[a]			
1990		-1.6	
2000	-4.6	-6.1	-7.9
2010	-8.0	-11.0	-12.5

[a]Values for the import-export balance are given in U.S. dollars even though the transactions are or will be carried out with socialist countries.

SECTION 3:

ENVIRONMENTAL QUALITY AND IMPACTS

9 POLLUTANT EMISSIONS

Given its large reserves of coal and lignite, its accelerating demand for energy, particularly by heavy industry, and its lack of hard currency, Poland is and will continue to be heavily dependent on these indigenous resources for most of its energy needs. At the same time, as Poland continues to draw on these coal reserves, the quality of the coal used will probably tend to be poorer and poorer, thus necessitating combustion of greater quantities of coal to obtain the same amount of useful energy, unless more efficient combustion is effected. These factors, along with increased reliance on old and inefficient industrial and power plants with little or no flue-gas controls, ensure that Poland will continue to be a heavy emitter of air pollutants. Only a vigorous policy of environmental protection can prevent this deterioration.

In addition, the lack of treatment and mitigation of industrial, agricultural, domestic, and mining wastes and the continued discharge of these untreated wastes directly into waterways ensure the existence and intensification of water pollution problems in Poland. The poor supply of water and the dangerous state of water and air pollution result from prolonged neglect during the industrialization drive and the rapid urbanization that followed. Investment outlays have always been insufficient in this field, and they were especially low during the early 1980s. Because the industrial-related ministries have always had more influence and power than the ministries responsible for health and the corresponding local authorities, production issues have always had precedence over health concerns (Fallenbuchl 1988).

9.1 AIR POLLUTION

The main air pollutants resulting from energy-related activities are SO_2, NO_x, CO_2 (Chap. 20), volatile organic compounds (VOC), and particulate matter (PM). The precise quantities of these pollutants released to the atmosphere each year are not known for a number of reasons, including the absence of national inventories in many countries and the secrecy of Eastern European governments about such statistics. However, because of the political reforms sweeping Eastern Europe and the realization that many of these pollutants can travel large distances, often across international borders, information on these emissions is rapidly accumulating. Estimates (from a number of sources) of air pollution emissions and deposition in various European countries, including Poland, are given in Table 9.1.

It has been estimated that 70% of air pollution emissions in Poland are from industrial sources and only 15% each are from transportation and district/domestic heating (McCormick 1985). Overall, there are relatively few individual sources of emissions; it is estimated that 83% of air contaminants result from only 94 production plants (Pawlowski 1990). This fact could have significant implications for the feasibility of implementing control measures.

It is generally believed that emissions of air pollutants will increase significantly in the near future as Poland attempts to resolve many of its economic difficulties through greater industrialization and modernization. For example, SO_2 emissions are

TABLE 9.1 Emissions and Deposition in Poland and Selected European Countries

	Emissions (Mt/yr)											
	SO_2			NO_x			HC			CO_2[c]		
Country	Yr[a]	Amt.	Ref.[b]	Yr	Amt.	Ref.	Yr	Amt.	Ref.	Yr	Amt.	Ref.
Poland	82	4.3	16	82	1.1-1.8	4,5	83-84	0.8	6	85	120	7
	85	3.8-4.3	1,2	85	0.8	1						
	88	4.2	3	85	1.4	15						
	75-85 avg.	4.5-5.5	14									
Czechoslovakia	85	3.2	7	85	1.1	7	83-84	0.4	6			
	88	2.8	3				85	0.4	7			
GDR	85	6.0	10	88	0.4	9				85	89	7
	88	3.0-4.9	3,9									
Hungary	83-84	1.3	6	83-84	0.4	6	83-84	0.3	6			
				85	0.4	7						
	85	1.4	7									
Sweden	84-85	0.3	6,12	84-85	0.3	6,12	83-84	0.4	6			
	88	0.4	3									
FRG	85	2.4-2.6	7,12	85	2.9-3.3	7,12	85	1.8	7	85	182	7
	88	1.5	3									

TABLE 9.1 (Cont'd)

Country	Emissions (Mt/yr)									Annual SO_2 Deposition (g/m^2)			
	NH_3			VOC			PM						
	Yr	Amt.	Ref.	Yr	Amt.	Ref.	Yr	Amt.	Ref.	Yr	Amt.	Area	Ref.
Poland	83-84	0.4	6,16	82	0.5	16	82-84	3.4	5	83	12.8	Total	17
											13.8	South	8
											50.0	Upper Silesia	8
											4075.0	Chorzow	8
Czechoslovakia	83-84	0.17	6							83	22.6		8
GDR	83-84	0.13	6							83	35.0		8
Hungary	83-84	0.13	6							82	10.0		17
Sweden	83-84	0.05	6							88	1.4	Total	17
										80	1.5-2.0	Southwest	13
											0.3	North	13
FRG										83	14.5		8

[a]Yr refers to the year(s) in which the data were measured. All occur in the twentieth century (i.e., 85 = 1985).

[b]Sources are as follows: 1 = UN (1987); 2 = Osterberg and Teknik (1989); 3 = French (1990); 4 = Cofala and Bojarski (1987); 5 = UNEP and WHO (1988); 6 = CDA/ERL (1988); 7 = WRI (1988); 8 = Kabala (1985); 9 = Scheerer (1989); 10 = Kuhn (1989); 11 = Highton and Chadwick (1982); 12 = Dovland (1987); 13 = Aniansson (1988a); 14 = Kabala (1989); 15 = Pacyna, Larssen, and Semb (1989); 16 = Pacyna (1989); 17 = calculated.

[c]The CO_2 emissions measured came only from the industrial sector.

projected to double (from the early 1980s value) to 7.3 million tonnes by the early 1990s (Kabala 1985), although such estimates vary considerably. In addition to its domestic emissions, Poland also receives a significant amount of air pollutants from other countries, which increases its burden of these substances. In general, Poland receives more air pollutants from other countries than it sends to other countries.

9.1.1 Sulfur Dioxide

Poland is a major emitter of SO_2, ranking seventh in world generation of this pollutant. The majority of SO_2 emissions in Poland occur in the vicinity of large power plants and industrial centers in the following areas:

- Upper Silesia and Krakow,
- Southwest Poland, and
- The Lotz-Belchatow region in central Poland.

The spatial distribution of SO_2 emissions in Central and Eastern Europe and Sweden is shown in Fig. 9.1. The majority of SO_2 emissions in Poland result from the production of electricity and industrial energy use (66%), which are obtained almost exclusively from coal and lignite. Smaller contributions are derived from domestic, agricultural, manufacturing, and commercial sources (32%). Only 2-3% of SO_2 emissions result from mobile sources. The sources contributing to SO_2 emissions in Poland are given in Table 9.2.

9.1.2 Nitrogen Oxides

NO_x emissions are also relatively high in Poland. Unlike most other industrialized nations, however, most of these emissions result from stationary sources, with a relatively small contribution (22%) from the transportation sector (Pacyna 1988; Larssen 1989). Most of the mobile source emissions are from road traffic; little result from agricultural vehicles, rail traffic, and internal navigation. The major stationary sources responsible for NO_x emissions in Poland are coal-fired power plants and coal combustion for heating. The remainder are from industrial processes, mainly cement production, and oil- and gas-fired boilers. The sources of NO_x emissions are given in Table 9.3.

NO_x emissions are projected to increase substantially over the next decade, particularly from the transportation sector (Agren 1988). Given the nature of the main emitters of NO_x, it is not surprising that the spatial distribution of NO_x emissions is very similar to that for SO_2. One additional area that is a large contributor of NO_x is the Warsaw metropolitan region, where many transportation- and heating-related emissions are located.

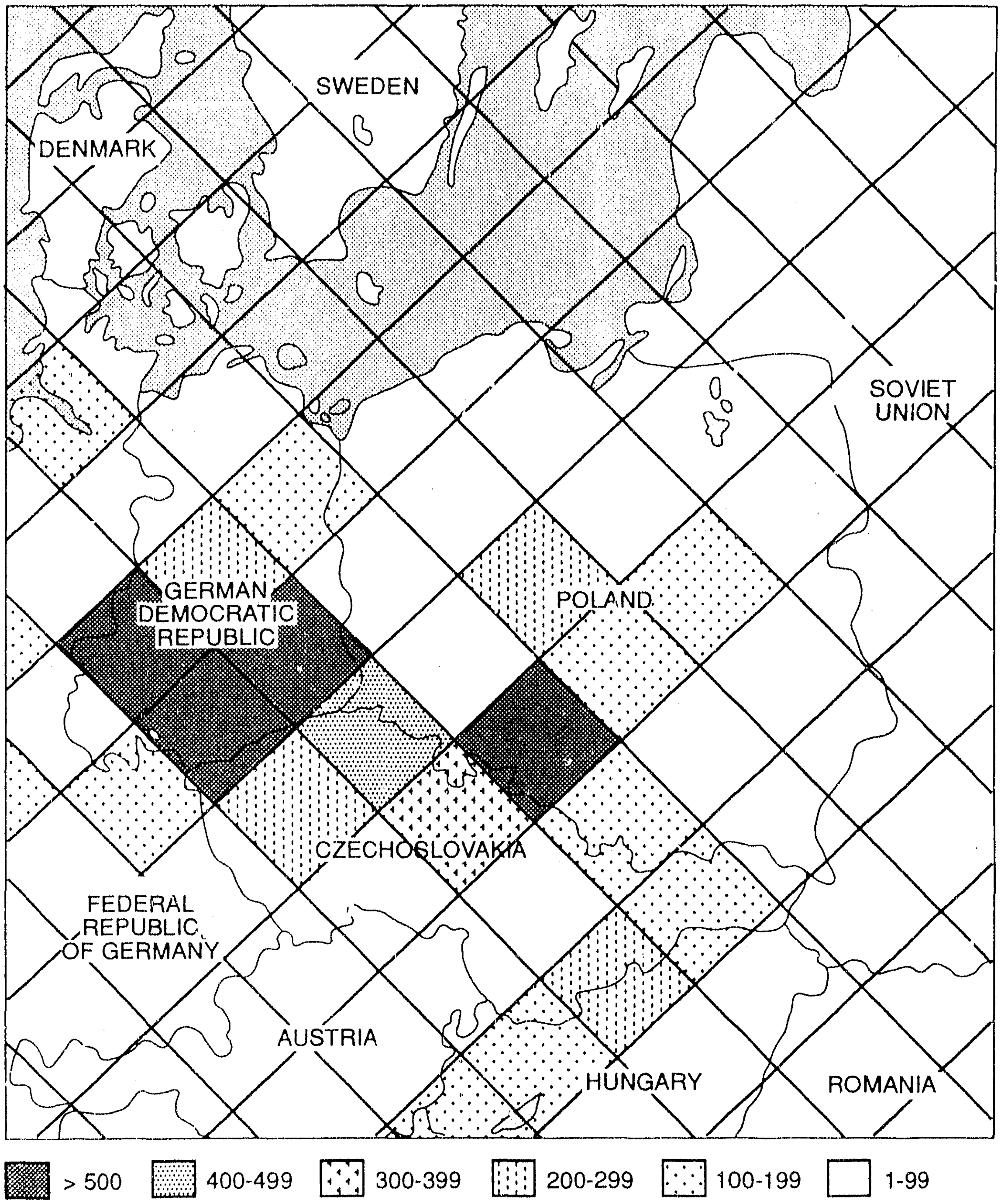


FIGURE 9.1 SO_2 Emission Distribution on a 150-km^2 Grid in 1980 (kt S/yr) (Source: EMEP, in Dovland 1987)

TABLE 9.2 SO_2 Emissions in Poland in 1985 (kt/yr)

Source	Emissions	%
Power plants	1,940	45.1
Industrial energy and heat	880	20.5
Domestic/agriculture	980	22.8
Manufacturing	400	9.3
Transportation	100	2.3
Total	4,300	100.0

Source: Agren 1988.

9.1.3 Hydrocarbons and Particulate Matter

Information on emissions of HCs and PM in Poland is scarce, but the available data indicate that these pollutants are significant contributors to both local and regional air pollution problems. Although PM emissions have declined somewhat over the past decades, the release of this pollutant is still considerable, approximately 1.8 Mt/yr (Kabala 1989).

9.1.4 Volatile Organic Compounds

A VOC emission inventory has recently been compiled for Eastern Europe, indicating that most VOC pollutants are released from stationary combustion, solvent use, and mobile sources, with smaller quantities from industrial processes. The highest emissions of VOC are from Upper Silesia, the Warsaw area, and southwest Poland (Pacyna 1989).

In addition to the above-mentioned energy-related air pollutants, Poland also produces significant emissions of ammonia (NH_3). These emissions are mainly from agricultural activities, which play an important role in Poland. The most important anthropogenic sources include fertilizer use, certain industrial activities, and animal wastes. The highest emissions of NH_3 occur in Upper Silesia, the Warsaw region, and central Poland.

9.2 WATER POLLUTION

Although air pollution problems, particularly air pollution crises in urban areas, have received considerable attention in recent years, it is generally believed that the most critical environmental problem in Poland is water quality. Untreated human

TABLE 9.3 NO_x Emissions in Poland in 1985 (kt/yr)

Source	Emissions	%
Stationary[a]		
Electricity production	531.9	38.7
Industrial processes	21.7	1.6
Coal combustion for heating	481.2	35.0
Oil + gas combustion in boilers	40.9	3.0
Total stationary	1,075.7	78.3
Mobile[b]		
Road traffic	211.0	15.4
Rail traffic	11.0	0.8
Agriculture	74.0	5.4
Internal navigation	2.0	0.1
Total mobile	298.0	21.7
Total	1,373.7	100.0

[a]Stationary sources are based on emission factors and statistics on consumption of fossil fuels and production of various industrial goods.

[b]Mobile sources are based on fuel-based emission factors and national gasoline and diesel consumption data.

Sources: Pacyna 1988; Larsson 1989.

sewage is commonly discharged into rivers and lakes, and the volume of such wastes is estimated to be approximately 2 Gm^3/yr (Kabala 1985). Industrial and mining wastes and agricultural runoff also add to the degradation of Poland's waterways, although these discharges have been very difficult to measure. It has been calculated, however, that approximately 1.9 Mt/yr of salt is discharged without treatment from hard-coal mines into waterways (World Bank 1987a). As the mining of deeper and deeper veins accelerates, the salinity of mine wastes will continue to increase (Pawlowski 1990). In addition, thermal pollution from power- and heat-generating plants can disrupt aquatic ecosystems because of changes in water temperature and mixing patterns in affected water bodies.

The main focus of this report is on air quality. To do justice to the magnitude of the water quality problems in Poland, an overview and assessment comparable in size to this report would be required. This task is beyond the scope of this current endeavor, and, therefore, water pollution issues are not addressed in detail, except for a discussion of the impact of air pollution on water resources (Chap. 19).

10 AMBIENT AIR QUALITY

Levels of air pollutants in many cities in Eastern Europe are among the highest in the world and often rival conditions that were present in London during the "Dickens" era. Ambient air pollution levels have not been extensively measured in Poland -- monitoring networks cover only 10% of the nation's area, and measurements are often performed sporadically, usually during daytime hours only (Pawlowski 1990). Nonetheless, the available data suggest that the concentration of some pollutants (especially SO_2 and PM) in Poland's largest cities often approaches dangerous levels (to human health). It has been estimated that more than half the country is exposed to ambient levels of SO_2 averaging more than 20 $\mu g/m^3$ and that most large cities have average levels of more than 60 $\mu g/m^3$ (Kabala 1989). This is within the range determined to be dangerous to human health.

The high concentration of air pollutants found in certain (usually urban) areas in Poland is due largely to the practice of locating both the extraction of raw materials and their conversion into finished products in the same general area. Also, plants tend to have low stacks, which hinder dispersion of air contaminants. In many urban areas in highly polluted Upper Silesia, atmospheric inversions and stagnation of air are common, which further trap and concentrate air pollutants.

Figure 10.1 illustrates the general level of ambient SO_2 concentrations in various parts of Poland. Note the very high concentrations of SO_2 in the vicinities of Krakow and Katowice. Table 10.1 gives average SO_2 levels in a number of areas in Poland. For comparison, Table 10.2 lists corresponding concentrations of SO_2 (as well as PM and ozone) in selected areas in Europe and the United States and also provides the standards established by the World Health Organization (WHO) and the EPA for these pollutants. In Poland, standards for most air pollutants are usually the same as those established by the WHO. Table 10.2 indicates that the average ambient SO_2 concentrations in Warsaw and Wroclaw resemble those experienced in Frankfurt and New York City and are within U.S. standards. Moreover, they are much lower than those in many urban areas of the GDR and in Prague. Particulate matter levels for Warsaw and Wroclaw are, however, double that of Frankfurt, but within the WHO standard.

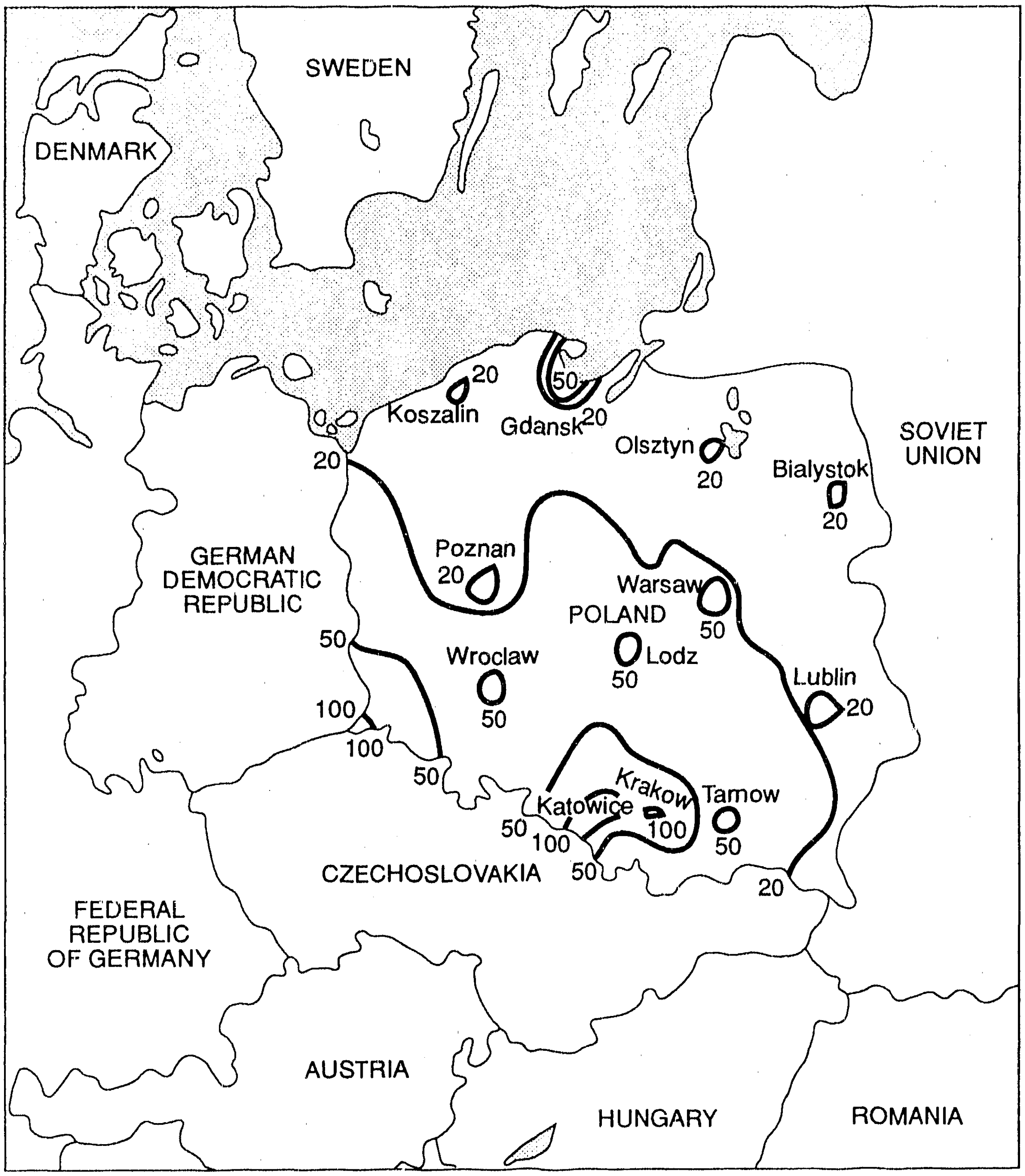


FIGURE 10.1 Ambient SO_2 Concentrations in Poland ($\mu g/m^3$) [Source: Adapted from Kabala (1989)]

TABLE 10.1 Ambient SO_2 Levels in Various Parts of Poland ($\mu g/m^3$)

Location	Annual Average	Peak (98th)[a]
SW half	20[b]	
Upper Silesia	50[b]	
SW corner	50[b]	>300[b]
Warsaw	39-50[b,c]	191[c]
Wroclaw	44[c]	177[c]
Katowice	100[b]	>300[b]
Gdansk	50[b]	>300[b]
Krakow	100[b]	>300[b]

[a]Peak level represents the 98th percentile of daily values.

[b]Levels were measured in 1990 and are taken from Kabala (1989).

[c]Levels were measured in 1982-1985 and are taken from WRI (1988).

TABLE 10.2 Ambient Air Pollution Levels and Air Pollution Standards in Poland and Selected Countries ($\mu g/m^3$)[a]

	SO_2		PM		O_3		
Country and City	Annual Avg.	Peak (98th)	Annual Avg.	Peak (98th)	Avg. Hourly	Peak (max. 1 hr)	Data Source[b]
Levels							
Poland							1
Warsaw	39[c]	191[c]	61.3[c]	235.0[c]			
Wroclaw	44[c]	177[c]	72.6[c]	272.3[c]			
Czechoslovakia							1
Prague	110[d]	348[d]	134[d]	380.3[d]			
GDR							2
Leuna	300-400[e]						
Leipzig, Halle, and Bitterfeld	>375[e]		>1000[e]				
Industrial regions (1/3 of country)	>160[e]		>150[e]				
Hungary							3
Larger cities	40-150[f]						
Sweden							4,5
Southern regions					60-80[g]	150-250[g,h]	
Northern regions					40-80[g]	100-150[g]	
FGR							1,4
Frankfurt	50-62[i]	163[c]	30-36[i]	117[c]			
Regional					100-150[j]		
Rhine Valley						>300[j]	
New York City	49[c]	93[c]	54[c]	107[c]			1
Standards (limits)							
U.S. EPA	80		50			240	1,2,4,6
World Health Org.	40-60		60-90			120	1,2,3,4

[a]For levels, "peak (98th)" refers to the 98th percentile of daily values; "avg. hourly" refers to the hourly mean concentration; and "peak (max. 1 hr)" refers to the maximum 1-hour mean concentration. For standards, values for SO_2 and PM give the annual mean limit; values for ozone give the 1-hour limit.

[b]Numbers correspond to the following references: 1 = WRI (1988); 2 = Charles (1990); 3 = UNEP and WHO (1988); 4 = Skarby and Sellden (1984); 5 = Aniansson (1988a); 6 = EPA (1989).

[c-j]These footnotes refer to the years that the levels were recorded: c = 1982-85; d = 1976-78; e = 1989-90; f = 1976-80; g = 1980; h = 1979; i = 1980-84; and j = 1983-84.

11 METEOROLOGY

Most of the focus on problems relating to air pollution in Poland (and Western Europe in general) has traditionally been concentrated on localized areas of high emissions and thus of high ambient levels of SO_2, PM, and NO_x. These areas usually consist of large urban centers and industrial zones. In recent years, however, with increasing industrialization, energy consumption (mostly coal), and population growth, the potential for regional-scale air pollution problems has increased in Poland. Also, the close proximity of a large number of nations in Europe has increased the possibility of conflicts over transboundary pollution fluxes and, thus, has heightened attention on regional air pollutants. The most notable of these are acid deposition and ozone.

In addition to the high levels of emissions of the precursors of these regional pollutants, the meteorology of the European continent and the mode of release of these substances favor the formation of acid deposition and ozone. For example, many of these precursors are released from tall smokestacks from which they can be transported long distances on upper-level winds. In addition, air masses in Europe generally tend to be unstable, generating large-scale storm systems capable of carrying pollutants great distances.

Regional-scale pollutants can generate political conflicts because there is often a jurisdictional separation of their sources and their receptors. As a result, a considerable amount of research is being focused on the transformation and transport processes involving the precursors of these regional-level pollutants. These precursors include SO_2, NO_x, and HC.

In general, the geographical distribution of regional-scale pollutants such as ozone and acid deposition is highly dependent on general wind flow patterns, precipitation rates, and the location of major emission sources. In Europe, the placement of these factors is as follows:

- Most emissions of SO_2, NO_x, and HCs are generated in Central and Eastern Europe and the United Kingdom (in addition to the Soviet Union).

- The general wind flow pattern is from the west and southwest to the east-northeast. In the summer, there is some northeasterly airflow into extreme Eastern Europe, particularly the eastern Mediterranean. In the winter, the Russian high-pressure system in Central Asia causes some east-southeasterly airflow into Eastern Europe. Figures 11.1 and 11.2 depict the general airflow patterns in parts of Europe in the summer and winter, respectively.

- Precipitation rates in most of Eastern Europe are between 500 and 1,000 mm/yr (20 and 40 in./yr), which is the range that is especially conducive to the formation of acid rain and the occurrence of ecosystem acidification. This range is amenable to large-scale acid deposition production for a number of reasons:

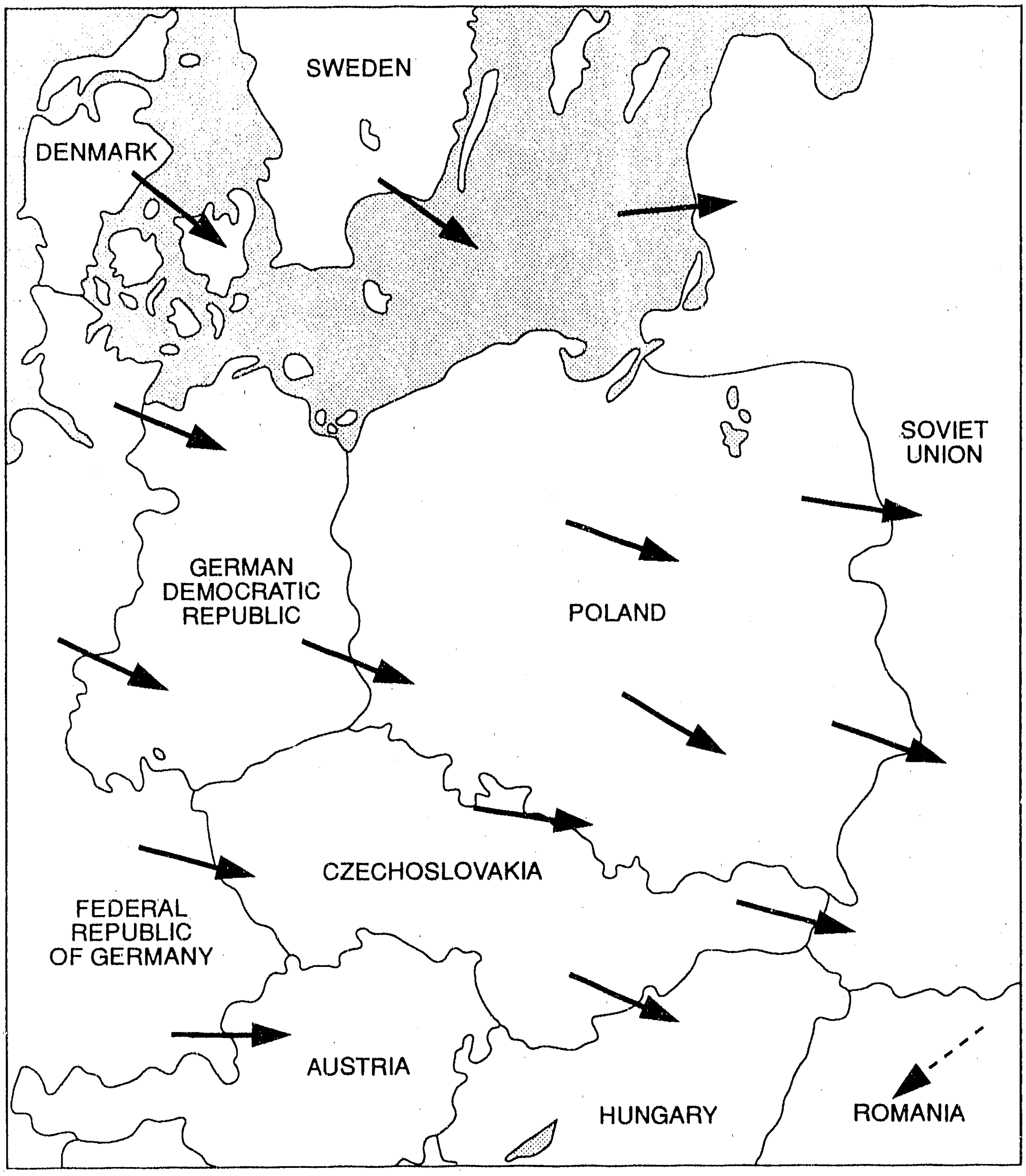


FIGURE 11.1 Predominant Wind Flow Patterns in Summer in Parts of Europe [Source: Adapted from Encyclopedia Britannica (1979)]

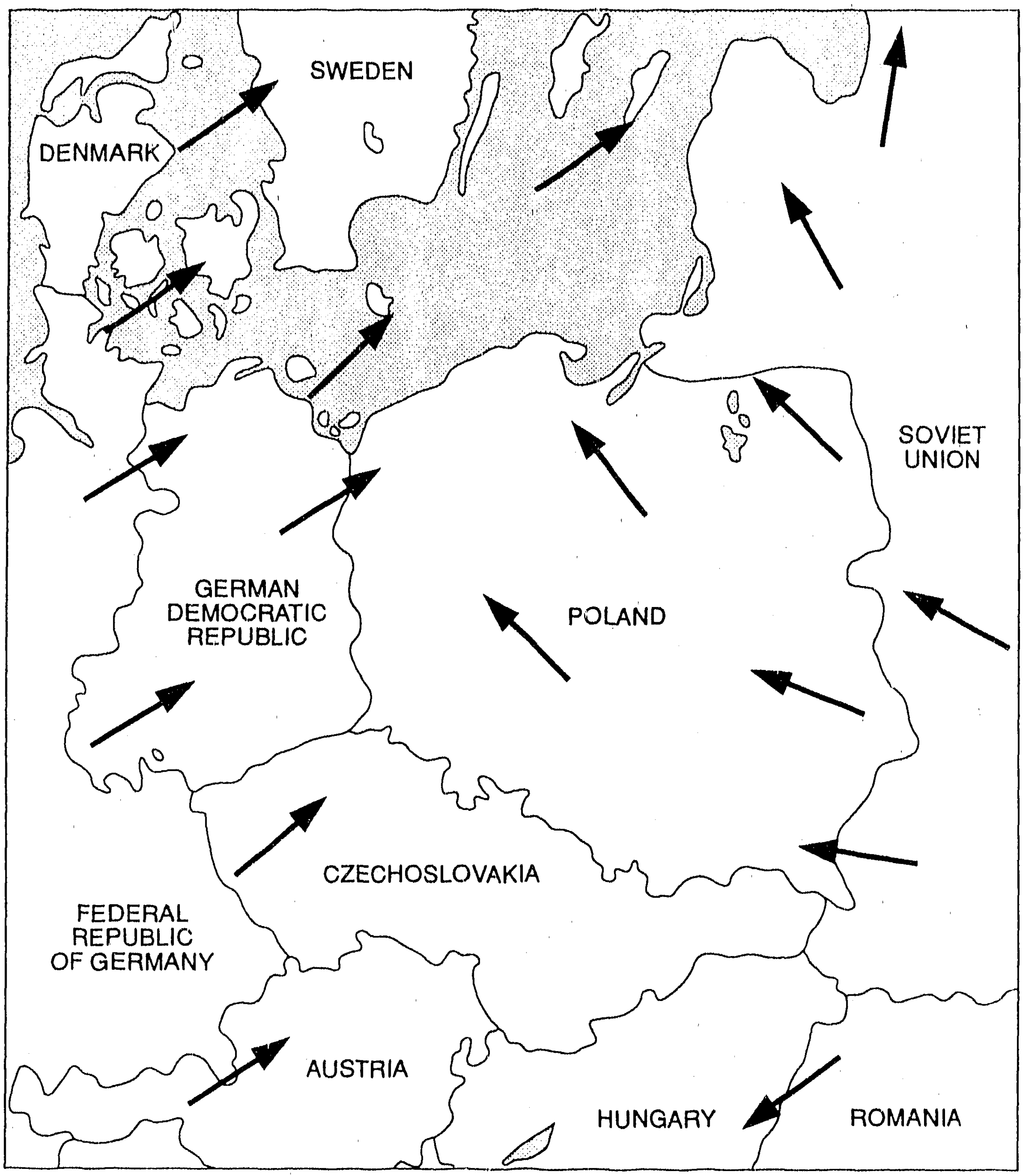


FIGURE 11.2 Predominant Wind Flow Patterns in Winter in Parts of Europe [Source: Adapted from Encyclopedia Britannica (1979)]

1. Precipitation rates of more than 500 mm/yr (20 in./yr) increase the proportion of SO_2 and NO_x that is converted to sulfates and nitrates via aqueous-phase reactions. These sulfates and nitrates can then be coupled to large-scale precipitation-producing weather systems and be deposited farther from the source than acidic substances produced by dry processes.

2. Precipitation rates of more than 500 mm/yr (20 in./yr) are also sufficient to leach basic nutrients out of the soil and thus encourage ecosystem acidification.

3. Precipitation rates of more than 1,000 mm/yr (40 in./yr), however, increase the quantity of iron and aluminum sesquioxides, which can bind incoming sulfates and thus prevent acidification.

In Poland, the only areas that do not fall within the 500-1,000-mm/yr precipitation range and thus are not very vulnerable to acidification are in central Poland and a small section of the central Carpathian Mountains along Poland's southern border (see Fig. 11.3 for an illustration of the areas at risk from acidification based on rainfall distribution alone).

By combining these factors, it can be postulated that much of Poland could receive a significant quantity of air pollutants, especially from the FRG, the GDR, and Czechoslovakia, throughout the year and that considerable amounts of air pollutants could travel to the Soviet Union from Poland. In the winter, it is also likely that some of Poland's emissions could travel to Sweden and Norway. Within Poland, where most of the air pollutants are emitted in Upper Silesia, it is probable that the prevailing westerly winds, particularly in the summer, would carry many of these emissions to Krakow and Warsaw. In the winter, the predominant southeasterly winds would transport pollutants to Wroclaw and Poznan. Chapters 12 and 13 discuss these transport patterns in greater detail.

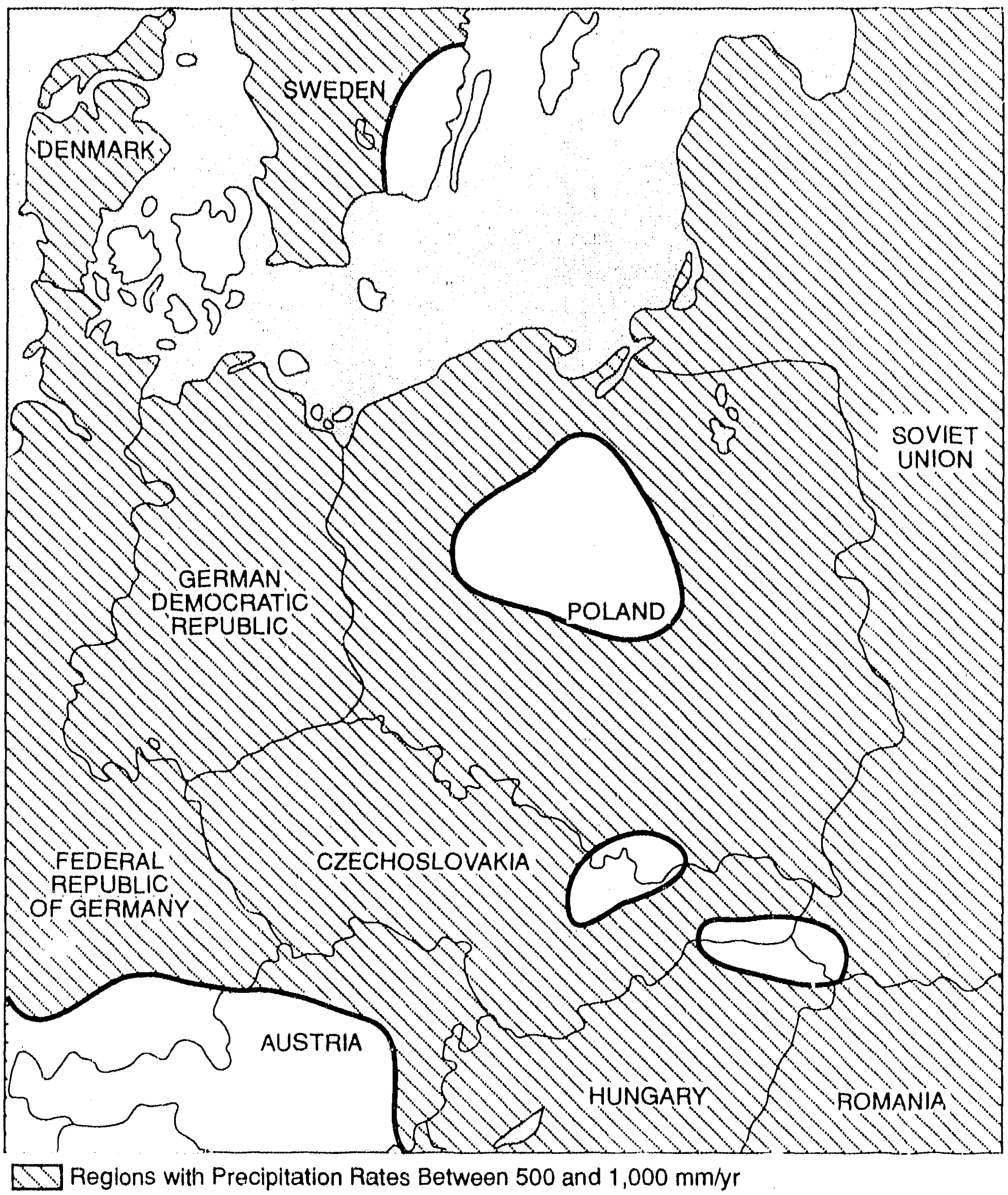


FIGURE 11.3 Regions Receiving 500-1,000-mm/yr Precipitation [Source: Adapted from Encyclopedia Britannica (1979)]

12 LONG-RANGE TRANSPORT OF SULFUR SPECIES

Emissions of sulfur species at high elevations can be transported over long distances by the prevailing winds and be deposited at locations far removed from the point of emission. This long-range transport phenomenon is very important in Europe, particularly with regard to the heavy emissions from Eastern European countries. The SO_2 emissions are transformed to acidic species during transport in the atmosphere and subsequently deposited in dry or wet (acid rain) form. Acid rain, which is largely derived from these sulfur emissions, is implicated in forest damage and related effects observed in Europe, for example, in the forests along Poland's south and southwestern borders in the Carpathian Mountains. Because pollution flows unrestricted across national borders, the concept is often referred to as *transboundary air pollution* and is the subject of extensive negotiations regarding emission-control measures.

A model has been developed by the European Monitoring and Evaluation Programme (EMEP) in Oslo to simulate the physical and chemical processes involved in the long-range transport, transformation, and deposition of pollutant species in Europe. The EMEP model operates at a geographical resolution of 150 km × 150 km but produces standard, aggregated, country-level matrices representing transfers of pollutants among the countries of Europe. The data presented in this chapter are derived from the most recent EMEP matrices for 1988 (EMEP 1989).

Figure 12.1 shows the primary sulfur emission flows affecting Poland. Significant quantities of sulfur are deposited within the borders of Poland in both wet and dry forms. The EMEP model estimated that 1.25 million tonnes of sulfur were deposited in Poland in 1988. This is the largest amount for any country, except the European part of the Soviet Union. Of this amount, roughly 54% (677,000 tonnes) is attributed to sources within Poland. This proportion of domestic contribution is typical of Eastern European countries. It is lower than it is in upwind countries such as the United Kingdom and Spain, but it is higher than it is in the smaller, Central European countries such as Austria and Switzerland.

Only two countries significantly contribute to deposition in Poland -- the GDR and Czechoslovakia. Because these countries are heavy emitters and are located predominantly upwind of Poland, pollution from these two countries tends to drift across the Polish border where it is deposited on Polish soil. About 19% (243,000 tonnes) of the sulfur deposited in Poland is attributed to sources in the GDR; about 10% (123,000 tonnes) is attributed to sources in Czechoslovakia.

Emissions from Poland also pollute its neighbors. Roughly 9% (63,000 tonnes) of sulfur deposition in Czechoslovakia is attributed to sources in Poland. Approximately 259,000 tonnes of sulfur from Poland is deposited within the Soviet Union, but the contribution is small (8%) in comparison with domestic Soviet sources.

Of particular interest with regard to long-range transport of pollution from Poland is its contribution to deposition in Sweden, particularly in the winter (see Figure 11.2). Because of its strong environmental awareness, Sweden has taken major

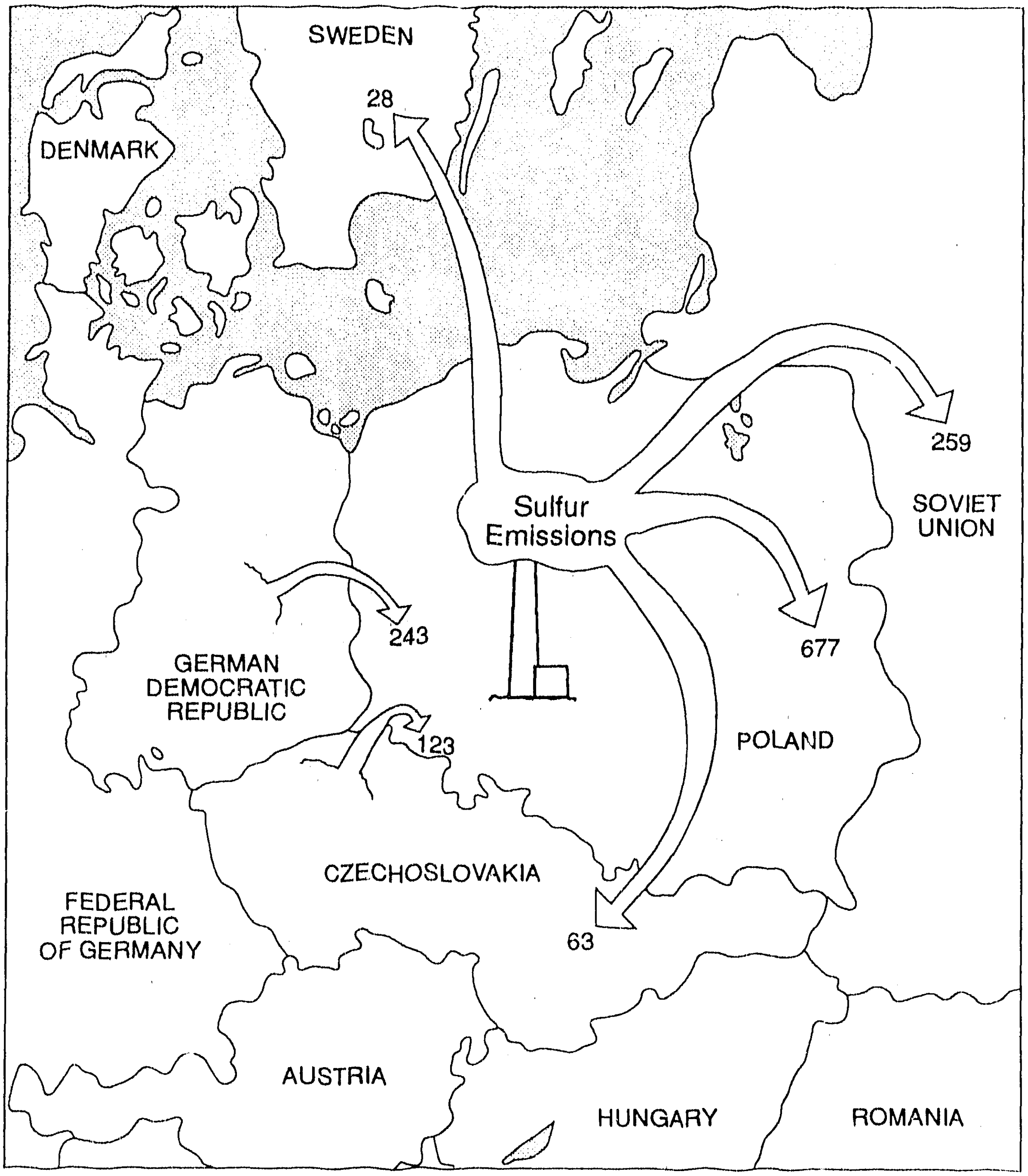


FIGURE 12.1 Significant Flows of Sulfur Involving Poland in 1988 (Deposition of Total Sulfur in kt/yr) (Source: EMEP 1989)

steps to reduce its own emissions of SO_2 in order to protect its sensitive lakes. Domest: emissions have been reduced to the point where Swedish sources now contribute only 11% (34,000 tonnes out of 306,000 tonnes) of the sulfur deposited in Sweden. Other European countries contribute the remainder, and Poland is responsible for a significant 9% (28,000 tonnes). In a radical departure from usual control practice, Sweden is providing $200 million to Poland to aid pollution abatement. This grant is considered a better investment in benefiting the Swedish environment than further control of Swedish sources.

13 LONG-RANGE TRANSPORT OF NITROGEN SPECIES

Nitrogen oxides are transported over long distances in a similar manner to sulfur, except that the quantities are smaller (by a factor of approximately 5), they are produced by a larger number of dispersed sources, and they tend to be emitted at lower release heights (from transportation sources, for example). Modeling the oxidation of nitrogen species in the atmosphere is quite difficult, and it is only recently that EMEP released a matrix of NO_x transfers. Consequently, recent estimates of nitrogen transport and deposition should be viewed with some caution.

The EMEP matrix for 1988 shows that total deposition of NO_x in Poland was about 226,000 tonnes, with about 67,500 tonnes (30%) attributed to sources within Poland. This proportion is lower than for SO_2 because of the greater diversity of sources and source types in neighboring countries. Other countries contributing to deposition of NO_x in Poland are the FRG (20%), the GDR (14%), and Czechoslovakia (11%). The FRG assumes greater importance for Poland with regard to NO_x deposition, because NO_x emissions are currently three times greater than SO_2 emissions in recent years. Polish emissions of NO_x impact primarily the European part of the Soviet Union (73,800 tonnes) and Czechoslovakia. Figure 13.1 depicts the transboundary flows of NO_x affecting Poland.

Some preliminary work has been performed to estimate the deposition of ammonia (NH_3) (Asman and Janssen 1986). Poland ranks third in total deposition among European countries, behind the Soviet Union and France. Sources in Poland are believed to contribute about 68% of the NH_3 deposited on Polish soil. Deposition of NH_3 is becoming more important as more is learned about ecosystem damage in Europe, but the state of the art in atmospheric modeling of these species is still in its infancy.

Nitrogen oxides and NH_3 both contribute to acidic deposition. Nitric oxide is rapidly converted to nitrogen dioxide, which is further converted to nitric acid. Nitric acid may be deposited in either dry or wet form and may contribute directly to hydrogen ion inputs (acidification). Alternatively, through photochemical reactions in the atmosphere, NO_x can contribute to the formation of ozone, which is a serious problem in much of Central Europe (Chap. 15).

Ammonia, although alkaline when emitted, contributes to acidification as a result of its reduction to the ammonium ion in the atmosphere, which can then be oxidized to the nitrate ion on interaction with soils, leading to the liberation of free hydrogen ions. In many agricultural countries of Europe (e.g., France and the Netherlands), NH_3 can be one of the leading contributors to soil acidification. The effect of NH_3-derived acidification in Poland requires further study.

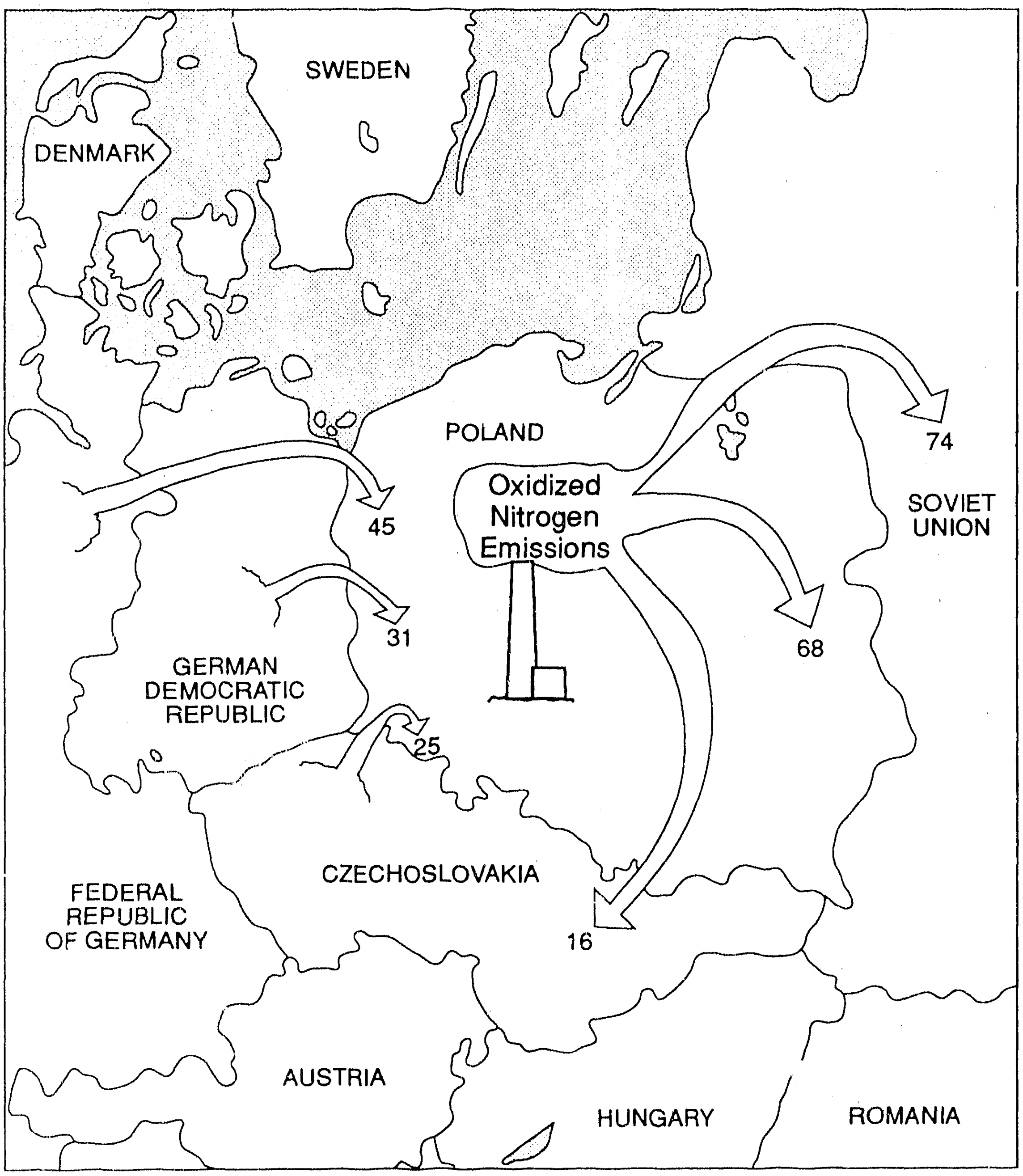


FIGURE 13.1 Significant Flows of Oxidized Nitrogen Involving Poland in 1988 (Deposition of Total Nitrogen in kt/yr) (Source: EMEP 1989)

14 DEPOSITION

14.1 SULFUR

Poland has one of the world's highest deposition levels of sulfur and its related compounds. It has been estimated that every square meter of the country receives an average of 12.8 g/yr of SO_2, which is approximately six times more than that received in the United States. Moreover, in parts of Poland, the level of SO_2 deposition is even higher. For example, in Upper Silesia, 50 g/m^2 of SO_2 is deposited annually; in Chorzow, a heavily industrialized city in the heart of Upper Silesia, annual deposition has reached an astonishing 4,075 g/m^2.

The last column of Table 9.1 compares the SO_2 deposition rates of various regions in Poland with those in other European countries. Although at the national level, other nations, particularly the GDR, Czechoslovakia, and the FRG, surpass the average Polish SO_2 deposition level, certain cities and/or regions within Poland have deposition rates among the highest in the world. The distribution of SO_2 deposition in Poland, as determined through observations, is pictured in Fig. 14.1.

Given the relatively abundant precipitation in Poland, much of the SO_2 is deposited in the form of sulfate in precipitation, resulting in significant levels of acid deposition. The mean annual concentrations of sulfate in precipitation throughout Eastern Europe are shown in Fig. 14.2, and the average pH of precipitation is given in Fig. 14.3. From the latter figure, it can be inferred that most of Poland (and the GDR) currently receives precipitation that is among the most acidic in Europe (pH < 4.3). In some parts of southwestern Poland (i.e., in the Sudety Mountains), pH levels as low as 2.7 have been observed (Mazurski 1990).

14.2 NITROGEN

The deposition of nitrogen and its related compounds (NO_x, NH_3, nitrates) has not been measured as extensively as for sulfur; however, some attempts to determine such levels have been made. Figure 14.4 illustrates the quantity of NO_x-N deposition for Eastern Europe and indicates that a significant portion of Poland receives fairly high levels of such compounds (>1.0 g/m^2 annually). Figure 14.5 depicts the spatial distribution of the mean annual concentrations of nitrate in precipitation. From this figure, it can be implied that Poland and much of Central and Eastern Europe receive more nitrates in precipitation than the rest of Europe. This nitrate, of course, contributes to the acidity of precipitation in this region, as shown in Fig. 14.3.

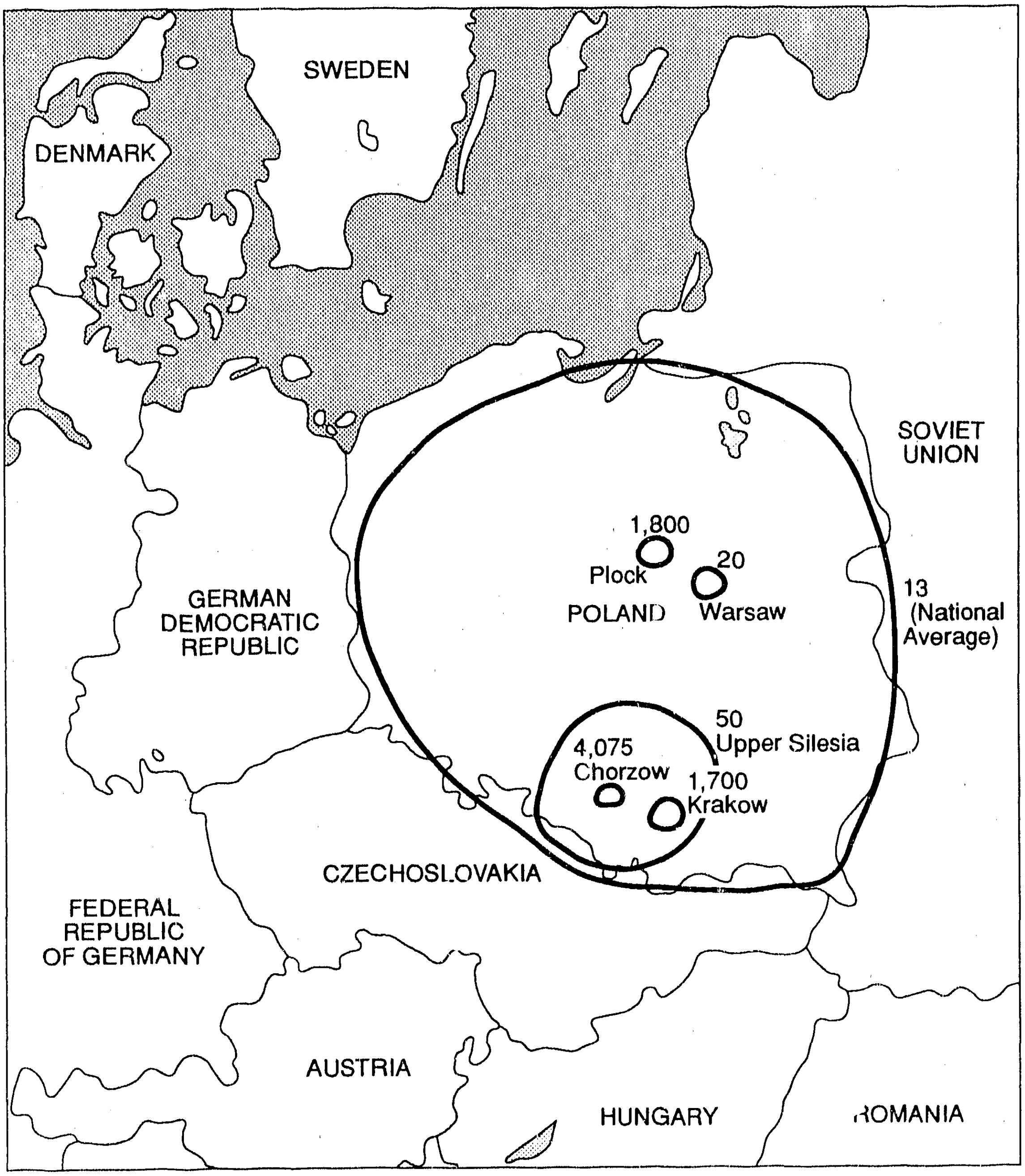


FIGURE 14.1 Annual SO_2 Deposition in Poland as Determined through Direct Observations in 1983 and 1984 (g/m^2) [Sources: Adapted from Kabala (1985); McCormick (1985); and Pudlis (1983)]

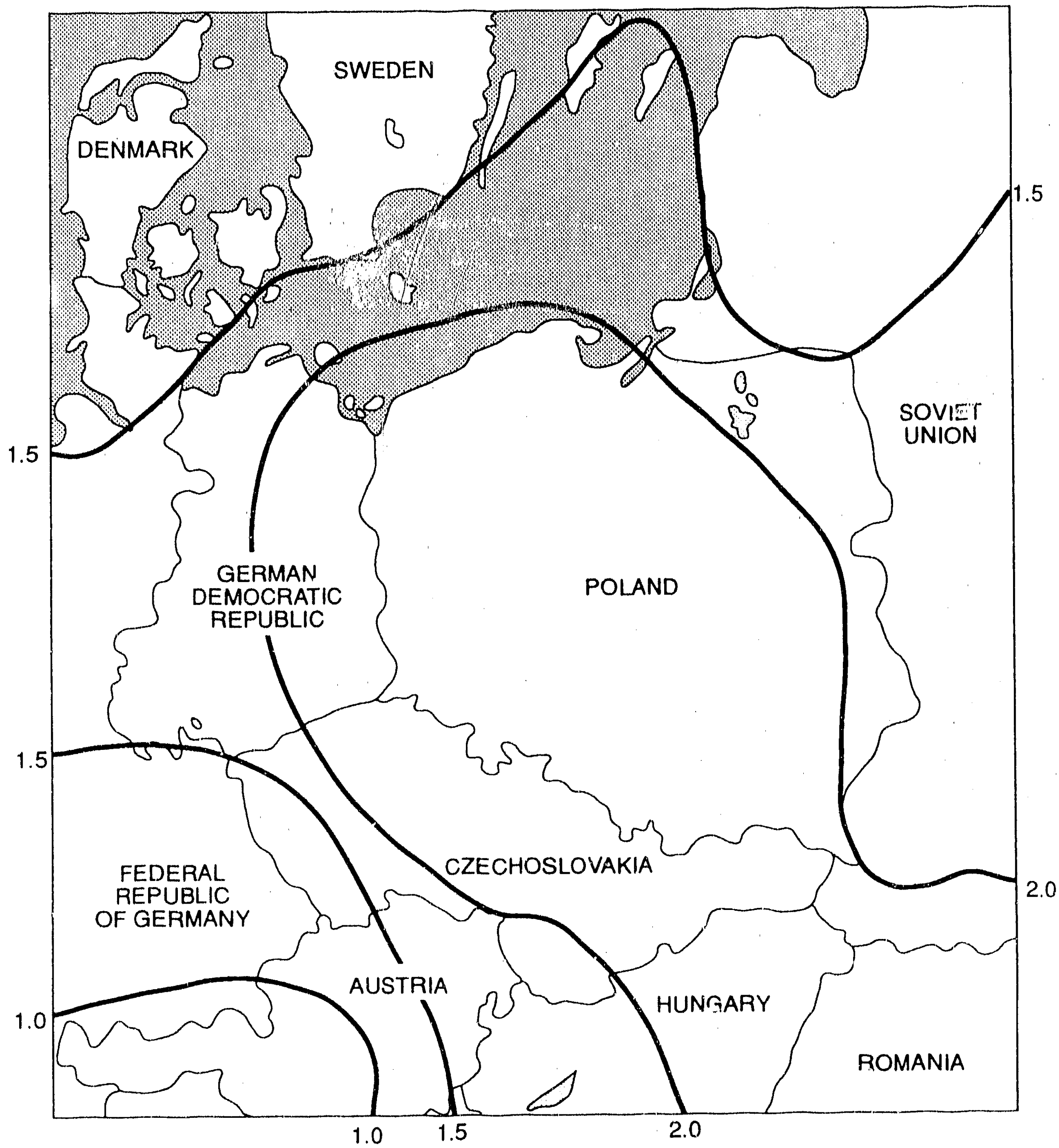


FIGURE 14.2 Mean Annual Concentrations of Sulfate in Precipitation between 1980 and 1985 (mg/l) [Source: EMEP (in Dovland 1987)]

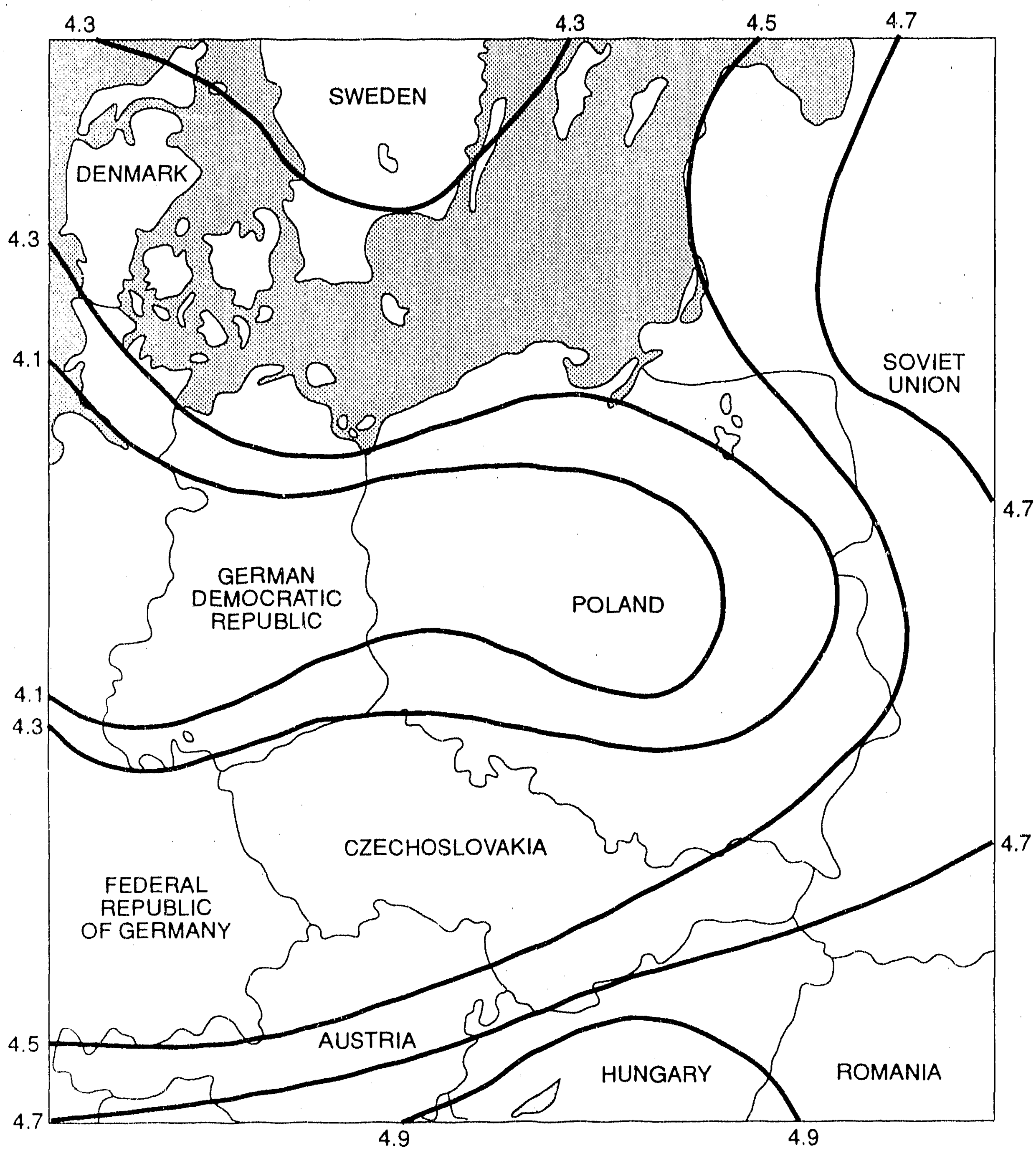


FIGURE 14.3 Average Acidity of Precipitation (pH) [Sources: Adapted from WRI (1988) and Falk (1988)]

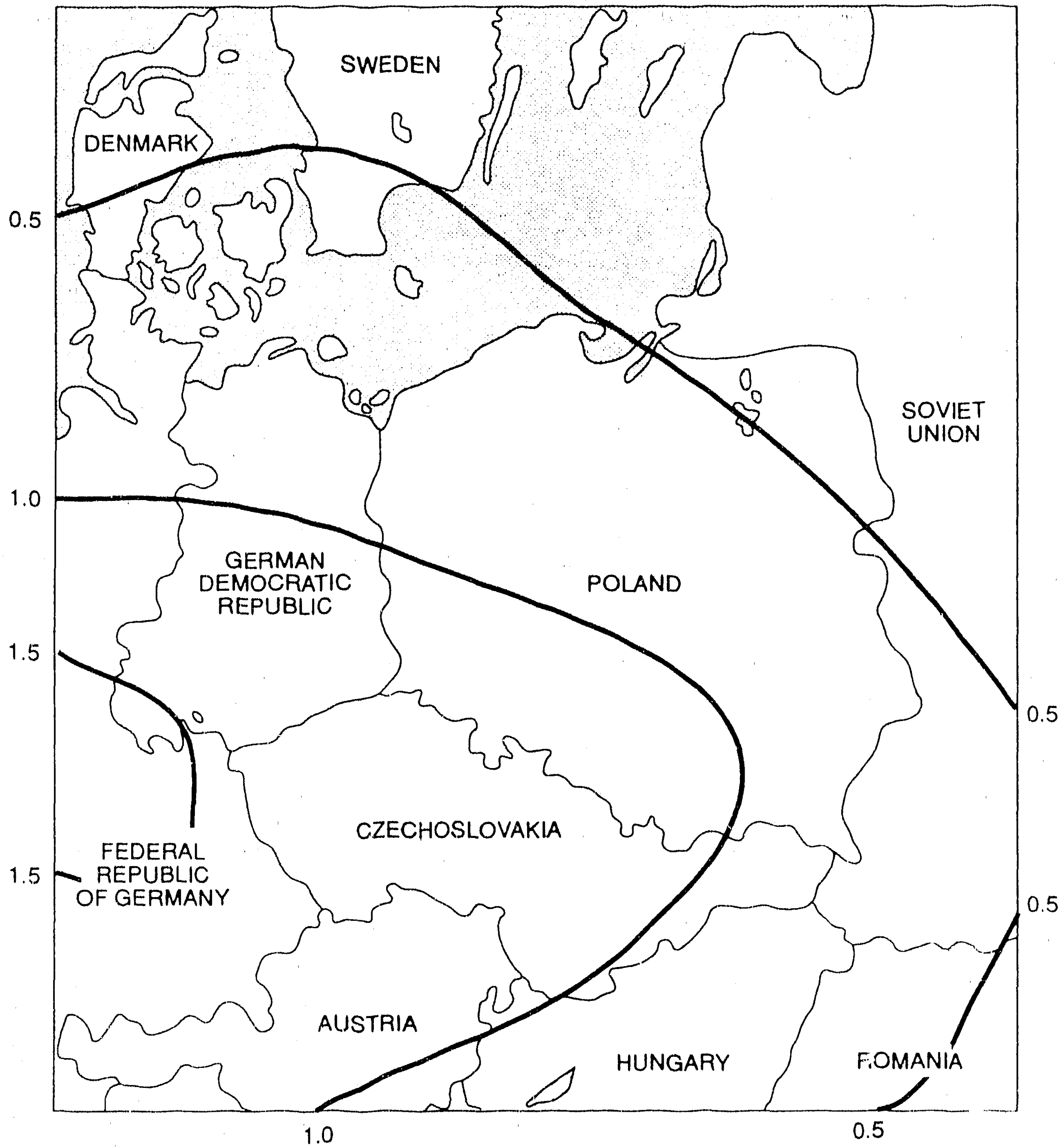


FIGURE 14.4 Annual NO_x-N Deposition in 1980 (g/m^2) [Source: Bartnicki and Alcamo (1989)]

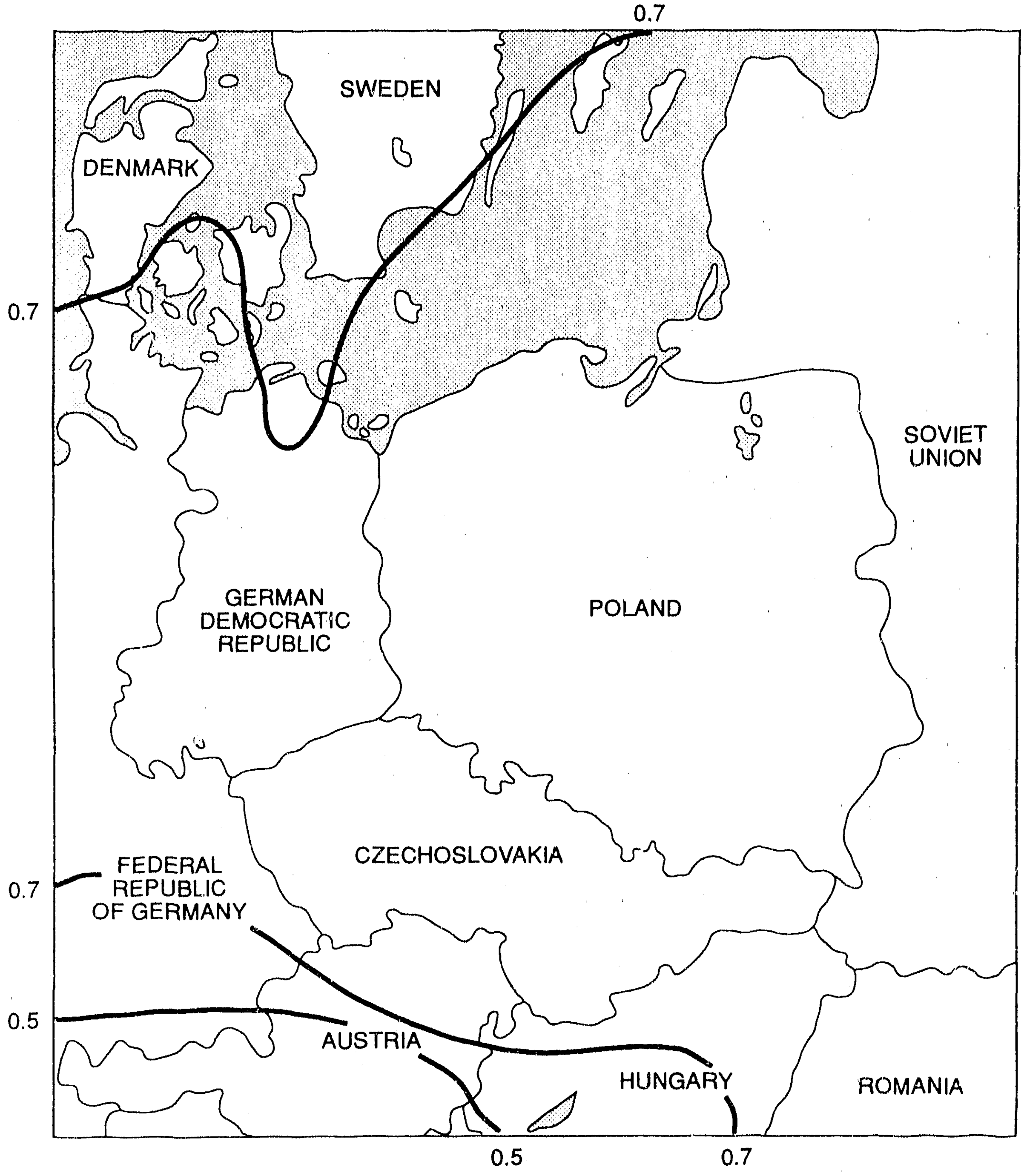


FIGURE 14.5 Mean Annual Concentrations of Nitrate in Precipitation between 1980 and 1985 (mg/l) [Source: EMEP (in Dovland 1987)]

15 OZONE

Most of the focus of air pollution problems in Eastern Europe has, thus far, involved SO_2, NO_x, and acid deposition. However, it is becoming increasingly evident that ozone should also be regarded as a major pollutant, especially at the regional level. Information on ozone conditions in Eastern Europe is scarce, but a few preliminary investigations have been conducted recently. These investigations have occurred in response to the realization that ozone can seriously impair human health and cause significant crop and forest damage.

Ozone, like acid deposition, is a secondary pollutant and is basically formed from the reaction of HC and NO_x with sunlight. Thus, conditions in much of Eastern Europe, particularly in the summer, are especially conducive to its formation, given the high emissions of both NO_x and HC in this region. In addition, rapidly increasing energy consumption and motor vehicle use in these nations is likely to exacerbate ozone conditions in Eastern Europe.

The few studies on ozone pollution that have been conducted in this region show that most of this area experiences relatively high levels of this pollutant, particularly in the summer. Figure 15.1 illustrates the concentration of ozone observed in various parts of Eastern Europe and Sweden during the summers of 1985 and 1986. These results indicate that much of Poland experiences summer ozone levels that, on the average, exceed 160 $\mu g/m^3$ (80 ppb). This level is within the range at which damages to sensitive plant species have been observed and is higher than the peak standard established by the WHO (which is not to be exceeded more than once a year).

Ozone is and will continue to be a serious threat to agricultural crops and forests in Poland. Because ozone is a regional-scale pollutant, its effects will dominate in those parts of the country that are considered to be relatively "clean." This situation exists because in or near urban and/or industrial centers, other pollutants are likely to be the main threats to natural and anthropogenic ecosystems.

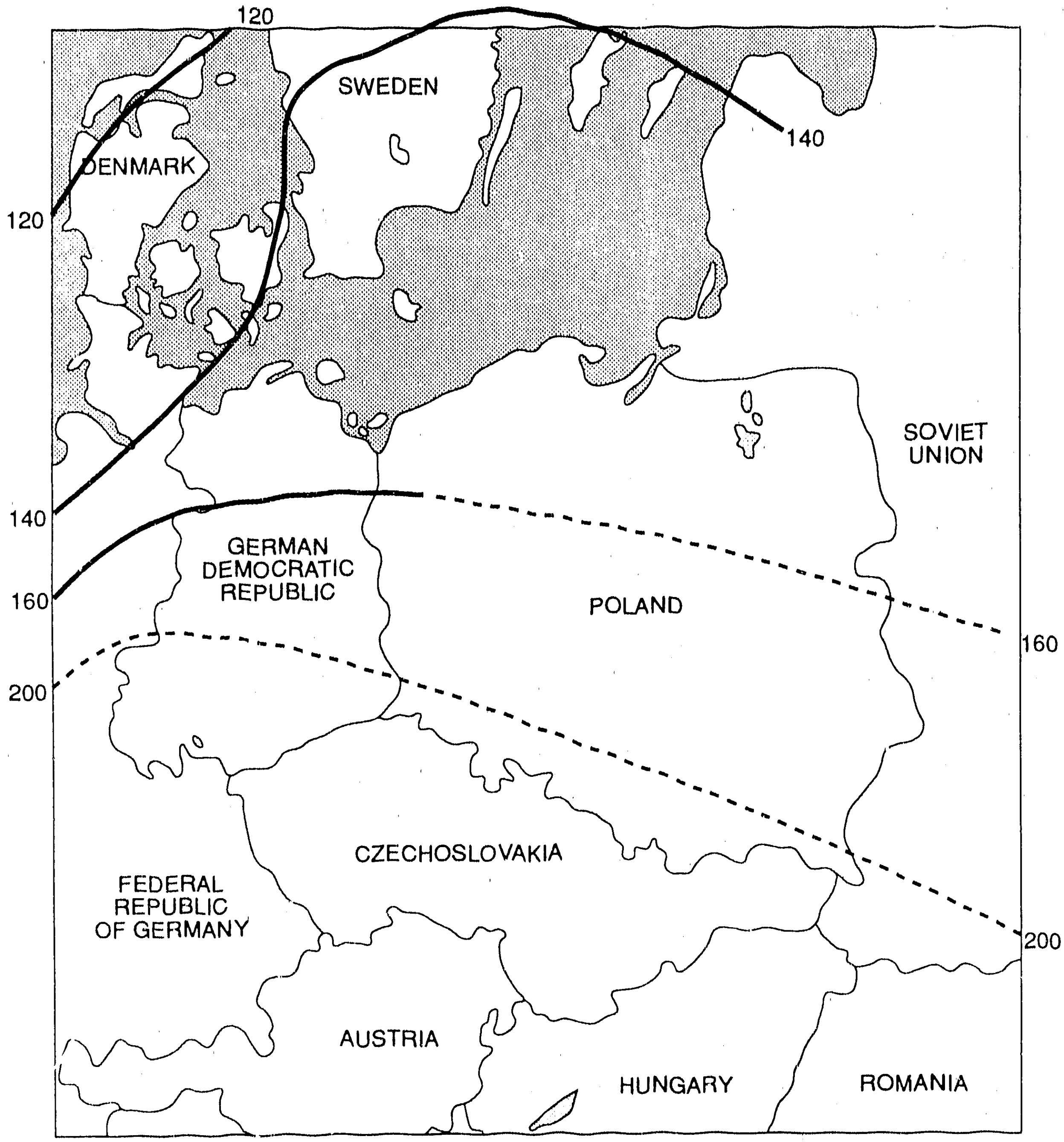


FIGURE 15.1 Average Ozone Concentrations in Eastern Europe and Sweden in 1985 and 1986 ($\mu g/m^3$) [Sources: Adapted from Dovland (1987) and CDA/ERL (1988)]

16 EFFECTS ON HEALTH AND MATERIALS

16.1 HEALTH

The recent concern about environmental degradation in Eastern European countries has developed mainly with respect to its potential impact on human health. The high levels of production of air and water pollutants coupled with the large population density of this region puts significant numbers of people at risk from the dangers of pollution. This situation is especially true in many areas of Poland, where the commitment to rapid industrial development, high energy consumption, lack of fiscal resources for pollution control, and the large proportion of the population living in urban centers (60% of total population) have intensified the health-related hazards of high pollution levels.

It is estimated that one-third of Poland's total population of 38 million is seriously endangered by air pollution, particularly SO_2 emissions (McCormick 1985; Kabala 1989). As emissions of air pollutants continue to increase, it is inevitable that this percentage will also rise. In a study conducted by the Polish League for the Protection of Nature, it was concluded that an additional 600 deaths per 100,000 persons were the result of SO_2 (Pudlis 1983). In certain areas, the risks to human health are even higher.

Upper Silesia, which has a population of 2 million, is perhaps the most severely affected region. Along with Krakow, Rybnik, Legnica-Glogow, and Gdansk, this region has officially been designated an "area of ecological disaster." These regions frequently experience peak ambient SO_2 concentrations of more than 300 $\mu g/m^3$ and average values of more than 60 $\mu g/m^3$, which is the level at which human health is endangered (Kabala 1989). In addition, many of these areas, particularly Krakow, have ambient concentrations of acid aerosols (mainly sulfates) that are high enough to result in significant deterioration of lung function (Jedrychowski and Krzyzanowski 1989).

As a result of atmospheric fallout of large quantities of toxic substances such as lead and cadmium, soils in Upper Silesia (and the crops grown therein) contain levels of toxic substances that are many times higher than those in other regions of Poland and are within the range that can endanger health. Furthermore, it has been estimated that because of the heavy load of air pollutants and stagnant air masses common in many cities of Upper Silesia and in Krakow, the oxygen content of the air can decrease by as much as 20% (Rosenbladt 1988). This can pose a serious health hazard, particularly to heart patients and asthmatics.

As a result of the extreme deterioration of environmental quality in the industrial egions of Upper Silesia and Legnica-Glogow, and on the basis of Poland's own environmental standards (which are similar to WHO and European Community standards for most pollutants, as discussed in Chap. 10), it would be reasonable to conclude that the persons living in many of these areas should be evacuated immediately to safeguard their health (Rosenbladt 1988). This suggestion, however, is not possible on a large scale, given that 30% of Poland's population lives in these regions. However, in five villages in

Silesia, environmental conditions were so severe in 1988 that the government was forced to relocate the inhabitants (Ember 1990).

Figure 16.1 illustrates the areas in Poland where human health is at the greatest risk from SO_2-related pollution. In Upper Silesia alone, it is estimated that 1 million persons are living in conditions that are a daily "health hazard." These conditions are considered to be responsible for the 15% higher circulatory problems, 30% more cancer cases, and 47% greater respiratory illnesses observed in residents of this region compared to those in the rest of Poland (Kabala 1985), and the health of the residents of this region appears to be worsening. For example, in Krakow, it has been observed that the incidence of malignant cancer has increased dramatically over the past decade and is currently six times higher than the world average (Carter 1987). Also, of the employees working at the Nowa Huta Lenin Steel Works from 1970 to 1980, only one-fifth left employment because of normal retirement. More than two-thirds received some form of disability pension (Carter 1987). In 1980, these figures were one-eighth and four-fifths, respectively.

Retardation in children is also greater in Upper Silesia than in other parts of Poland. In fact, 50% of Poland's schools for the mentally retarded are located in Katowice, in the heart of Upper Silesia. Furthermore, 35% of children and adolescents in Katowice have symptoms of lead poisoning and high concentrations of cadmium. This finding is not surprising because lead and cadmium levels in the soil in parts of this region are the highest ever recorded anywhere in the world (Kabala 1985). Lead and cadmium are probably deposited in the soil either directly, through industrial and power plant emissions, or indirectly, through acid-induced mobilization in the soil. In Poland, as a whole, 10-15% of students are chronically ill, and many of these illnesses are due to environmental degradation (Tye 1990).

Unlike most other nations, life expectancy in Poland is decreasing, and, for males, it is now lower than it was 20 years ago (Kabala 1985). Between 1980 and 1985, male life expectancy decreased by 0.4 years and female life expectancy decreased by 0.6 years (World Bank 1987a). In addition, male life expectancy at age 45 decreased from 28.2 years in 1965-1966 to 26.0 years in 1985 for Poland as a whole. Furthermore, for individuals living in Upper Silesia, life expectancy is 2 years less than the rest of the country (Laas 1990).

Environment-related threats to human health are not exclusively the result of air pollution -- water pollution also plays a major role. In fact, as already mentioned, water quality is considered by some to be the most critical environmental problem in Poland. Many of the waterways are considered unfit even for industrial use, and 18% of the water supply in urban areas is classified as of "uncertain" quality or simply as "bad" (Kabala 1985). In Krakow, more than 50% of the municipal water supply is unable to meet national standards (Carter 1987).

16.2 MAN-MADE MATERIALS

Damage to man-made materials from air pollution is also common in many urban areas in Poland. The most dramatic effects have been observed in Krakow, which was

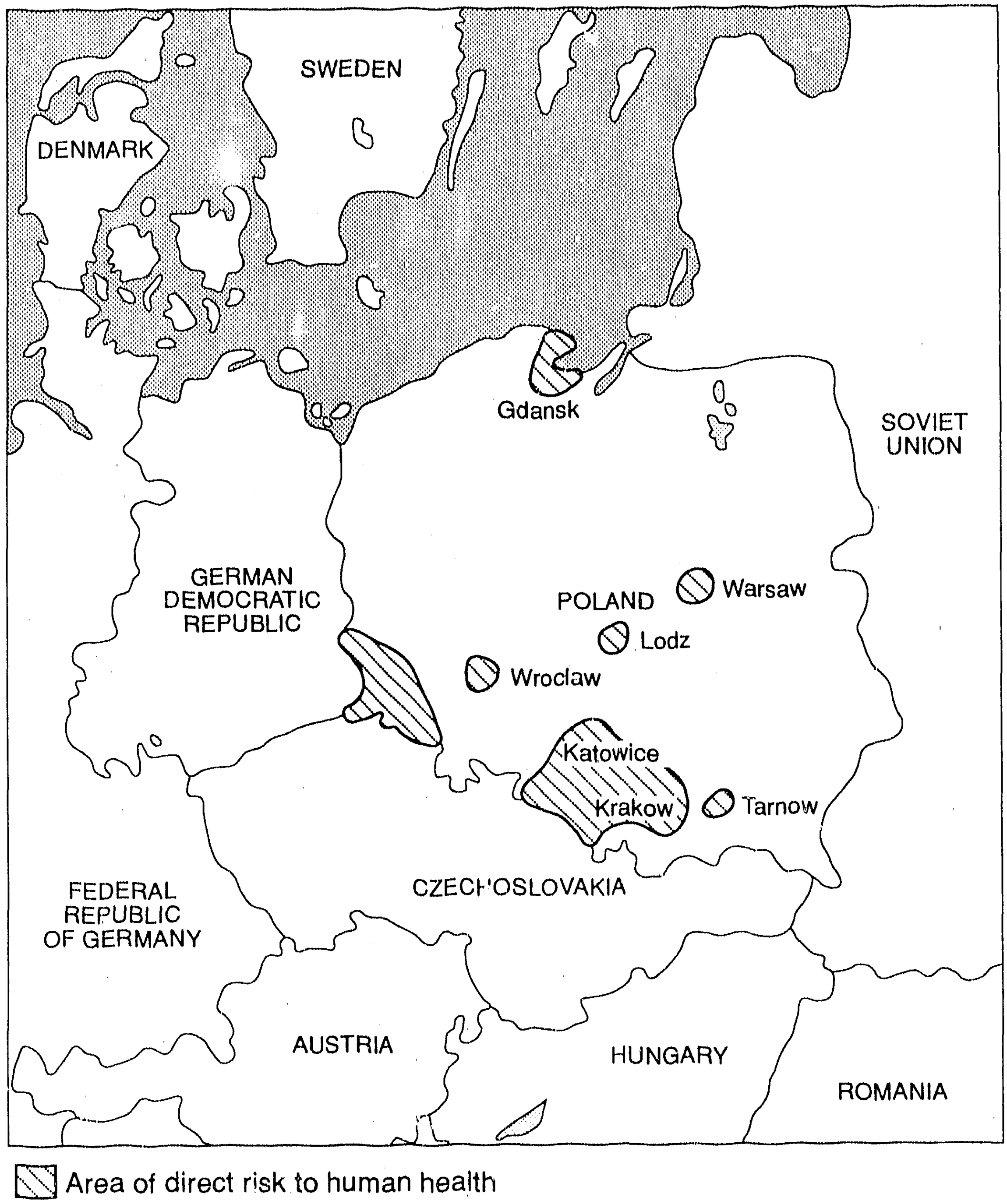


FIGURE 16.1 Areas of Greatest Risk to Human Health in Poland from SO_2-Related Pollution [Source: Adapted from Kabala (1989)]

one of the first cities to be included on the United Nations Educational, Scientific, and Cultural Organization's (UNESCO's) list of world cultural-heritage sites (because it was one of the few cities to survive World War II intact). Because of its location downwind from the industrial centers of Upper Silesia and its position at the bottom of a humid valley, Krakow has become one of the most heavily polluted cities in Europe. As a result, many of its medieval buildings and monuments are becoming corroded. At the Church of Saints Peter and Paul, statues that were once used as copies to replace statues worn down by the weather must be kept indoors for protection. The new copies made from these copies are themselves badly corroded (Aniansson 1988b). In addition, the gold roof of the chapel at Wawel Castle is dissolving. It is estimated that from 1975 to 1980, the equivalent of $3 million was spent on building restoration, most of which was needed to combat pollution-related damage (McCormick 1985).

Krakow is not the only city being impacted by pollution. Katowice is also suffering from considerable damage to its buildings and other man-made structures. In many areas, railroad tracks are so corroded that trains cannot travel at more than 25 miles per hour (McCormick 1985). It is probable that damage to man-made materials and structures is now or is likely to be as severe in other urban areas as it is in Krakow and Katowice, since ambient air pollution levels in many parts of Poland are already high enough to cause material damage.

17 FOREST RESOURCES

One of the most dramatic impacts of pollutants, particularly air pollution, has been that on forests. Widespread damage to forest resources has been observed in much of Central Europe, Canada, and the northeastern United States; although the exact cause is yet unknown, air pollutants, particularly acid deposition and ozone, are the prime suspects. Once awareness of large-scale forest damage in these areas intensified, other countries also began to survey forest health. Preliminary results of these surveys, which are still in progress, indicate that forest decline and death may be far more widespread and severe than initially believed.

In Europe, up to 35% of the total forested area appears to be undergoing some level of decline and/or death (French 1990). However, damage is considerably more extensive in certain regions, the most notable of which are the southern portions of the FRG, the high elevations of Czechoslovakia, the Czechoslovakian-GDR border, and southern Poland. Figure 17.1 shows the extent of currently observed forest damage in Central and Eastern Europe as well as areas of potential damage, especially in Poland and Hungary, based on soil vulnerability.

The highest percentage of forest damage has been observed in Czechoslovakia, where damage to the country's total forested area is estimated to be 71% (French 1990). Other damage estimates range from 16% to 52%. In general, it is agreed that almost all forests at elevations above 800 m are undergoing some decline and that this damage is most severe in the Bohemian region (McCormick 1985). The loss of forest resources is very significant for the Czechoslovakian economy because timber is a major export commodity that earns valuable foreign exchange.

In the GDR, where 27% of the total land area is forested, information on forest damage is scarce, and estimates of such damage vary considerably, from 12% to 86% of total forested area, depending on the source. The extent of forest damage is generally believed to be between 37% and 44%, with much of this damage occurring along the Czechoslovakian border and at high elevations in other parts of the country (Agren and Pape 1989).

In the FRG, where observations of forest damage were first noted, the extent of decline and death has increased steadily. In 1982, 8% of the forested area was undergoing decline; this rose to 34% in 1984 and 54% in 1986. Currently, it is believed that 50-52% of the forested area is undergoing decline (French 1990). However, even here in the FRG, where extensive research into forest health has been conducted, estimates of forest damage vary. Most of the damage has been observed in the southern portion of the country, and the toll to the economy of the FRG from this decline is estimated to be between $3 billion and $5 billion per year.

In Poland, approximately 28% of the land area is forested, with the majority of the tree species belonging to the mixed temperate zone. Most (80%) of these trees are coniferous, which are more vulnerable to damage from acid deposition than deciduous species. News of widespread forest damage in neighboring countries triggered concern

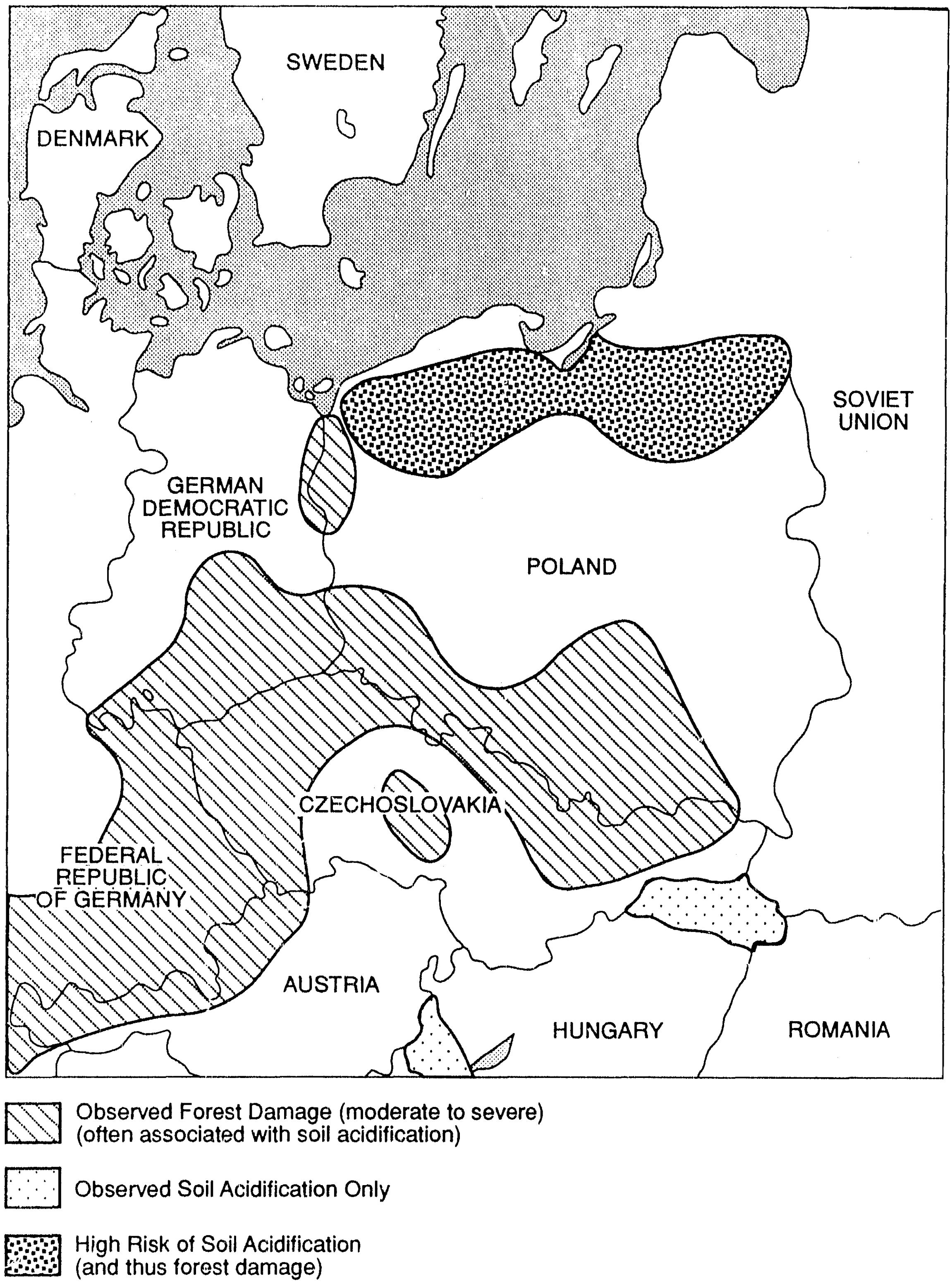


FIGURE 17.1 Location of Damaged Forest and Soil Resources in Central and Eastern Europe

that damage could also exist in Poland, and forest surveys were begun. Preliminary survey results indicate that 18% of the coniferous and 7% of the deciduous species are currently undergoing decline or are already dead (Nilsson and Duinker 1987). Other reports estimate that up to 50% of the trees in Poland are badly damaged and another 17% are harmed to some extent (Tye 1990).

The threshold level for SO_2 damage to coniferous trees is generally believed to be approximately 20 $\mu g/m^3$ or a deposition level of 7.5 g/m^2 (Pawlowski 1990). Since much of Poland experiences ambient and deposition levels of SO_2 that exceed these limits, it can be concluded that many of the still-forested areas of Poland are at risk from damage from this pollutant alone.

Forest damage is the most extensive in Upper Silesia where the highest density of power generation and industry are located. In this area, it is estimated that all remaining forests are damaged to some degree (Przybylski 1989). Damage is also known to be severe in the vicinity of Krakow, in the Carpathian Mountains along the Czechoslovakian border, and in the area near the Legnica-Glogow copper basin (Pudlis 1983). If the current policy of accelerated development and industrialization, along with continued consumption of indigenous coal resources continues, it is highly likely that forest damage will not only spread but will intensify. This situation is particularly true in certain parts of Poland, especially in Central Poland where continued development of the giant lignite-fired Belchatow power plant complex is expected to destroy the forests surrounding this region within the next decade (McCormick 1985).

Other areas at risk are forests growing in marginal locations where extreme environmental conditions such as low temperatures, very low or high precipitation levels, strong winds, and/or poor soils are prevalent. In addition, it is likely that the remaining Polish forests are at particular risk from acid deposition because they contain large proportions of older trees, which are less able to withstand acidic conditions than younger trees (Options 1990). Damage will likely be observed first at high elevations where trees are subjected to cloud or fog conditions; acidity of these forms of precipitation can be several orders of magnitude greater than that of rainfall.

Damage to Poland's forest resources could significantly affect the already fragile Polish economy. Timber losses due to air pollutants currently range from 3 million m^3/yr to 12 million m^3/yr, with associated damage to forest undergrowth and disruption of wildlife populations. This damage is increasing and steadily expanding to the eastern parts of the country (Mazurski, 1990; Options 1990). The economic loss from forest damage alone is estimated to reach more than $1.5 billion per year by 1992 (French 1990). In addition, loss of forests would have a negative impact on the tourism and recreation industries, and on soil and water quality, further stressing the Polish economy.

18 AGRICULTURE

It has only been relatively recently (compared with impacts on other components of the ecosystem) that damage to agricultural resources, particularly crops, has been attributed to pollution. In this respect, ozone has been shown to be the most damaging air pollutant in most industrialized nations.

In Poland, 65% of the land is classified as agricultural and most is under cultivation (Kormondy 1980; World Bank 1987a). Almost one-third (30%) of the population is involved in farming. The most important crops are potatoes (world's second largest producer), rye (also world's second largest producer), wheat, and sugar beets (fifth largest in the world) (Encyclopedia Britannica 1979).

As a result of environmental pollution, it is estimated that 33% of Poland's food supply is contaminated (McCormick 1985). In Upper Silesia, in particular, where lead and cadmium levels are the highest in the world (186 and 1,000 times background levels, respectively), the government is considering banning vegetable growing (French 1990; Pawlowski 1990). In the vicinity of Krakow and Katowice, measurements of lead and cadmium levels in vegetables and other crops revealed concentrations that were 21 to 88 times higher than the Polish permissible limit for these metals (Carter 1987; Gzyl 1990). In the Glogow copper region, the levels of these substances in crops were even higher -- cadmium levels were 220 times and lead 134 times higher than the government limit (Rosenbladt 1988).

In addition, dust deposition to soils is high, reaching 200 million g/km^2 in the southwestern agricultural regions of Poland (Mazurski 1990). Such high levels of dust, which can contain toxic substances such as heavy metals, likely stunt the growth of agricultural crops and further endanger human health. It has been estimated that 25% of the crops produced in the Upper Silesian and Krakow regions are unfit for human consumption (Rosenbladt 1988).

In addition to direct inputs from atmospheric fallout, soil acidification (from acid deposition), which is prevalent in the podzol soils of northern Poland, can leach out toxic substances that can then accumulate in crops (Pudlis 1983). It has been estimated that 83% of cultivated soils in Poland are acidic and thus are susceptible to producing crops with high levels of toxic substances.

Levels of ozone are high in much of Poland, often reaching levels that are hazardous to crops. Potatoes, an extremely important crop in Poland, are particularly sensitive to ozone, exhibiting reduced yields in the presence of ozone levels of 112 $\mu g/m^3$ (Dovland 1987). As discussed in Chap. 15 and illustrated in Fig. 15.1, summer (growing season) ozone levels often exceed 160 $\mu g/m^3$ in most of Poland, thus endangering the potato crop in particular.

Elevated levels of SO_2 also damage crops. For example, grain crops exhibit reduced growth at average SO_2 levels of 80 $\mu g/m^3$ or more. As illustrated in Table 10.1, SO_2 levels averaging 100 $\mu g/m^3$ are common in the Katowice-Krakow region, with peaks often exceeding 300 $\mu g/m^3$. Thus, grain crops, particularly wheat and rye, which are the staple diet of most Poles, would be seriously affected by air pollution.

In spite of these potentially damaging impacts of air pollutants on crops, a definite link between growth declines and/or yield reductions and these pollutants has not yet been established. In fact, it is argued that increased levels of nitrogen and CO_2 from anthropogenic activities could actually increase productivity. This increase may be possible in a few localized areas and in the short term, but in most regions and with increased industrialization and energy (coal) use, it is likely that damage to the agricultural sector will continue to increase. This damage will be exacerbated by the fact that the most fertile parts of Poland are located in the same areas that are most heavily industrialized.

Figure 18.1 illustrates the location of the main agricultural regions in Poland and those areas that are currently threatened by localized pollution. Most of the agricultural zones in Poland are also potentially at risk from regional-scale pollutants such as acid deposition and ozone.

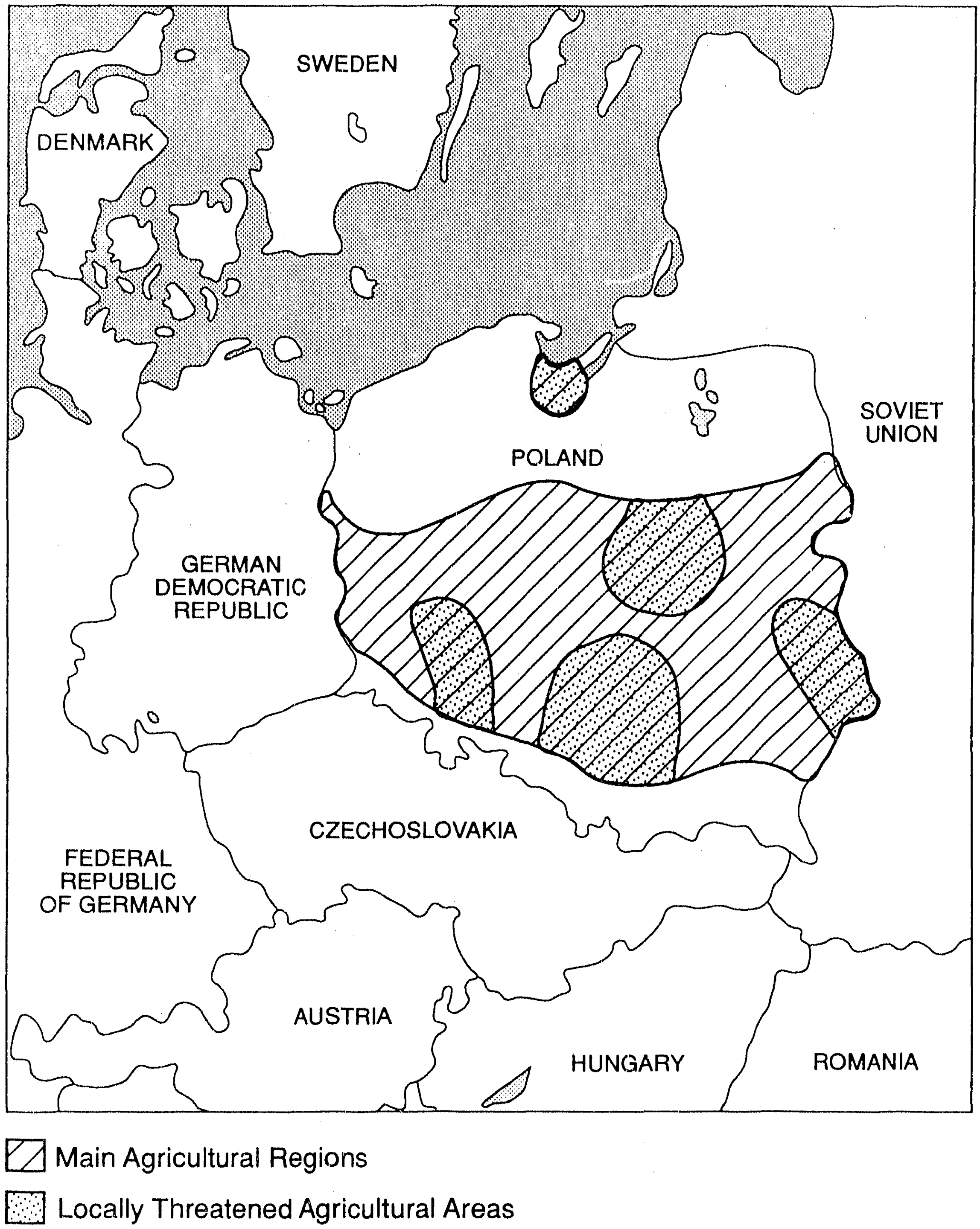


FIGURE 18.1 Main Agricultural Regions and Areas Threatened by Localized Pollution in Poland

19 AIR-QUALITY IMPACTS ON WATER RESOURCES

Perhaps the most obvious and direct link between pollutants and ecosystem damage involves water resources. Because damage to water systems is readily visible and tangible, much of the focus of environmental concern in many countries, including Poland, has centered on these resources.

To date, water quality is considered by some persons to be the most important environmental problem in Poland, and most of the investment in environmental control has involved water pollution (McCormick 1985). In spite of this expenditure, however, Poland's water resources remain heavily polluted. Poland's major rivers -- the Warta, Vistula (Wisla), and Odra -- are all severely degraded. Drainage of industrial waste to rivers, inadequate sewers, and insufficient sewage treatment facilities are cited as the major problems (Fallenbuchl 1988).

According to the Polish system of water classification, water quality in the country as a whole has deteriorated very rapidly in recent years. For example, between 1977 and 1980, the proportion of rivers belonging to Classes I and II (suitable for human and animal consumption, respectively) fell from 41% to 19% (Kabala 1985). In addition, the proportion of surface waters in Class I (suitable for human consumption) declined from 33% to 6% from 1965 to 1985 (Levin 1989). Recently, it was estimated that two-thirds of river water was unfit even for industrial use (Class III) (Tye 1990); at the present time, more than three-quarters of the Vistula, Poland's largest river, is in this same condition (Laas 1990).

Poland also has a large number of lakes (9,300 with areas of more than 1 hectare), constituting 1% of the total surface area of the country. It is believed that 78% of these lakes are currently polluted beyond most acceptable standards. Some of this pollution results from acidification because many of these lakes are in the northern portion of the country, which contains easily acidified podzol soils, as shown in Fig. 17.1.

However, the majority of the pollution in Poland's waterways, at the present time, is the result of untreated industrial, mining, agricultural, and domestic wastes. One-half to three-quarters of the municipal and industrial wastes are still not treated when discharged (Kabala 1985). Furthermore, the majority of highly polluted mine wastes are discharged directly into waterways without treatment. The increased use of artificial fertilizers in the agricultural sector, which run off into water systems, further increases pollution of Poland's water resources as well as encourages eutrophication of water bodies. Industrial wastes discharged into the Warta are generally believed to be responsible for the destruction of the once-thriving salmon industry that was based in this river system. In addition, in most of Upper Silesia, where much of Poland's industrial and energy sectors are located, nearly all rivers are polluted beyond "all acceptable standards" (Kabala 1985). The mercury levels of the Vistula downstream from Krakow, for example, are approximately 200 times more than the acceptable limit, and concentrations of lead and iron are also extremely high (Carter 1987).

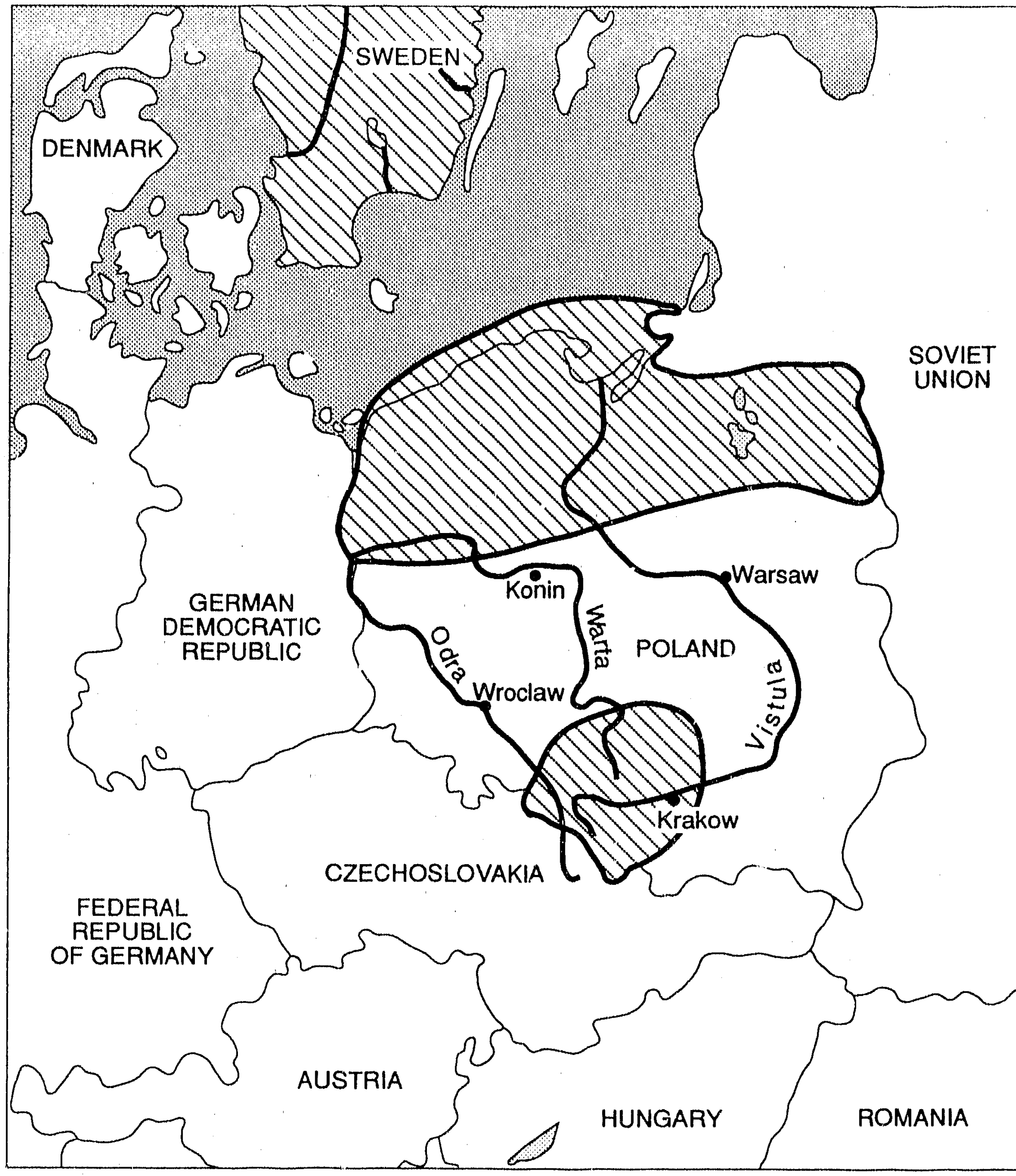
Since most of the major rivers in Poland flow northward into the Baltic Sea, much of this water system, especially along the Polish coastline, has also become highly polluted. The Baltic Sea contains unusually high levels of agricultural runoff, untreated sewage, and industrial wastes. The input of large quantities of pollutants into the Baltic Sea off the coast of Poland is aggravated further by the physical features of this water body. It has a relatively low average depth, and little mixing occurs with the surrounding North Sea, thus leading to the concentration of any pollutants it receives (Kabala 1985). In the recent past, the Baltic Coast was a prime tourist resort for millions of Poles and other Eastern Europeans; today it is unfit for most water-related activities. Even the beaches are unable to be used, because the sand contains dangerous levels of bacteria (French 1988).

Water pollution in Poland is not limited to surface waters -- groundwater is also contaminated. This situation is especially true in industrial regions, where hazardous substances often enter the groundwater system. Sources of these substances include atmospheric fallout, agricultural application of chemicals, raw sewage disposal, dumping of garbage, and industrial discharge. In addition, in the northern areas in particular, soil acidification can acidify groundwater leading to the subsequent release of toxic metals into this water system.

In a recent survey, 52% of water drawn from public wells was classified as being "bad" and less than 37% was considered "good" or acceptable (Pawlowski 1990). This deterioration of water quality, along with a significant lowering of the water table observed throughout Poland due in part to accelerated deforestation, has increased concern over the availability of adequate water supplies in the future. Already, a considerable number of villages and towns constantly experience water shortages.

Figure 19.1 illustrates the extent of damaged and threatened water resources in Poland. The water resources located in northern Poland (the large shaded area in Fig. 19.1) are threatened mainly by acidification, whereas damaged and threatened water resources in other parts of the country result mainly from the direct discharge of industrial, agricultural, domestic, and mining wastes.

Figure 19.1 also shows the location of damaged and threatened water resources in southern Sweden where much of the damage to water systems is from acidification by acid deposition. It is estimated that groundwater acidification is prevalent in southern and western Sweden, with 44% of all wells tested in these areas containing water with copper levels above the recommended limit (copper is solubilized and leached from soils by acid water into the groundwater) (Falk 1988). In addition, 56,000 miles of streams and rivers and 21,500 lakes contain water too acidic to support sensitive fish species or have pH levels low enough to cause ecological damage (Aniansson 1988c). Because much of Sweden's air pollution originates in other countries, including Poland, the goal of the Swedish government has focused on bilateral and international research and negotiations in order to reduce pollution loads within Sweden.



Note: Shaded areas represent locations of damaged/threatened water resources.

FIGURE 19.1 Location of Damaged and Threatened Water Resources in Poland and Southern Sweden [Source: Adapted from WRI (1988) and Falk (1988)]

20 GREENHOUSE GASES

20.1 EMISSIONS

Poland is a significant contributor to emissions of gases that are known to be implicated in global climate change, otherwise known as the greenhouse effect. Because of Poland's heavy use of coal, emissions of CO_2 are of particular concern. This chapter describes the current state of knowledge of emissions of greenhouse gases in Poland, in comparison with other countries.

20.1.1 Carbon Dioxide

As Fig. 20.1 shows, emissions of CO_2 in Poland have risen rapidly in the last 40 years, from about 31 million tonnes in 1950 to 124 million tonnes in 1986. Most of these emissions (about 85% in 1986) are associated with the combustion of coal and lignite. The rapid growth in coal use to fuel economic expansion is reflected in the growth in CO_2 emissions. Indeed, the drop in coal production associated with the miners' strike in 1981 is manifested as the dip in the CO_2 emission-trend line. Table 20.1 shows the contributions to CO_2 emissions from various sources in Poland.

In comparison with other countries, Poland has consistently ranked about eighth in the world in CO_2 emissions, behind the United States, Soviet Union, the PRC, Japan, the FRG, United Kingdom, and India in 1986. Table 20.2 shows the magnitude of Polish emissions of CO_2 in relation to the other Eastern European countries and selected Western nations. The continued growth in emissions in Eastern Europe (as opposed to a decline or stabilization of emissions in the West) is as much a cause for concern as their absolute magnitude. It is clear that any international protocol to limit greenhouse gas emissions, which is currently being contemplated by the Intergovernmental Panel on Climate Change, would need to seriously consider the case of Poland.

Interesting insights are obtained by comparing the per-capita emissions of CO_2 in Poland with that of other countries. Marland et al. (1989) examined 36 years of CO_2 emissions records, which showed that per-capita emissions in Poland grew from 1.25 Mt/yr to 3.32 Mt/yr (Fig. 20.2). This continuous increase reflects a rising demand for goods and services, sustained essentially by the use of fossil fuels, with very little improvement in energy efficiency in recent years. This trend is mirrored by the situation in the GDR, which currently has the highest per capita emission rate in the world, but with somewhat greater efficiency of energy use than in Poland.

The United States, in contrast, has reversed the trend of ever-increasing per capita emissions, partly by the use of nuclear and other nonfossil energy sources to furnish portions of the energy supply and partly by the introduction of energy conservation measures since the oil price surges of the 1970s. The higher standard of living in the United States (compared with Eastern Europe) should also be considered when studying Fig. 20.2; i.e., the quantity and quality of goods and services delivered per capita is much higher. Sweden is an example of a country with a high level of energy conservation, a policy of limiting the use of fossil fuels, and a standard of living comparable to the United States.

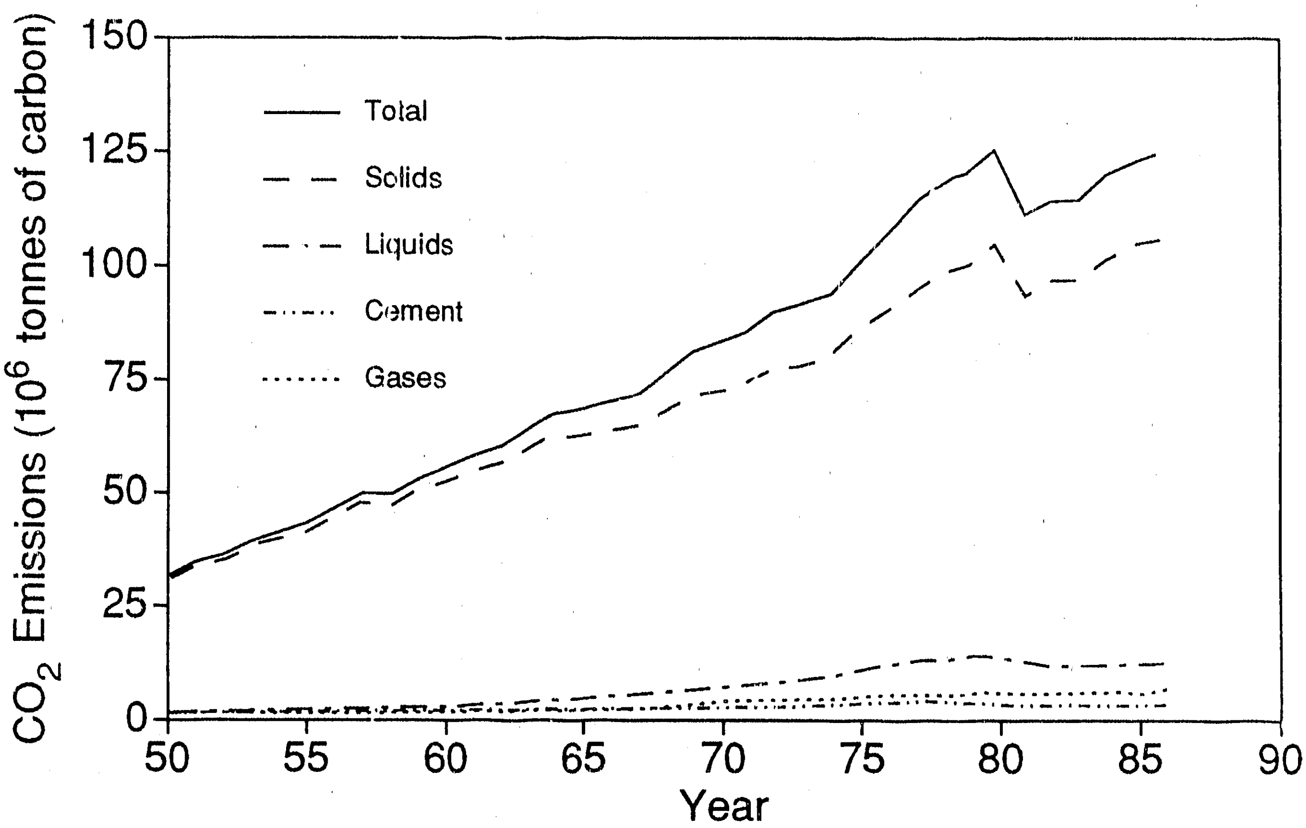


FIGURE 20.1 Emissions of CO_2 in Poland since 1950 (Source: Adapted from Marland et al. 1989)

TABLE 20.1 Emissions of CO_2 in Poland (Mt/yr)

Source Type	1950	1970	1986
Solids	30.1	71.9	105.3
Liquids	0.4	6.2	11.8
Gases	0.1	3.0	5.3
Cement	0.3	1.7	2.1
Total	31.0	82.8	124.5

Source: Marland et al. 1989

TABLE 20.2 National Emissions of CO_2 in Eastern Europe and Selected Countries (Mt/yr)

Country	1950	1970	1986
Poland	31.0	82.8	124.5
GDR	43.5	73.8	92.3
Czechoslovakia	20.8	54.3	65.8
Hungary	4.8	18.7	21.1
Romania	5.3	32.4	55.8
United States	684.4	1,158.5	1,201.6
Soviet Union	185.8	628.2	1,010.8
FRG	94.9	200.9	186.3

Source: Marland et al. 1989.

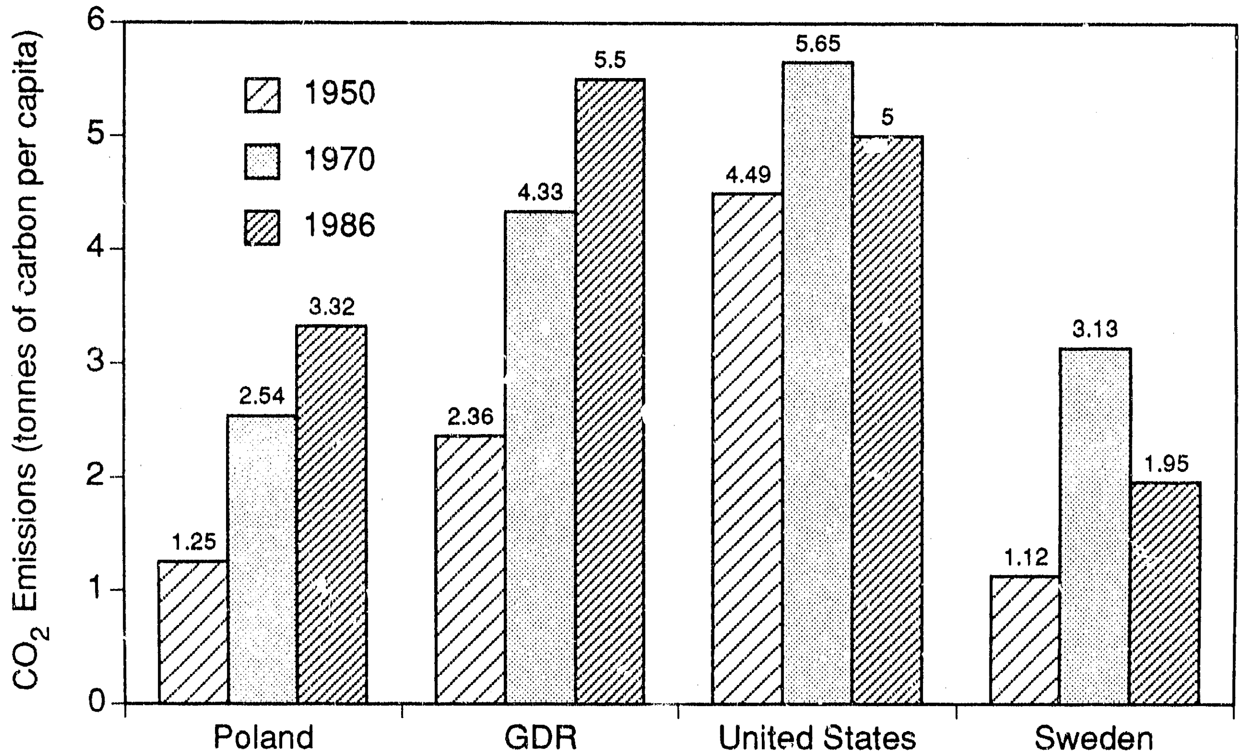


FIGURE 20.2 Trends in per-Capita CO_2 Emissions in Selected Countries (Source: Marland et al. 1989)

Lovins (1989) noted the comparative energy intensities of Sweden, the United States, the GDR, and Poland (Table 20.3). The typical disparities between energy intensities in market-oriented economies (MOEs) and centrally planned economies (CPEs) are attributed by Lovins to a combination of (1) poor price formation in the CPEs; (2) use of perverse industrial accounting methods in the CPEs; (3) obsolete technologies and maintenance practices in the CPEs; (4) greater emphasis on manufacturing rather than basic materials in the MOEs; and (5) larger service sectors in the MOEs.

Clearly, actions need to be taken to improve the efficiency of energy use in Poland and other Eastern European countries. These actions would reduce energy costs, decrease fossil-fuel imports, and limit emissions of greenhouse gases. Achieving these benefits will require major overhaul of the energy and industrial manufacturing sectors.

20.1.2 Nitrous Oxide

Nitrous oxide (N_2O) is another greenhouse gas that is generated primarily by the combustion of coal and the application of nitrogen-based fertilizers. Pacyna (1989) has presented a preliminary estimate of N_2O emissions in Poland from these two sources. However, emissions of N_2O from fossil fuels are currently a subject of controversy as a result of recent experiments (Lyon et al. 1989), which suggested that some (or much) of the N_2O measured in gas samples may be an artifact derived from transformations of the NO_x in the sampling vessels.

Pacyna (1989) estimates N_2O emissions to be about 163 kt/yr from coal combustion and 53 kt/yr from fertilizer application (about a 3:1 ratio). These total emissions (216 kt/yr) rank slightly below those of the GDR (Table 20.4).

20.1.3 Methane

Methane (CH_4) is derived from a variety of sources, both anthropogenic and natural. Anthropogenic sources include the combustion of fossil fuels, extraction of fossil fuels, distribution of natural gas, and other industrial and incineration operations. Natural sources include enteric fermentation in animals, particularly ruminants, and marsh vegetation. Pacyna (1989) has calculated, with a high level of uncertainty, CH_4 emissions from combustion of fossil fuels only. The calculated value of 38 kt/yr would be the highest in Eastern Europe. There is a need to develop a comprehensive inventory of greenhouse gases other than CO_2 in these Eastern European nations.

TABLE 20.3 Energy Intensities in Selected Countries (MJ/unit of gross national product)

Country	Energy Intensity
Sweden	8.6
United States	19.3
Poland	26.9
GDR	29.0

Source: Lovins 1989.

TABLE 20.4 Emissions of N_2O and CH_4 in Eastern Europe (kt/yr)

Country	N_2O Emissions	CH_4 Emissions from Combustion
Czechoslovakia	112	19
GDR	250	26
Hungary	40	6
Poland	216	38
Romania	117	18

Source: Pacyna 1989.

20.2 IMPACTS

The potential impacts induced by climatic changes resulting from a rise in greenhouse gas concentrations could be extremely significant for much of Eastern Europe. However, uncertainties in our understanding of the complexities of the natural world, as well as in our ability to project future emissions of greenhouse gases, make it extremely difficult to determine the nature of the changes that may result from this phenomenon, even at the global level. This situation is even more the case on the regional scale; at this level, it is only possible to make very general predictions of the most typical and probable consequences of climatic changes on specific nations such as Poland.

It is likely that the boreal (northern or taiga) forests of northern Poland and the mountain regions of southern Poland would be particularly susceptible to climatic changes. These forests are at the southern extreme of the boreal range; any warming trend could lead to rapid deterioration and mortality of these ecosystems. The rapidity at which these changes could occur at the southern edge of the boreal range would preclude the migration and establishment of more suitable species into this zone.

Poland also contains the northern edge of the temperate mixed forests, which may be preferentially favored under a warmer climatic regime. It is also possible that, for vegetation such as these temperate forests (which are able to tolerate the new climatic regime), the elevated concentrations of CO_2 could directly increase the growth, vigor, and water-utilization efficiency of these species. However, there remain considerable gaps in our knowledge, not only of the extent and magnitude of possible climatic changes but also of the response of various plant species to these altered environmental conditions.

In addition to impacts on forest ecosystems, climatic changes would also affect agricultural production. Shifts in crop zones and management strategies would be necessary to compensate for any disruptions caused by climatic changes in a given region.

In general, it is anticipated that, in northern Poland, there will be a moderate increase in temperature in the summer and a large increase in the winter; in the southern region, there will be a moderate increase in both winter and summer. These increases will likely be accompanied by increased precipitation and evapotranspiration and a greater frequency of extreme weather events.

The result of these changes would be the increased variability of water supplies, rendering water-management strategies more difficult. Global warming would also cause an increase in the overall sea level that would threaten to inundate parts of the low-lying Baltic Coastal Plain in Poland. It would also result in salt intrusion of inland water systems, leading to additional contamination of drinking and irrigation water supplies.

SECTION 4:

CONTROL STRATEGIES

21 RESOURCES

Poland is rich in energy resources, specifically hard coal and lignite. Its resources of natural gas are small and those of oil are almost insignificant. Hydroelectric potential is also low. There are no domestic resources of uranium, and the nuclear construction program is at a standstill for technical, financial, and environmental reasons. Thus, hard coal continues to be one of Poland's greatest national resources, playing an essential role in the Polish economy. And Poland remains one of the most coal-dependent countries in the world. Poland's coal reserves rank seventh in the world, with recoverable coal reserves estimated at 42.6 billion tonnes (Sec. 3.1). Poland is the fourth largest producer of hard coal in the world; production has exceeded 190 million tonnes annually in recent years (Chap. 3.2).

Until the 1980s, Poland's coal production exceeded its consumption, and its coal exports more than covered the imports of other needed fossil fuels and supplied sorely needed hard currency. That situation has changed; Poland is now a net energy importer, and its financial and hard-currency picture is unclear since it has no other export of quite the same significance. Coal exports accounted for 12% of the total convertible currency export earnings in 1988 (Craig 1990).

It appears inevitable that emissions of air pollutants, particularly NO_x and SO_2, will continue to be extremely high in Poland. This situation is likely to increase the pressure to control such emissions. In this regard, several strategies are presented here for consideration. Those relating to the energy resources themselves are described in this chapter; other control strategies are discussed in the chapters that follow.

21.1 STRATEGY 1: PRODUCE AND USE A HIGHER-QUALITY DOMESTIC COAL

With domestic-coal consumption likely to rise, two options readily come to mind. First, physically clean the existing domestic coal. This option can be considered a technology-related option and is discussed in Chap. 23. Second, produce and use a higher-quality coal.

The consumption of low-grade coals is currently much higher in Poland than other coal-rich nations. The central allocation of coal serves to force some large coal consumers (mainly power stations) to use lower grades of coal than they would purchase if they had a choice. The use of higher-quality coal would be desirable from a technical as well as an environmental point of view. Over the years, however, Polish power plants have adapted their coal-combustion facilities to coals of lower quality for a variety of reasons. (One reason is that in the centrally planned economy, the organization responsible for producing coal was not the same organization as the one concerned with using the coal to produce electricity or steam. One group was mandated with producing as much coal as possible; the other was charged with using whatever quality material it received.) Consequently, a considerable amount of effort was expended on modifying Polish coal-handling equipment and adjusting the construction and original design specifications of boilers that were better suited to higher-quality coal. A return to the original specifications, using an appropriately suited coal, would:

- Increase the generating capacity available during peak periods,
- Increase the boiler efficiency and reduce the consumption of electric energy for the plant's own needs,
- Reduce the number of breakdowns and lower repair costs (and lag time spent in waiting for repair parts to be imported),
- Reduce the costs of handling ash and other residues, and
- Reduce emissions of SO_2 and particulates and thus reduce the pollution charges that would be assessed if pollution controls were enforced.

Although use of higher-quality coal would be desirable from a technical point of view, it has not been justified in financial terms to date. In 1987, the charges actually levied for environmental pollution represented a very small component of the total cost of operating a power plant. For example, the charges imposed on the Kozjenice power plant for emissions of SO_2 and dust made up only 1.3% of its total costs. The equivalent figure for the Siekierki power plant was 1.1% (D. Craig 1990). Nevertheless, in response to the increasing public awareness of the environmental degradation that is occurring, the economics could be shown to be far more favorable by taking into account the entire cost of pollution to the population relative to the benefit to be achieved in increased air quality.

However, if tougher environmental constraints were placed on coal users and enforced, and if it became profitable to invest in additional coal-beneficiation equipment to convert some low-quality coals into higher grades that might sell at higher prices, some producers would do so. Invariably, some high-cost producers of low-grade coals would find it unprofitable to sell their product at the discounted price that would be demanded because of the extra handling charges that would be required to dispose of the fly ash and bottom ash that would be collected from their low-grade coals. These high-cost producers of low-grade coals would then cease to produce.

21.2 STRATEGY 2: IMPROVE EFFICIENCY OF COAL MINING AND PREPARATION OPERATIONS

21.2.1 Hard-Coal Subsector

In accordance with recommendations worked out in the scope of the Restructuring Program of Polish Energy Sector (NERA 1990), the principal actions that would lead to substantial progress and savings in the hard-coal subsector are the following:

- Underground operations
  - Improve the shifting index of longwalls (use fewer faces and more production shifts),
  - Optimize face lengths for different seam heights,
  - Reduce manpower in areas not directly related to face production through redeployment,
  - Improve machine running time,
  - Make use of alternative mining strategies to minimize the extent of stowing in thick seams, and
  - Improve the effectiveness of maintenance.
- Surface operations
  - Reduce manpower in support and administrative functions through better organization and simplification of working practices,
  - Cut employee absenteeism, and
  - Eliminate nonmining activities.
- Coal preparation
  - Improve the quality of the feed by selective mining,
  - Increase the use of automated control devices and monitoring, and
  - Reduce the number of products.

According to Cofala, Parczewski, and Umer (1990), the priorities in the Polish hard-coal subsector should be as follows:

- To deeply restructure this subsector by liquidating about 10% of the mines (or production sections) that have the highest production costs (especially those where the dismissed workers can get a job in other neighboring mines) and by considering production only in highly productive seams (which would decrease costs).
- To work toward more efficient environmental protection, deposit mining wastes underground, efficiently and completely manage saline mine waters, and achieve a higher level of participation in

maintaining and upgrading the coal industry infrastructure (which would increase costs).

- To renew the detailed consideration of a coal beneficiation program. Although such programs have been elaborated, the technical and economic parameters associated with cleaning plants are not sufficiently reliable. Pilot plants should be built, and an analysis of the effectiveness of existing programs should be undertaken based on the results obtained from running these plants.

- To closely consider the advisability of exporting coking coal and importing steam coal. Calculations performed show the efficiency of such an undertaking. The world market price would allow for the transport costs. Such a possibility should not be excluded from consideration for "ideological" reasons.

21.2.2 Lignite Subsector

This subsector is closely linked with the electricity subsector. Because there are very few economical uses for lignite other than as a fuel for electricity generation, in practice, a single-buyer/single-seller relationship has been created between enterprises in the two subsectors. For this reason, Coopers & Lybrand Deloitte (1990a) posited a common set of objectives for the two subsectors, although their distinctive characteristics also imply that there should be some specific objectives for each one. For these subsectors, the aims of restructuring (i.e., the creation of enterprise and relationships between them) should be to ensure that these conditions occur:

- Production costs are minimized subject to the external constraints of safe and reliable supplies.

- Enterprises have the freedom to negotiate prices for their inputs (labor, capital, fuel) and outputs (lignite, electricity) that are efficient in economic terms.

- The new structures are conducive to attracting new sources of debt and equity capital for existing and potential new enterprises, to augment the resources available from the Polish government.

- The structures are capable of smoothly evolving from the status quo to being suitable for the market environment envisaged in the long term.

- The enterprises are able to meet the new environmental standards imposed by the relevant authorities by deploying appropriate skills and financial resources.

Issues in the lignite subsector that must be considered (Coopers & Lybrand Deloitte 1990a) are as follows:

- The price of lignite is now set on a cost-plus basis, which makes it significantly cheaper than hard coal. However, from an economic standpoint, the most appropriate pricing basis might be to use a hard-coal reference, adjusted for differences in quality and consumption costs.

- Future investment in the lignite subsector will be required, primarily to replace equipment and possibly to develop Szczercow as a satellite mine to Belchatow. In the longer term, new lignite deposits may also be developed. In a market economy, decisions about which company should develop new mines should be made on a competitive basis.

According to Cofala, Parczewski, and Umer (1990), technical and economic data on the most profitable (according to Poland's Power and Lignite Board, WEWB) new lignite mine, Szczercow, must be updated. The results of their investigation show the lack of systemic effectiveness of this mine (in comparison with imported fuels). Practically, this effectiveness (in a broader social context) would be even lower if the costs of extending the town of Belchatow and shortening its mining operations were considered. On the basis of the limits set for the development of the nuclear power system and the level of coal imports, the construction of this particular mine appears to be necessary only in the high growth scenario, which was estimated to have a low probability of occurring. (The scenarios were discussed in Chap. 8.) For these reasons, the construction of this mine and its associated power station is not recommended.

21.3 STRATEGY 3: ELIMINATE CENTRAL ALLOCATION OF COAL

If major coal consumers, mainly power stations, were allowed to bid separately for coal supplies from individual mines or mine groups, individual mines would be forced to increase their coal quality by using better mining techniques or coal beneficiation. Some mines would go out of business, but others would be able to expect increased revenues from the sale of better-quality coal. Shifts in regional labor patterns would probably occur. What is suggested by this strategy is the demonopolization of coal production and its distribution, the introduction (in some cases) and continuation of free-market pricing of coal, and the regulation of other energy prices in market-oriented relationships. Some of these suggestions have already been taken.

21.4 STRATEGY 4: CONSIDER ALTERNATIVE FUELS

Switching to another fuel is one of the cheapest ways to avoid coal-related emissions and solid wastes. If the government would improve its collection of fees and fines for air pollution and solid-waste disposal, both gas and oil might penetrate more rapidly in environmentally sensitive (i.e., highly polluted) as well as protected (relatively unpolluted as yet) areas.

The massive conversion of consumers of small amounts of energy from coal to gas might be appropriate. To do so, however, would require increased imports of gas (and perhaps oil), at their corresponding nonsubsidized prices. Households would be expected to switch on a major scale from coal to gas as soon as the gas network was extended to their area. In the industrial sector, the less energy-intensive (and typically smaller) enterprises would also be expected to switch to gas. However, energy-intensive industries, which already benefit from economies of scale in coal-handling costs, would still be expected to remain dependent on coal.

One aspect of this strategy is that Poland's domestic natural gas subsector could increase its production. All the accessible funds to accelerate production through foreign credits and joint ventures could be used. The next step could be to increase imports from countries other than the Soviet Union. The high degree of dependence on Soviet imports that now exists would endanger the domestic gas system if any disturbance in supplies were to occur. In addition, a diversification of import sources would improve Poland's position in negotiations with the Soviet Union, even though it will still probably be Poland's biggest supplier for a long time.

According to Cofala, Parczewski, and Umer (1990), by 2000, the Polish economy will be able to absorb an additional 3 billion m^3 of gas under the low scenario described in Chap. 8 and about 7 billion m^3 under the medium scenario. In the high scenario, gas imports grow by about 12 billion m^3, including about 5 billion m^3 of liquefied natural gas (LNG). Any strategy that involves an increase in gas imports, however, will require thorough consideration with respect to what the source of that gas will be.

Coopers and Lybrand Deloitte (1990b) recommend some measures that the gas subsector should take in three stages:

- Stage I -- Dismantle monopoly structures and commercialize activities:
  - Reorganize activities on a sustainable basis,
  - Set up investment holding companies as an interim measure, and
  - Increase incentives to enterprises, managers, and employees.
- Stage II -- Establish a corporation with 100% government ownership:
  - Increase enterprise autonomy, but with defined accountabilities and targets, and
  - Assess performance by results.

- Stage III -- Change ownership:
  - Develop legal mechanisms for ownership change,
  - Develop appropriate market mechanisms for the sale of shares, and
  - Sell businesses in stages (noncore businesses, services, exploration and production, distribution).

Coopers & Lybrand Deloitte (1990b) also advise restricting the allocation of the main current production areas to two domestic exploration and production companies. Bidding for other concessions should be as follows:

- Foreign/domestic 50/50 joint venture,
- Front-end high-risk foreign partner, and

Cut in 50/50 investment on discovery.

21.5 STRATEGY 5: DEVELOP COAL-BED METHANE RESOURCES

Poland has considerable quantities of untapped coal-bed methane reserves, and these could be harnessed as an important fuel source. U.S. A.I.D.'s Office of Energy is cosponsoring, with the U.S. EPA's Global Change Division, a resource assessment and project prefeasibility study of Poland's abundant coal-bed methane. The study will evaluate the state of the country's assessment, development, utilization, and managment of its coal-bed methane resources and assess opportunities for harnessing this resource to provide multiple economic and environmental benefits. These benefits include the following:

1. Developing an economically attractive natural gas resource to provide efficient energy and to reduce greenhouse gas emissions, in the context of Poland's heavy dependence on domestic coal and the increasing constraints it faces with respect to fuel imports;

2. Bolstering Poland's foreign exchange reserves by generating additional hard currency from increased coal exports;

3. Reducing atmospheric methane concentrations that contribute to global warming; and

4. Improving mine safety and efficiency by reducing the potential for explosion through recovery of methane before or during mining operations.

The interdisciplinary study team consists of experts who will review the government's priorities and assist in formulating programs to develop and utilize coal-bed methane resources, designing strategies for the solution of some energy-related environmental problems, and minimizing negative, associated socioeconomic impacts.

21.6 OTHER CONSIDERATIONS

21.6.1 Nuclear Subsector

The scenarios presented assume that the development of nuclear power will be limited after the year 2000 (a maximum of 2,000 MW in 2005 and 6,000 MW in 2010). Stopping the construction of the nuclear power station at Zarnowiec is assumed, since Poland will not be able to complete this power plant on its own.* The search for a foreign partner who would complete this facility, equip it with safety systems that meet Western standards, and then undertake its economic operation, has not yet succeeded. The continued construction of this power station based on its existing design is probably precluded, especially in light of lately published information concerning the catastrophic conditions of nuclear power stations in the GDR. The problem of the Zarnowiec power station should be seen in a proper light. This power station would have a small impact on Polish energy problems. Its capacity (Stage I is 880 MW) is less than 3% of the domestic energy system's capacity. Until 1995 (or even 2000), ensuring the proper control of the electric power system through construction of peak power capacities would be a problem. The costs of completing this nuclear power station would probably exceed the costs of constructing the equivalent capacity in conventional power stations. From the energy-balance point of view, the importance of this power station is rather limited, since an equivalent coal-fired power station would use less than 2 million tons of fuel.

The economic benefit of nuclear power cannot be based on calculations performed so far in the countries of the Council for Mutual Economic Assistance (CMEA), since these calculations have included neither the full costs of fuel (because the rouble rate is overestimated in relation to the dollar and underestimated in relation to the zloty) nor the costs of nuclear waste management. In reality, the cost of nuclear fuel is 25-40% of the cost of an equivalent amount of coal. Investment outlays for nuclear power stations are at least 60% higher than outlays for conventional (coal) power stations provided with adequate environmental control equipment. These costs explain why, in the West, the production costs for nuclear power stations are only somewhat lower than those for conventional power stations. If an adequate long-term interest rate for Poland is taken into account (at least 8%, considering the scantiness of capital resources), the production costs for electric energy are comparable with those for conventional power stations. In addition, the risk of expanding the construction period for nuclear power stations and the associated investment-cost overruns make them even less economically efficient.

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*At the beginning of September 1990, the Polish government decided not to build the Zarnowiec nuclear power station. However, this text describes the assumptions used for the scenario, when the future status of this plant was not known.

The domestic power system could be developed without nuclear power until 2000. The issue of constructing nuclear power stations after 2000 in Poland could be considered again in 3-4 years time. Answers to questions associated with the process of reforming Poland's economy, electric energy demand (after price adjustment), and the safety and costs of nuclear power will be better known at that time, providing an opportunity to make more accurate decisions. However, studies on the issue could still be performed continually.

21.6.2 Power and District Heating Subsectors

Cofala, Parczewski, and Umer (1990) maintain that the following measures should have priority in the electric power systems subsector:

- To rehabilitate existing power stations and simultaneously increase efficiency through cogeneration (CHP); also, to equip these plants with efficient emission-abatement installations;

- To use the appropriate fuel at peak power times (utilizing natural gas);

- To switch smaller units from coal to natural gas (heating plants in particular) and build new, small units based on natural gas or fuel oil;

- To rapidly complete the plants now under construction (especially the Opole power station) and provide them with FGD units (allowing new plants to operate for at least 30 years without emission control is inadmissible); and

- To use combined-cycle gas power stations.

The necessity of the consistent modernization of existing networks in the district heating subsystem is obvious. A detailed analysis of new heating systems based on international costs, including consideration of proper flow control systems and regulation in networks and radiators, could be conducted. It would be very important to integrate the world prices of fuels and equipment in the analysis, since price distortions in Poland are so large that they do not enable reliable calculations. For example, it is possible that an economic analysis would imply limiting the development of large district heating systems and promoting decentralized systems based on gas-fired plants. It is also inevitable that such an analysis would recommend the reconstruction and replacement of the rusted and damaged district heating network in Warsaw, which is in danger of suffering from catastrophic problems during the winter.

22 ENERGY CONSUMPTION

Nearly 97% of Poland's total energy production is constrained to coal and lignite, almost 99% of Poland's public electricity production is fueled by coal and lignite, and coal's share of Poland's primary energy consumption is in excess of 80%. These statistics make it obvious that coal reigns as the supreme fuel in Poland. In fact, coal consumption is considered to be a rational response to the availability of what once was cheap, domestically produced energy. However, this response results in Poland being heavily reliant on coal -- a reliance that is actually too high. Only the PRC and India rely on coal to a greater extent than does Poland. It is significant that no market-oriented Western economy relies on coal to the extent that Poland does. Even Australia, which exports more than three times as much coal as Poland, depends upon coal for less than 50% of its domestic energy consumption.

More than half of Poland's current gas requirements are imported from the Soviet Union. How long can this situation be maintained with the centrally planned economies ending their economic symbiosis and the Soviet economy in shambles? Environmentally, it would make great sense for Poland to use gas in its households and in small industrial applications, if a gas network were implemented. But where will the gas come from?

The same situation, or lack thereof, exists with respect to oil requirements -- only it is worse! Heavy fuel oil is used in Poland only in industry as an auxiliary boiler fuel or a furnace fuel and, of course, in transportation as a feedstock for gasoline. Nuclear power has really not even entered Poland's energy scene, except in the planning stage. And even that planning process has been shut down for the near term or longer. So, where does Poland go from here?

22.1 STRATEGY 1: USE ENERGY RESOURCES MORE EFFICIENTLY

Some sectors of Poland's economy would prefer to use a higher quality of coal than they are able to obtain under the system of central allocation. In the case of the electricity sector, this shift to higher quality (i.e., higher calorific value) would enable some power stations to improve their conversion efficiencies quite substantially, thus leading to a fuel savings of about 10%. Considering that the electricity sector alone accounts for about 55% of the hard-coal consumption in Poland, any shift in the composition of its demand would have an immediate impact on the balance of supply and demand for different grades of coal.

As described in Chap. 6.8, beneficiation of coal has been considered a controversial matter in Poland. From the miners' perspective, beneficiation would result in the loss of delivered product. From the power plants' perspective, beneficiation would result in lower total costs of electricity generation. From the environmentalists' perspective, use of cleaner coal would result in cleaner air and cleaner water, unless the process of beneficiation produced wastes that would contribute to the pollution sphere more significantly on a different plane.

22.2 STRATEGY 2: APPLY CONSERVATION MEASURES

If coal conservation measures could be [illegible] effectively, Poland would have more coal to export. If that coal were of internationally traded quality, hard currency would result. The standard of living for many Poles would thus be expected to increase. If coal conservation measures were initiated, Poland might be able to export coal by wire, exporting its electricity to Scandinavia, much like France exports its nuclear-generated electricity surplus to Italy.

Of course, energy conservation is not possible without a change in fuel and energy pricing systems. Energy conservation will not happen spontaneously. Thus this strategy proposes that an agency might be created to promote the rational use of energy in all sectors of the economy. The agency could support energy savings through the dissemination of reliable information, preference credits, production of energy-efficient equipment, etc. Another important task of this agency could be to encourage foreign partners to enter the Polish market on the principle of third-party financing. The agency could take up the coordination of foreign aid, which is offered in that domain to Poland as so-called aid funds. This is an opportunity that it should not miss. Of course, all these measures would have to be preceded by energy-pricing reform. Only then could energy savings be achieved and could investments in equipment that consumes less energy be economical.

22.3 STRATEGY 3: CONSIDER FUEL SWITCHING

Fuel switching is one of the cheapest ways to avoid coal-related emissions and solid wastes. However, at the heart of the Polish economic/energy system is the assumption that coal will or should be used unless there are overwhelming technical reasons to substitute another fuel. Thus gas is used for high-temperature processes, as it is in other industrial countries, but steam-raising and space heating invariably depend upon coal, even when gas might be a more economical, convenient, or environmentally desirable fuel. Potential import sources of natural gas need to be explored and identified. Domestic sources might also be reconsidered.

22.3.1 Liquid Fuels

The share of hydrocarbon fuels in the final energy demand is actually so low in Poland that the supply of these fuels could be increased without significant risk. All energy studies conclude that the supply of oil needs to be increased by at least 5 million tons by 2000. This conclusion indicates that a new refinery would have to be commissioned around 1995. Actually there is a substantial excess of capacity in foreign refineries, which creates the potential for Poland to import liquid fuels at advantageous prices. However, this strategy would not be profitable for a long period, since it would cause excessive dependence on imports and deprive the country of any benefits that could result from the development of its own petroleum industry. To weigh and judge these considerations, a program of petroleum and refinery industry development could be worked out.

22.3.2 Natural Gas

Preferred measures associated with natural gas utilization in Poland are as follows:

- Gas use could be increased in households in towns with old building stock and in urban areas with low population densities for space heating.
- Gas could be used in new and currently rehabilitated (where boiler replacement is necessary) municipal heating plants.
- Gas could be used in small heating plants, industrial power plants, and small public power plants with CHP. (These undertakings may be effective when the overhaul and replacement of boilers are necessary.)
- Natural-gas-fired peak power plants could be developed. The economic viability of combined-cycle gas-fired power stations requires further study, especially with respect to the possibility of purchasing natural gas at relatively low prices ($70-80/1,000 m^3).

In all these undertakings, the use of natural gas would essentially have the effect of decreasing investment outlays. In addition, it would be much less hazardous to the environment. Thus, it is thought that using natural gas in dispersed emission sources (households, small municipal heating plants) should be given preference. The proposed trends of gas utilization are being thoroughly analyzed in a separate study performed under the auspices of the World Bank.

22.4 STRATEGY 4: CONSIDER THE PRIVATIZATION OF POWER

Private participation in the power sector is another way to potentially address the difficulties of developing a modern and reliable electricity supply system for Poland. To date, countries have followed one or both of two routes: (1) privatization of whole or part of the state-owned utility or (2) independent private power generating facilities, either tied into the grid or providing power to individual industrial and commercial consumers.

Private companies would construct an appropriate generating plant, then deliver electricity to the grid as specified in the contract, which would probably have take-or-pay provisions (i.e., if the electricity generated by the private power plant is not needed, payments must still be made). Private power is thought to allow for more efficient plant operations and maintenance as well as to provide a way to avoid the financially constrained options imposed by the current government situation.

"Interest in private sector participation in the power sector [in countries such as Poland], has expanded significantly from the area of trade to include the area of investment. . . . In the past few years, many A.I.D.-assisted countries . . . have instituted laws and national policies that allow and encourage private sector participation in their power systems. A.I.D.-sponsored studies on private sector power generation or privatization of utility functions have been completed for Barbados, Pakistan, Thailand, India, the Philippines, and the Dominican Republic. These studies identified barriers to private sector participation and possible opportunities" (U.S. A.I.D. 1988).

The major benefits that private sector involvement can bring are the introduction of market forces and the attraction of additional financial and managerial resources. Market forces include competition and efficiency, which can result in improved system management and allocation of resources. Private ownership and operation also tend to result in prices being set to cover operational and capital expansion costs. Efficiencies in system design, procurement, construction, and operation can reduce overall costs if undertaken by private rather than public enterprises. Finally, of particular importance to Poland, private firms have generally proven to be more able to adopt, construct, and operate innovative power production and pollution-control technologies than state-owned companies in developing countries.

The substantial interest shown by private companies to date in participating in the Polish power sector indicates that the difficulties of raising debt and equity for these projects can be overcome. Favorable policies by the Polish government and continued commitments from export credit agencies and multinational lending agencies will accelerate this process.

22.5 STRATEGY 5: ADJUST ENERGY PRICING

To correctly develop the energy system, it is necessary to properly adjust energy pricing. For that purpose, at least two important issues have to be considered. The first is how to assign the proper relationships between fuel and energy prices. A suggestion for how this should be done with respect to the hard-coal price has already been considered. The second important issue is whether to raise fuel and energy prices to the level of international prices within a relatively short period (2-3 years). It is also related to whether the domestic price of hard coal should take into account properly calculated transport costs and differences in coal quality. Work on resolving this second issue has already begun.

The often expressed opinion that a strong inflationary effect is caused by increases in fuel and energy prices is, in general, exaggerated. Energy prices do have an impact on inflation, but this effect can be limited by proper economic policy. The most important examples of a "limitation policies" are the partial compensation of living costs or the imposition of hard budget constraints on enterprises so they cannot use the so-called cost-plus mechanism. The latter can be achieved through a special customs policy (for example), because if there is competition for foreign products, domestic enterprises cannot transfer the whole increase in their production costs to the price of their output. Also, it can only be achieved if the devaluation of domestic currency does not occur at the same time as the energy price increases (when the actual exchange rate of the dollar is rather high). Thus, possible ways already exist to lower the inflationary impact of higher fuel and energy prices on the prices of other goods.

On the other hand, the Polish prices of raw materials such as steel, cement, and chemicals have almost reached their world prices or even exceeded them. In this situation, maintaining distorted energy prices (2-3 times lower and, in the case of households, about 15 times lower for natural gas and 7-8 times lower for electricity) leads to completely obscuring the real production costs and the real consumption level. It is misleading to render the growth in energy prices as being totally responsible for the inflationary growth in other prices.

In conclusion, a change in the energy pricing system would be indispensable, assuming that the inflationary consequences of this type of strategy are usually not as dangerous as often claimed. Since there are so many systemic reforms in Poland that have a direct impact on the inflation and consumption level, continuing to maintain fuel and energy prices at a low level does not have any rational justification. These prices are actually lower now -- in the real sense -- than they were in 1988. This situation does not provide any incentives for rational energy use.

23 TECHNOLOGY

Three technological strategies rank foremost. The first strategy would be to apply conventional and (as they develop and become demonstrated) innovative scrubbing techniques to existing power plants and central heating plants to reduce their SO_2 and NO_x emissions. The second would be to perform coal cleaning (coal beneficiation) at the production site, on coal that is to be burned domestically as well as on coal that is shipped abroad and overseas to reduce transportation and handling costs. This strategy would allow plant operators to use the combustors as they were designed and permit the clean burning of domestic resources. In the third strategy, when new capacity would become warranted, the new units being built would employ clean coal technologies (like the fluidized-bed combustion and integrated gas combined-cycle units being demonstrated in the United States and elsewhere) as appropriate. Other applicable technologies are mentioned in the following discussion.

23.1 STRATEGY 1: USE DOMESTIC COAL IN EXISTING COMBUSTORS MORE CLEANLY -- INSTALL FLUE-GAS SCRUBBERS

Of the almost 29 GW of coal-fired generating capacity in Poland, only some units have electrostatic precipitators (ESPs) to remove particulates. None of the power plants use FGD to control SO_2 emissions. Although approximately 15 installations in Poland have some form of desulfurization, they are only at pilot-plant scale. Transference of the pilot-plant experience to full scale is anticipated in the early 1990s, according to the Polish Ministry of the Environment. Further details on specific strategies to reduce SO_2 and NO_x emissions proposed by the Polish government are described in Chap. 26.

The U.S. DOE is in the process of fitting one unit at one Krakow power plant (50 MW at Skawina) with flue-gas scrubbers, but no matter how modern or innovative this effort is, it is only a beginning. If it is to serve as a prototype, others must follow in a logical, planned sequence. But the financing issue cannot be swept aside. Financing is a valid concern and must be generated in some way to permit the refurbishment and rehabilitation to take place.

Additional research is needed to determine which sulfur-control technologies are best suited to Polish coals and plant designs. Consideration must be given to the cost and availability of needed resources and to the disposal of waste products and resale of by-products. Dry SO_2 techniques (such as duct injection) may be appropriate for small industrial facilities, where disposal of liquid wastes would present a problem. Combined SO_2/NO_x removal techniques could further reduce acidic-deposition problems.

23.2 STRATEGY 2: PHYSICALLY CLEAN DOMESTIC COAL -- BENEFICIATE IT BEFORE TRANSPORT AND BURNING AND CONSIDER BLENDING

Polish coal is beneficiated for the export market. Hence, at market prices, the cost of beneficiating coal for domestic use should be within profit margins and thus well within the realm of possibility. However, no one knows whether Polish coal has been sold under cost, because to date, export sales from a centrally planned economy have been hard-currency driven. Issues that are also uncertain are whether Polish coal can be cleaned in a conventional fashion and what the level of newly generated wastes is likely to be if the coal is cleaned to a greater extent than before.

Studies could be performed to determine the characteristics of the Polish coals with respect to beneficiation. Assessments could evaluate the extent to which new problems would be created from the wastes resulting from the beneficiation of coal to be burned domestically. In work being conducted by Argonne National Laboratory, a potential market for coal beneficiation has been identified in Poland, based on its desire or need to improve the quality of its indigenous coals and lignites so they can be used more cleanly and efficiently in domestic facilities (with accompanying ambient-air improvements) or so they can be improved before being exported.

Blending domestically cleaned coal (depending on the cleaned coal's burn characteristics and the combustor's design specifications) or blending poorer-quality, domestic, unbeneficiated coal possibly with low-sulfur imported coal for use in individual power plants could also be considered in specific cases.

23.3 STRATEGY 3: USE DOMESTIC COAL MORE EFFICIENTLY AND IN A MORE ENVIRONMENTALLY PRUDENT MANNER — APPLY FBC OR IGCC SYSTEMS IN NEW OR REPOWERED PLANTS

Some of the challenges involved with an expanded use of coal (which are the same for any resource) are to do so safely, efficiently, and effectively while minimizing adverse environmental impacts. These challenges are especially evident in Poland. Here coal has had the reputation, deservedly, of being a dirty fuel. It connotes images of black clouds emerging from smoke stacks and chimneys, accompanied by soot-covered cars and clothing -- a situation that is still a reality in Poland.

In recent years in the West, however, great progress has been made in dispelling the basis for this image, as improvements in combustion efficiency, particulate removal, and SO_2 removal by FGD systems allow coal to be burned while rigorous environmental standards are maintained. Improved efficiencies have also resulted in fewer CO_2 emissions (per unit of energy input) than those from earlier coal-fired facilities. This consideration will become more important as concerns about global warming become more intense.

Extensive research, development, and demonstration (RD&D) is under way in the West to further improve coal-based technologies, so that the use of this energy resource can be expanded while strict environmental standards are maintained. By developing a slate of technological options, decision makers are provided with greater latitude in balancing the needs of a growing population, desired economic expansion, environmental concerns, and costs.

Atmospheric fluidized-bed combustion (AFBC) can be used in both the industrial and utility sectors, and in both new and refurbishing applications. One particularly attractive feature is that it can use lower-quality coals while maintaining environmental standards at or near the levels currently required in the United States and other industrialized countries.

Pressurized fluidized-bed combustion (PFBC) offers more efficiency than AFBC while also maintaining high environmental standards. Several versions of PFBC are currently in various stages of RD&D. The combined-cycle concept, in which a water/steam-cooled bed feeds a steam turbine with the combustion gas and in which the fluidizing air is sent to an expansion turbine, yields a very efficient power plant.

An integrated gasification combined-cycle (IGCC) system can use one of many gasification processes and a wide variety of coal types and sulfur contents. Although the IGCC system's most likely potential is in the electric utility sector, the basic technology can also be used in industrial applications, as a cogeneration facility or as a producer of ammonia or chemical feedstocks.

All these technologies could be considered carefully for use in Poland, especially by utilities whose plans for new construction call for nonnuclear expansion.

24 MITIGATING THE IMPACTS OF AIR POLLUTION

One of the major incentives to reduce emissions of air pollutants is to halt and reverse the rapid decline of air quality that is occurring in many parts of Poland and to alleviate the impacts that this deterioration has caused and continues to cause (discussed in Chaps. 15-20). Therefore, another way to deal with air pollution problems in Poland would be to protect the receptor sites or to treat the symptoms resulting from air pollution rather than (or in conjunction with) tackling the cause of this air pollution.

The basic premise of this strategy is to reduce emissions in certain areas or at critical times so that such efforts will result in optimal benefits (i.e., produce the greatest amount of benefit for the least cost or least amount of emission reduction). Thus, unlike the control options discussed in the previous chapters, this method involves changing the abatement strategy from one that results in general emission reductions to one that involves either optimized, targeted emission reductions or treatment of the symptoms of pollution damage. The implementation of such an option could entail a number of different strategies.

24.1 STRATEGY 1: REDUCE AMBIENT AIR POLLUTION LEVELS DURING CRITICAL PERIODS

It has been observed that air pollution in Poland is highest in urban areas during the winter, when atmospheric inversions (which trap and concentrate pollutants) are common. Also, during winter, coal consumption for heating and cooking is highest. Limiting the use of highly polluting energy sources during this time of the year is one option that could alleviate some of the problems resulting from the very high air pollution levels present during winter. Possible mechanisms for implementing this strategy include (1) burning only very high-quality, low-sulfur coal; (2) banning coal use altogether; (3) importing power from plants located in more open, rural areas; (4) limiting optional electrical generation from CHP plants and other city-located electricity-generating plants; (5) restricting the amount of coal used by households, industry, and businesses; and (6) curtailing motor vehicle use. A seventh variant of this strategy that has potential in Poland is the selective use of natural gas during episodes of poor air quality.

24.2 STRATEGY 2: REDUCE AMBIENT AIR POLLUTION LEVELS IN CRITICAL LOCATIONS

Many of the urban areas that suffer from the most severe episodes of air pollution are located in valleys, where air circulation is poor and inversions are common. For example, Rosenbladt (1988) estimated that Krakow experiences stagnant air and inversions for 135 days every year. Therefore, more stringent control of air pollutant emissions in such areas would probably result in greater benefits than implementing uniform pollutant reductions over wider regions. The actual method used to curtail emissions in these locations would be similar to those described in Strategy 1.

A variation of this control option would be to reduce emissions in areas located closest to the most sensitive natural or man-made sites, i.e., curtailing emissions on a critical-load basis. This strategy might require greater reductions in some areas, but these would be offset by less severe curtailment in others. What this strategy offers is a lowering of pollution-deposition loads in those areas that are most sensitive to such pollutants or in those regions where the highest concentrations of valuable resources (natural, anthropogenic, human settlements) are located. Implementation of this strategy would maximize the benefit obtained per unit of emissions reduced. On the basis of this strategy, emissions that are closest to areas of high population density, sensitive forests and lakes, pristine locales such as national parks, and culturally significant buildings and structures would be reduced the most. Unfortunately, such areas would include much of Upper Silesia and Central Poland, where the highest concentration of polluting industries is also located.

24.3 STRATEGY 3: MINIMIZE DAMAGE TO RECEPTOR SITES

This strategy would involve adapting the environment to pollutant loading by treating the receptors of pollutant deposition so as to render them more resistant to its effects. In the case of acid rain, this treatment could involve (1) liming acid-sensitive lakes, (2) planting pollutant-resistant tree species, (3) restocking aquatic ecosystems with acid-tolerant species, (4) fertilizing terrestrial (agricultural and forest) ecosystems, (5) cultivating only those crops that do not tend to absorb toxic substances from polluted soils, (6) using corrosion-resistant metals and other surfaces for buildings and other structures, (7) frequently washing marble and stone surfaces, and (8) restricting outdoor activities for the most sensitive segments of the human population, particularly during high-pollution episodes.

24.4 STRATEGY 4: ADOPT THE MOST EFFECTIVE AND LEAST COSTLY MEASURES FIRST

There is no doubt that economic constraints will play a critical role in whether and how Poland will attempt to resolve its air pollution problems. All the methods discussed in this chapter try to optimize the benefits obtained from a given level of emission reduction. This control option could be extended so as to first use those methods that obtain large, initial increments of emission reductions first, deferring further reductions and controls on more difficult plants until more technologically advanced and less costly methods of control are available.

25 INSTITUTIONAL ISSUES

The discussions in the previous chapters on control strategies clearly demonstrate that many methods could significantly improve the state of the environment, especially air quality, in Poland. However, none of these strategies are likely to be implemented unless market forces make them more economically attractive and/or unless regulatory policies force their use. The most commonly used method to implement pollution-control strategies in recent years has been the use of institutionally mandated policies. Traditionally, this strategy has been used to limit the concentrations and/or emissions of pollutants in a given region, state, or nation. A number of different mechanisms that are available to accomplish these reductions are described below.

25.1 REGULATORY STRATEGIES

Regulatory mechanisms are the most direct way to implement the pollution-control strategies described in Chaps. 21-24. These regulatory measures could be legislated at various levels -- local, state, federal, or international. Most of these legislative policies could involve setting standards for ambient pollution concentrations or mandating percentage emission reductions for specific substances. Some flexibility could be permitted in how these reductions and standards would be attained, and free-market mechanisms could be built into this strategy.

Until recently, little effort had been made in the Eastern European countries to legislate control measures for air pollutants. This situation is not surprising, given the emphasis of communist-dominated governments on low-technology production, mainly of heavy machinery and metal processing, which was dictated by government quotas and heavily subsidized in terms of energy and natural resources. These factors are largely regarded as the root causes of the poor environmental quality present in these nations; and the close relationship between industry and the state has made environmental protection through regulatory control virtually impossible. However, because of the increasing severity of air pollution problems and the experience of Western nations, some attempts to control pollution through legislative means have been suggested.

In Poland, even before Solidarity's rise to power, a number of provisions to improve air quality had been set forth. In 1966, Poland passed a regulation establishing maximum ambient air-quality concentrations for 16 different pollutants. In 1980, this law was strengthened so that it extended regulation to 54 substances (Kapala and Herman 1987; Kabala 1985). The maximum permissible yearly average level for SO_2, for example, is currently 64 $\mu g/m^3$; this level is to be reduced to 32 $\mu g/m^3$ in 1991. In certain parts of Poland, these standards are even more stringent -- in Krakow, the official limit is 11 $\mu g/m^3$. However, levels of most of these pollutants usually exceed the maximum permissible levels, as enforcement of existing legislation is virtually nonexistent. To illustrate, SO_2 concentrations in Krakow often average over 100 $\mu g/m^3$ (Kabala 1989).

In 1986, partly in response to the worsening air quality in many parts of Poland, a special working group, the Sulfur Commission, was appointed by the government to study the air pollution situation in the country and provide recommendations on how best to deal with this problem. The commission drafted its findings in 1987 in a report entitled *The Program for the Reduction of Airborne Sulfur and Nitrogen Compounds up to the Year 2000.* The main provision of this program is to reduce sulfur emissions by 3.6 million tonnes (represents a decrease of approximately 30% from 1985 levels) and NO_x emissions by 0.9 million tonnes by the year 2000 (Agren 1988). It is assumed that these reductions would be achieved mainly through the use of a combination of control technologies such as coal desulfurization, combustion modification, FGD, lime injection, diesel-fuel desulfurization, catalytic converters on mobile sources, and energy efficiency.

These reductions in SO_2 and NO_x emissions would enable Poland to meet the requirements set by the European Economic Community (EEC) "30% Protocol" for sulfur, albeit seven years after its 1993 deadline. Poland, which was a signatory to this "Protocol on the Reduction of Sulfur Emissions or their Transboundary Fluxes by at Least 30 Percent," adopted at Helsinki in 1985 and entered into force in 1987, has consistently stated that without financial help, there is very little chance it will be able to comply with this regulation (McCormick 1985; Pape 1990). The current Environment Minister, Bronislav Kaminski, has said that all Poland can promise at present is a 10-20% reduction in SO_2 emissions during the next 5 years.

The recommendations of the Sulfur Commission, as described above, were adopted into the National Program of Environmental Protection by the Ministry of the Environment in 1988. In addition to the reductions mentioned above, this program stipulates a further 30% reduction in SO_2 emissions and a 50% reduction in NO_x emissions to be achieved by the year 2010. If enacted, these reductions should enable Poland to meet its own 32 $\mu g/m^3$ national ambient air quality standard for SO_2 as well as the NO_x protocol set by the United Nations Convention on Long-Range Transboundary Air Pollution in Sofia in 1988.

It is clear that in spite of these initiatives and regulations, little improvement in air quality has ensued in Poland; in fact, air pollution problems continue to worsen as a result of the fact that in Poland (as in most other Eastern European nations), environmental laws have not been strictly enforced. Lack of technical equipment, small enforcement staffs and budgets, exemption of many industries and processes, planning programs that only reward production, and the difficulty in forcing state-owned businesses to comply have all contributed to making enforcement of any environmental laws that do exist extremely difficult (Levin 1989). Only in the past year has there been hope that legislative mechanisms to control air pollution may become effective. This hope stems from the recent democratization of the Polish government system and the concomitant shift from a centrally planned economy to a more market-based one.

Some progress toward improving environmental quality has been made during the past year, particularly in the area of energy pricing. Brown-coal prices are currently being fixed with respect to their sulfur content, and energy prices increased overall by 600% in January 1990 (Pape 1990). Also, the government has ordered the closing of approximately 100 highly polluting plants and industrial establishments. However, opposition, particularly from Upper Silesia where most of these plants are located, is likely to be intense. Finally, a number of bills dealing with environmental policy, pollution taxes, and forestry are currently under consideration in the Polish parliament.

Further reductions in air pollutant emissions in Poland (in addition to those resulting from enforcement of existing laws and regulations) are likely to be brought about by Poland's desire to join the EEC. One of the requirements that Poland would have to fulfill to become a member of the EEC would be to meet the strict air-quality regulations set by this body. One of these EEC regulations, known as the "Council Directive on the Limitation of Emissions of Certain Pollutants into the Air from Large Combustion Plants," was adopted on November 24, 1988. This directive is legally binding on EEC member states and includes emission standards for SO_2, NO_x, and particulates, for both new and existing plants.

For existing plants with a thermal input of more than 50 MW, this directive requires a specified percentage reduction from 1980 levels for the 1990s, with some countries allowed deviations from this percentage for a number of reasons. These reasons consider the quantity of reductions achieved before 1980, the relative contribution of emissions to long-range transboundary pollution, and the current state of economic development in the country under consideration (Vernon 1988). The overall objective of this section (existing plants) of the EEC directive is for such plants to achieve a total reduction in emissions from 1980 levels of 58% for SO_2 and 30% for NO_x by the year 2003.

For new plants (licensed after July 1, 1987) with a thermal capacity of more than 100 MW, the directive's emission-limit values are based on the best available technology that does not involve prohibitive costs. For plants between 100 and 500 MW, SO_2 limits are set on a sliding scale; plants greater than 500 MW are subject to fixed emission-limit values.

Another provision of the EEC directive that would have special relevance to Poland is that new lignite-burning plants (which are particularly highly polluting) are given special exemption. This exemption allows these plants to exceed emission limits if it is determined that lignite is an essential fuel for these plants and implementation of controls would entail excessive costs. Such an exemption must be agreed to by the EEC member states and be approved by the EEC commission. This exemption could allow the predominantly lignite-burning Belchatow, Szczercow, Konin, and Turow power plants to exceed emission limits even if Poland joined the EEC.

In an initial step toward complying with EEC regulations and thereby easing its entry into this organization, Poland, in negotiations with the World Bank, recently agreed to apply the EEC environmental standards to all new plants. In addition, Poland stated that all older plants would comply within seven years. Again, however, Poland has reiterated that it can accomplish this feat only if international aid and cooperation are forthcoming (Pape 1990).

It should be realized that in order to comply with just the existing regulations on environmental quality would impose extreme hardships on the already fragile Polish economy. The Polish Minister for Environmental Protection estimated that enforcement of existing Polish environmental legislation would close one-third of the Polish plants (JAWMA 1990). Thus, unless air-quality regulations are supplemented with other strategies such as energy-efficiency improvements, a shift away from heavy industry, implementation of a free-market economy, and financial backing from foreign countries, the enforcement of such regulations would probably cause chaos to Poland's economy. The first of these strategies was discussed in Chap. 22; the latter three are discussed below and in subsequent chapters.

25.2 MARKET MECHANISMS AND ECONOMIC INCENTIVES

Until recently, most pollution-control strategies had been implemented mainly on the basis of their economic merit. For example, long before environmental concerns became important, coal was washed because it increased the specific energy content of the coal and removed impurities, which reduced fouling and corrosion of boilers and decreased transportation costs. Thus, it is likely that if there were significant economic incentives to control air pollution and improve air quality, these measures would be adopted fairly readily. A number of such economic measures are currently available, including these:

- Subsidies for the installation and use of pollution-control devices,
- Tax incentives for plants that use control equipment,
- Taxes levied on the electricity produced from uncontrolled plants,
- Taxes and effluent fees on sulfur and nitrogen,
- Taxes on carbon,
- Transferable permits and pollution rights,
- Taxes on energy production and use,
- Fines for heavy polluters (such fines already exist in Poland but are currently so low that it is cheaper to pollute and pay the fine than to install pollution control devices), and
- Creation of a market for the by-products of controls (e.g., gypsum) to encourage their use.

Most of these economically oriented strategies assume the presence of a market-based economy. Thus, for any of these strategies to work effectively, there must be a shift in production away from state-dominated, heavily subsidized industry and a dismantling of state monopolies so that genuine ownership and competition are present, especially in the power sector (Levin 1989). This shift would allow pollution costs to be internalized by the industries in question. Because of the change in Poland's political regime and its transition to a free-market economy, it is possible that many of these economically based measures could be effective in limiting air pollution there. It should be realized that in addition to the fact that most of these economic incentives to control pollution must operate in a market-based system, they also require the implementation of the regulatory strategies described earlier in this chapter to mandate their use.

25.3 SPECIFIC ECONOMIC AND REGULATORY STRATEGIES FOR INDIVIDUAL ENERGY SUBSYSTEMS IN POLAND

It is extremely important to make decisions about the organizational structures of individual energy subsystems in a relatively short time. These decisions are directly connected to other decisions that have to be made about the ownership patterns in energy industries, responsibilities for investment decisions, supply obligations, pricing policies, and the forms and ranges that state intervention will take in the sphere of energy management.

In addition, it is necessary to attract foreign capital to support the reconstruction and development of the energy sector. Such offers are being made by Western firms and they should be thoroughly examined. However, the basic conditions that must be fulfilled to make foreign investments feasible are the adjustment of pricing policies for energy carriers and the implementation of suitable decisions about structures and private ownership in the energy sector.

The results presented in the following scenarios are mainly examples and should not be taken as detailed plans of domestic energy development. However, they show the possible directions that energy-system development could take. They serve as a basis for elaborating the development programs for individual energy subsystems (e.g., the hard-coal power system, gas industry), the modernization and reconstruction plans for individual plants (e.g., power stations, mines), and the construction plans for new energy plants.

25.3.1 Hard-Coal Subsector

The National Economic Research Associates (NERA 1990) recommended the establishment of a royalty setting and licensing agency. Because the coal in Poland will continue to be owned by the state, this type of agency is an essential prerequisite to any form of liberalization or privatization of the mining operations. This agency would be responsible for granting licenses for the right to mine and collecting royalties that would be based on the coal quality and ease of mining at a particular pit location. The licensing arrangements could also be used to levy rents for existing capital stock at each mine. NERA also proposed the creation of a coal mining trust to oversee mine companies while they are under state ownership; in July 1990, such an institution was, in fact, established (Polish Coal Mining Agency). This trust would be responsible for administering the subsidies and their disbursement as well as closing uneconomical mines and rationalizing mine companies that get into difficulties.

The structure recommended by NERA would consist of the following organizations:

- 12-15 independent mining companies;
- A coal mining trust to close/rationalize uneconomical mining companies and administer subsidies if required;

- 8-10 regional distribution companies;
- An independent, self-sufficient mining support organization;
- A licensing and royalty setting agency for coal extraction; and
- Nationwide regulatory bodies for health and safety and environmental protection.

2[illegible].3.2 Power and Lignite Subsectors

The Power and Brown Coal Community (WEWB) was placed into liquidation by a law passed by the Polish Parliament in February 1990. By September 30, 1990, the functions hitherto performed by WEWB were to be transferred to other organizations. Coopers & Lybrand Deloitte (1990a) recommend that the following efforts be made:

- Preserve the existing legal separation of the lignite mines, power-generating enterprises, and distribution/supply enterprises, respectively, while transforming them into financially autonomous joint-stock companies (initially wholly-owned by the state) using the mechanisms of the privatization law passed by the Polish Parliament.
- Similarly preserve the separate enterprises for construction and maintenance in both subsectors, but again transform them into companies.
- Create a new (joint-stock) transmission company (called ETEE), in which the state would always retain a 51% shareholding. The ETEE would:
  - Dispatch, at the central and regional levels, power stations for designated systems;
  - Prepare national load forecasts and plan, fund, and commission new system generation and transformation capacity;
  - Own and maintain the high-voltage transmission network;
  - Own and operate the pumped storage capacity;
  - Internationally import and export power;
  - Negotiate power purchase prices with generating companies and establish a bulk-supply tariff for the sale of power to distribution/supply companies; and

- Conduct central research and development for the industry on a commercial basis.

- Establish two tiers for regulating the activities of the constituent companies in the industry:

  - Surveillance councils, which would regulate the activities of the distribution/supply companies and the ETEE and would be subject to local government and central government control, respectively, and

  - A national surveillance organization, which would regulate the activities of the industry as a whole by licensing the generating and distribution/supply companies, approving bulk supply tariffs, setting profit rates for ETEE and the generating companies, and approving system investment.

Since August 1990, such an organizational structure has been implemented in Poland. The studies on the district heating subsector are at the preliminary phase.

25.3.3 Natural Gas Subsector

The Polish Oil & Gas Company (PGNG) was established in 1982, with responsibility for coordinating all activities within this subsector. The operating companies lost their autonomy and their links with municipal authorities. In the opinion of Coopers & Lybrand Deloitte (1990b), key issues in restructuring are as follows:

- Vertical integration -- the relationship between upstream and downstream activities;

- Upstream structure -- the relationships among exploration, geophysical, drilling, and production businesses;

- Downstream structure -- the organization of transmission and distribution businesses and trading relationships with producers;

- Peripheral activities -- the relationship between manufacturing and construction businesses and the mainstream gas industry.

The more practical onclusions were to be formulated by Coopers & Lybrand Deloitte in the latter part of 1990 in a report on the scope of the reconstruction program of the Polish energy sector.

25.4 SOCIAL REGULATION

Although not an institutional control strategy in the strictest sense, social regulation, such as that initiated by public pressure and collective public action, can be effective in achieving environmental integrity. During the early and mid-1980s when Poland was under communist rule, the condition of the environment was perhaps the only issue on which it was somewhat permissible to challenge the state (Economist 1990). The Polish Ecology Club, for example, initiated vocal opposition to environmental pollution in the 1980s and is now the most active environmental organization in Poland. In 1981, it was responsible, through its allies in the trade union, for shutting down the Skawina Aluminum Works south of Krakow, which was contaminating the surrounding region with fluorine emissions (Rosenbladt 1988).

Social regulation and pressure, however, are more likely to be effective in a democratic society; with Poland's democratization in the past year, it is possible that such a strategy would work well. This method of control would be further facilitated by the severity of environmental conditions in Poland and the public's current focus on free speech, civic duty, and government participation following the repression of such activities for so many years. In fact, the Polish Ecology Club now finds itself in the position of helping draft the environmental agenda for the new democratic government.

25.5 INTERNATIONAL PRESSURE

Because air pollutants, particularly those associated with acid rain, ozone, and global warming, do not respect political boundaries, pressure from outside Poland could be another institutional control strategy for improving air quality within Poland. International pressure could be implemented in a number of ways, including pressure from international organizations in which Poland is, or is likely to become, a member (i.e., the United Nations, the EEC) and through bilateral or multilateral agreements. In addition, pressure could be exerted by neighboring countries, particularly those in Western Europe that receive pollutants from Poland (such as Sweden), through the threat of withdrawal of assistance and/or through the imposition of sanctions.

26 POLISH PROPOSALS TO REDUCE EMISSIONS OF SULFUR DIOXIDE AND NITROGEN OXIDES

26.1 SPECIFIC TARGETS AND ASSOCIATED MECHANISMS

Work done within the Governmental Research Program (PR-8) "Complex Development of Energy System" (Jedrzejewski et al. 1986) suggests a list of measures that should be taken in Polish power plants to prevent an increase in SO_2 emissions from public utilities up to the year 2000. On the basis of the assumption that electricity production in Poland will rise to 230 TWh by 2000 (1985 emissions = 138 TWh), a doubling of SO_2 emissions will result -- an increase from the present level of approximately 1.8 million tonnes to 3.7 million tonnes. To decrease these potential emissions by 50%, use of the following measures has been proposed:

- Coal fines cleaning (for 52 million tonnes of coal, of which 9 million tonnes is high-sulfur coal), which would result in a 40% decrease in the sulfur content of coal;

- High-efficiency FGD systems (wet-limestone or spray-dryer methods), which would be used in power plants with a total capacity of 12,500 MW; and

- A dry method of FGD, which would be used in lignite-fired plants with a total capacity of 9,700-MW.

Attempts have also been made to estimate the costs of this proposed pollution-control strategy.* Capital investments for the above program have been estimated at 400 billion zl at 1985 prices. Taking into account the damage to the environment that could result from SO_2 emissions (75-108,000 zl/tonne, depending on the region where the pollution occurs), the authors stress the high economic effectiveness of this program, because the average payback time is only 4.5 years. However, as is the case for all other studies done in this area, the figures require updating and verification with respect to coal cleaning costs, coal losses in the process, future electricity production levels, and cost data. Also, attempts to find a least-cost solution have not been made.

As discussed in Chap. 25.1, the development of a strategy to reduce Poland's SO_2 emissions by 30% from the 1980 level by 2000 was the responsibility of the government's special working group on the subject, the Sulfur Commission (Sulfur Commission 1987). According to the commission's sectoral analysis of sources of SO_2 in the Polish economy, more than 90% of the country's emissions emanate from the production of energy. This activity consumed 160.5 million tonnes of hard coal and 56.5 million tonnes of lignite in 1985; virtually all of this total was burned in its natural state and without sulfur control technology. The use of hard and brown coals for energy production is expected to increase until the year 2000, and with it, the emissions of air pollutants. The Sulfur

*The majority of other programs are limited to their physical aspects, without any economic evaluation of the proposed measures provided. Sometimes only capital costs are given.

Commission estimated SO_2 emissions at 4.1 million tonnes and NO_x emissions at 1.4 million tonnes in 1980. On the basis of the assumption that no measures will be taken to reduce emissions, these emissions would be expected to increase to 5.5 million tonnes of SO_2 and 2.3 million tonnes of NO_x by the year 2000.

The commission has elaborated a program to reduce emissions. This program is based on the measures proposed by ministries supervising major economic sectors in Poland. The following measures are designed to reduce SO_2 emissions to 2.9 million tonnes by 2000.

- Hard-coal cleaning (for 53 million tonnes of coal), which would result in a 570,000-tonne decrease in SO_2 emissions;

- FGD in hard-coal-fired power plants (4,800 MW), which would lead to a 400,000-tonne reduction in SO_2 emissions;

- FGD (limestone injection) in lignite-fired power plants (10,000 MW), which has the potential to reduce SO_2 emissions by 400,000 tonnes;

- Fluidized-bed combustion (FBC), which could reduce SO_2 emissions by 65,000 tonnes;

- Desulfurization of diesel oil, with an associated reduction of 100,000 tonnes of SO_2;

- SO_2 emission control for industrial facilities, yielding a 305,000-tonne reduction in SO_2; and

- Energy conservation, which could result in an 800,000-tonne reduction in the amount of SO_2 emitted.

The Sulfur Commission's program also assumes a 380,000-tonne reduction in NO_x emissions by 2000, of which 120,000 tonnes would result from low-NO_x burners and 150,000 tonnes from energy conservation. The remainder would result from the proper operation of combustion facilities and from limiting emissions from technological processes.

The capital investments needed up to the year 1995 to implement this program are placed at 500 billion zl (1985 prices). An assessment of total costs associated with this program, including operation and maintenance costs of emission-abatement technologies, has not been performed by the commission.

Details of a coal cleaning program are specified in the information provided by the Ministry of Industry and the Hard-Coal Board (WWK 1989). This program involves the cleaning of 54.2 million tonnes/yr of coal fines, including 9.7 million tonnes of high-sulfur coal (sulfur content of >1.5%) by the year 2000. After this year, it is assumed that an additional 8 million tonnes of high-ash coals would be cleaned each year. As a result, it should be possible to reduce SO_2 emissions by 590,000 tonnes/yr by 2000 and by 670,000 tonnes/yr by 2010. This program would produce more than 15 million tonnes of solid waste, which cannot be dumped in the Silesian region because of a lack of space. Therefore, it is proposed that approximately 45% of the waste be transported about 150 km to the dumping site in the Belchatow lignite mine. Total investment costs of this program are estimated to be 290 billion zl (1988 prices). The information cited above does not specify coal losses during the cleaning process, but a more detailed study (GBSiPG 1988) shows that they may be quite high (6-13%). Thus, the program should be carefully reviewed and optimized after detailed data on costs and technical performance are known from the operation of pilot plants.

Measures aimed at reduction of SO_2 emissions from public utilities have also been proposed in the program developed by the Power and Lignite Board (WEWB 1989). The program assumes a reduction in SO_2 emissions by 30% from the 1980 level (1.9 million tonnes) by the year 2000 and further reductions until 2010. Without implementation of control measures, emissions are estimated at 2.7 million tonnes by the year 2000. It is expected that coal beneficiation will result in a decrease of SO_2 emissions by 590,000 tonnes in the year 2000 and by 670,000 tonnes in 2010. Another measure proposed is FBC (40 boilers with a total capacity of 8,000 MWt), which has a reduction potential of 100,000 tonnes by 2000 and 185,000 tonnes by 2010. The balance (i.e., 740,000 tonnes in 2000 and 855,000 tonnes in 2010) would be achieved through FGD (limestone injection in lignite-fired plants and high-efficiency methods in hard-coal-fired plants, the latter being 7,000 MWe in 2000). The total investment cost for FGD installations is estimated at 400 billion zl (1988 prices). The above program would require more than 3 million tonnes of limestone per year after 2000. Costs of the program have not been specified. Of note, also, is the fact that a reduction in SO_2 emissions at the national level by 30% usually requires utilities to reduce their emissions by more than this amount. Also, in reality, a large proportion of cleaned coal will probably be used in industrial power and heat plants. These facts should be taken into account in any elaboration of a new version of the program.

In 1988, the Ministry of Environment (MOSiZN) detailed a program for the reduction of atmospheric SO_2 emissions (MOSiZN 1988). This program, as briefly mentioned in Chap. 25.1, was based on the report of the Sulfur Commission. Assumed emission targets would be achieved in two steps. In the first step, which covers the period to the year 2000, a 30% reduction is assumed; this meets the requirements of the Helsinki Protocol to the Convention on Long-Range Transboundary Transport of Atmospheric Pollutants, but seven years later than specified. In the second stage, which covers the time to 2010, a further decrease by 30% is assumed; this should allow for compliance with ambient standards (average annual concentration of less than 32 $\mu g/m^3$ after the year 1991) throughout the whole country. Capital investments associated with this program are estimated in the above-cited document to be 1.3 billion zl (1986 prices) (approximately \$3 billion).

MOSiZN (1989a) has also elaborated an analogous program for NO_x emission reductions, which assumes a reduction from the 1987 level of 10% by 2000 and of 50% by 2010. These reduction levels meet the requirements of the Sofia Protocol to the above-mentioned convention and also ensure that ambient standards will be met at the national level by the end of the period. The program proposes several measures for NO_x reduction, such as fluidized-bed boilers, low-NO_x burners, and changes in boiler design, flue-gas denitrification, and catalytic converters and low-emission engines for cars. The emission reduction potential assumed by this program, in many cases, is very optimistic and requires more detailed studies. Total cost of the program, based on a very rough estimate, is placed at 940 billion zl (1988 prices).

The above programs have been used to prepare the National Program of Environmental Protection (MOSiZN 1989b). However, the latter document gives only very general information about measures indispensable in achieving the assumed targets in the absence of any cost estimates.

26.2 MODELING LEAST-COST STRATEGIES

A study by Cofala, Balandynowicz, and Parczewski (1989) aims to elaborate a least-cost strategy for SO_2 and NO_x abatement up to the year 2010 at the national level. It was performed with the use of the energy-environment model set called SPSEK-E. This model set is an extended version of an analogous energy model, and it includes macroeconomic, final energy demand, and energy supply and conversion models. The SPSEK-E model set computes emissions of airborne pollutants (particulates, SO_2, and NO_x) under scenarios that specify different economic growth conditions, fuel-use structures, and emission-control technologies. It is able to perform simulations of the changes in energy intensities of individual products and services as well as of interfuel substitution and their relationships to final energy utilization and the latter's effect on pollutant emission levels. In the sphere of energy production and conversion, the model chooses a technology mix, including emission-abatement technologies, to meet energy-demand and emission constraints in a cost-effective way. The model takes into consideration environmental protection technologies. Because the costs of applying abatement technologies differ, depending on whether they are used in existing (within updating processes) or new plants, the characteristics of the technologies differ.

The following abatement technologies are implemented by the model:

- Hard-coal cleaning with desulfurization,
- FGD in hard-coal-fired power plants by the spray-dryer method or wet-l mestone method,
- FGD in lignite-fired power plants by the dry method or the wet method,
- Flue-gas denitrification in power plants by primary measures (i.e., combustion modification) or by the selective catalytic reduction (SCR) method.

In addition, the model considers new integrated technologies such as:

- Steam-gas combined-cycle power plants,
- Power and heating plants with fluidized-bed boilers,

- Production of synthesis gas based on hard-coal gasification,

- Production of medium-Btu gas and methanol from hard coal and lignite, and

- Gasification of oil residuals.

The model takes into account 28 types of energy carriers, including 10 types of hard coal. This aggregation reflects the sulfur and ash contents in the fuels. The SPSEK-E model set has been implemented on personal computers.

The model has been applied to analyze the energy-system expansion strategy for Poland up to the year 2010 under various SO_2 and NO_x emission-reduction requirements. Four pollution-control scenarios were formulated:

1. "Doing nothing" case.

2. 30% case: This assumes a 30% reduction in SO_2 emissions from the 1980 level by the year 2000.

3. Legal case: This assumes the application (where feasible) of the emission targets imposed by the National Program of Environmental Protection (MOSiZN 1989b): a 30% reduction in SO_2 emissions by 2000 and a 50% reduction by 2010; stabilization of NO_x emissions after the year 1995 at the present level, then a 10% reduction until 2000 and a 50% reduction until 2010. Because there was no feasible way to achieve the last target, a 10% reduction of NO_x emissions in the period 2000-2010 was assumed instead.

4. CEC (Commission of European Communities) case: This accounts for the effects that would occur if Poland were to comply (with a delay of seven years) with the directive on emissions from large combustion plants adopted by the European Economic Community (CEC 1988). This case was described in Chap. 25.1, where it was referred to as the EEC directive.

Computations for all four scenarios were performed based on a "rationalization" scenario of economic growth. This scenario assumes slow growth rates at the beginning of the planning period (2.2%/yr) and a faster rate (3.0%/yr) after the year 1995 with a simultaneous radical change in production structure. This change depends on liquidating outdated plants that produce energy-intensive raw material (steel, cement, fertilizers, etc.), phasing out exports of these, and promoting imports. Also, in the manufacturing industries, a rapid decrease in material and energy intensities is assumed as a result of phasing in market forces, successful pricing and tax reforms, and other measures. This scenario does not ensure repayment of Poland's foreign debt. Thus, it requires an additional supply of foreign exchange or restructurization of the Polish debt.

In the "doing nothing" case, emissions of SO_2 increase from approximately 3.8 million tonnes in 1980 to 4.1 million tonnes in 2010; emissions of NO_x increase from 1.3 to 1.8 million tonnes. This increase is lower than that indicated in other studies because a lower energy demand and a switch from coal to natural gas as the final energy carrier in the residential sector are assumed, even without taking into account environmental constraints.

To achieve a 30% reduction of SO_2 emissions in the period 2000-2010 from the 1980 level, it is necessary to clean about 20 million tonnes of hard coal and to install, by the year 2000, FGD units in power plants with a total capacity of about 17,000 MW (high-efficiency FGD for 8,000 MW of hard-coal-fired plants and sorbent injection for 9,000 MW of lignite-fired plants). Also, all plants built after the year 2000 will have to be equipped with FGD. Because high coal losses occur in the beneficiation process, the model prefers to use selected coal assortments, including high-sulfur coal, in new power plants equipped with FGD. The optimal extent of coal cleaning requires further analyses after characterizations of coal cleaning technologies are verified on the basis of pilot-plant operating experience. Also, the feasibility of other technological paths not included in the present version of the coal cleaning program (WWK 1989) should be analyzed; for example, the burning of sludge from cleaning processes in boilers with fluidized beds.

Requirements of the legal case can be fulfilled, provided FGD units are installed in 15,000 MW of power plant capacity (9,000 MW of which is in lignite-fired plants). The extent to which hard coal should be cleaned would be the same as in the 30% case. Also in the legal case, using fluidized-bed boilers for smaller CHP public power plants as well as industrial CHP plants seems to be an appropriate option -- 6,000 MWt in the year 2000 and three times more by the year 2010. Fluidized-bed boilers become an option when NO_x reduction is necessary; in cases where only SO_2 emissions have to be reduced, they are not a cost-effective option. To achieve the assumed reduction in NO_x emissions, extensive use of denitrification technologies (SCR method) in power plants would be required. Additionally, with the very low emission limits imposed in this scenario, fueling of industrial heating plants with natural gas becomes economical. Thus, the consumption of natural gas in this scenario is 6 billion m^3 higher in the year 2010 than it is in other scenarios.

In addition to computations for the four main scenarios, separate computations were made to determine the most cost-effective way of reducing emissions of SO_2 and NO_x in the period 2000-2010 by a fixed amount, irrespective of legal requirements. From the model runs, it appears that a 60% reduction in SO_2 emissions from the 1980 level is feasible. For NO_x, only about a 15% reduction is possible, because of the much higher growth of the NO_x emission level in the "doing nothing" case. This increase is caused mainly by the growth of demand for liquid fuels in the transportation sector. NO_x and SO_2 reduction cost curves are shown in Fig. 26.1. Reducing SO_2 by 30% in the period 2000-2010 results in cost increases of 200 billion zl (1984 prices, values discounted as of 1985). Reducing NO_x is much more costly. For instance, even maintaining emissions at the 1980 level requires additional expenditures of more than 200 billion zl. For a 10% reduction, costs rise to 350 billion zl. In Figs. 26.2-26.4, the so-called step functions are shown; these illustrate which technologies enter the optimal solution when environmental restrictions are tightened.

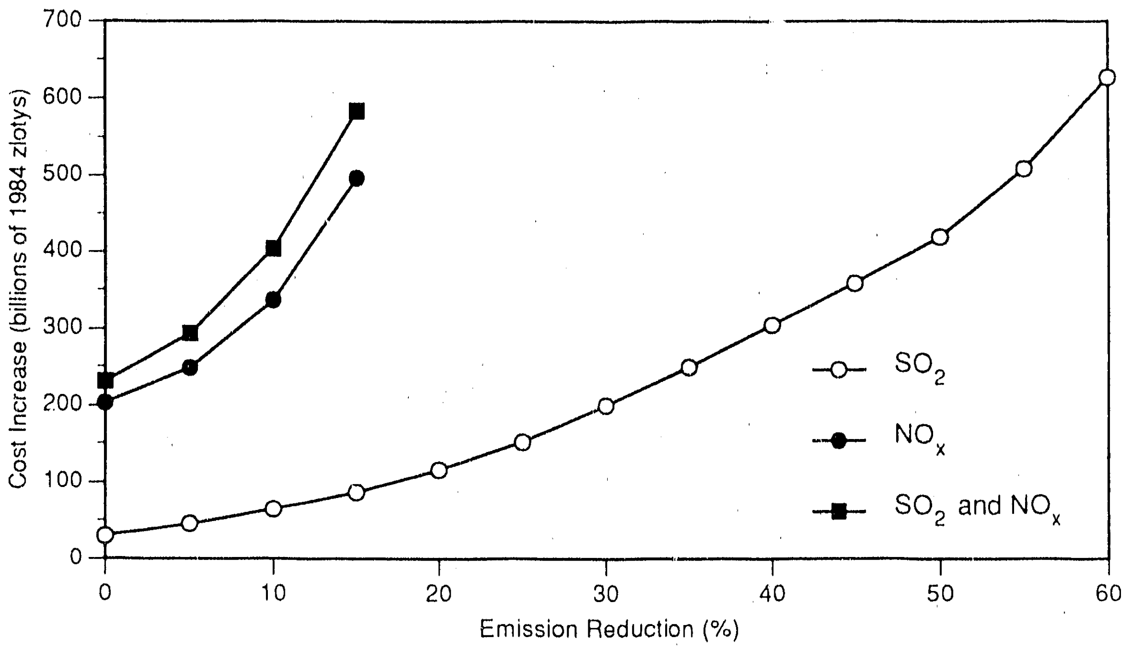

FIGURE 26.1 Costs for Reducing SO_2 and NO_x Emissions in 2000-2010 (discounted costs)

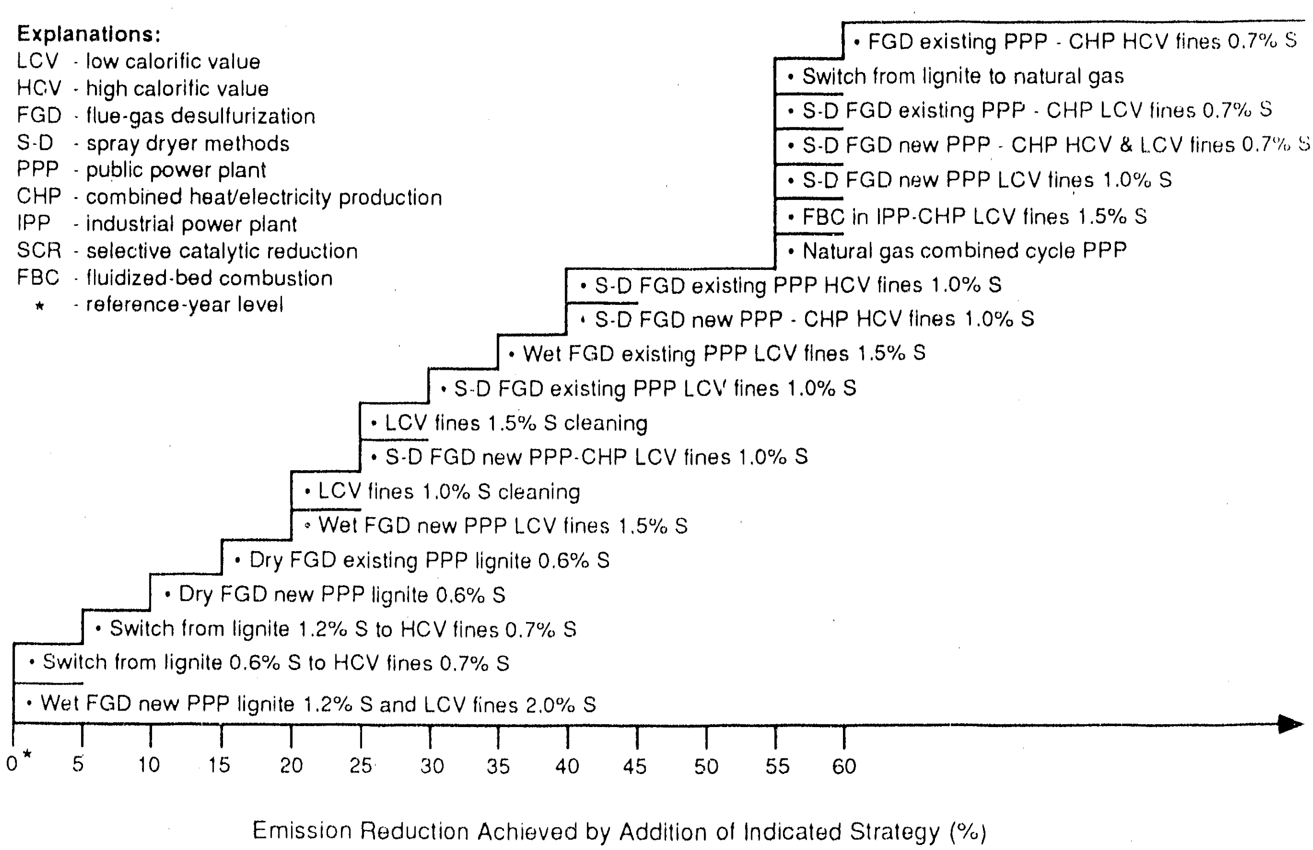

FIGURE 26.2 Cost-Efficient Strategies for SO_2 Reduction

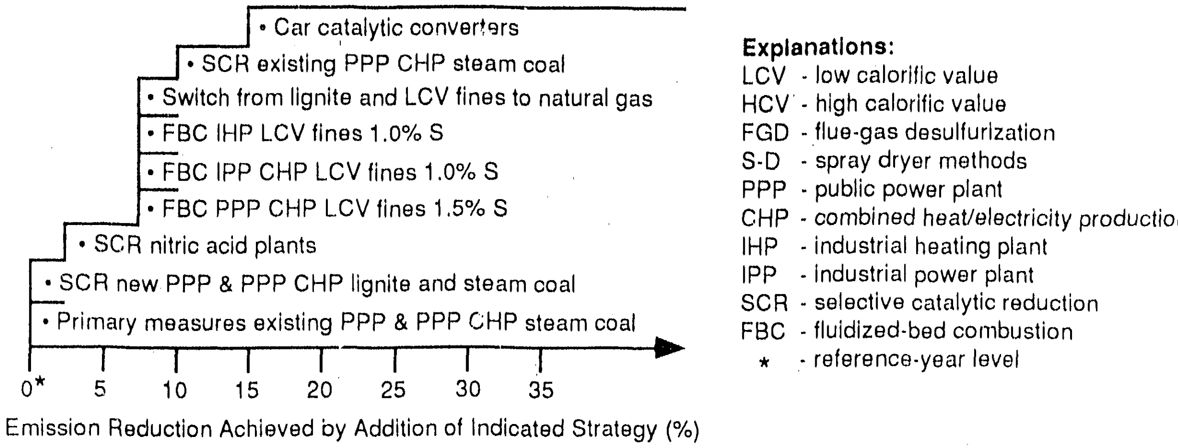

FIGURE 26.3 Cost-Efficient Strategies for NO_x Reduction

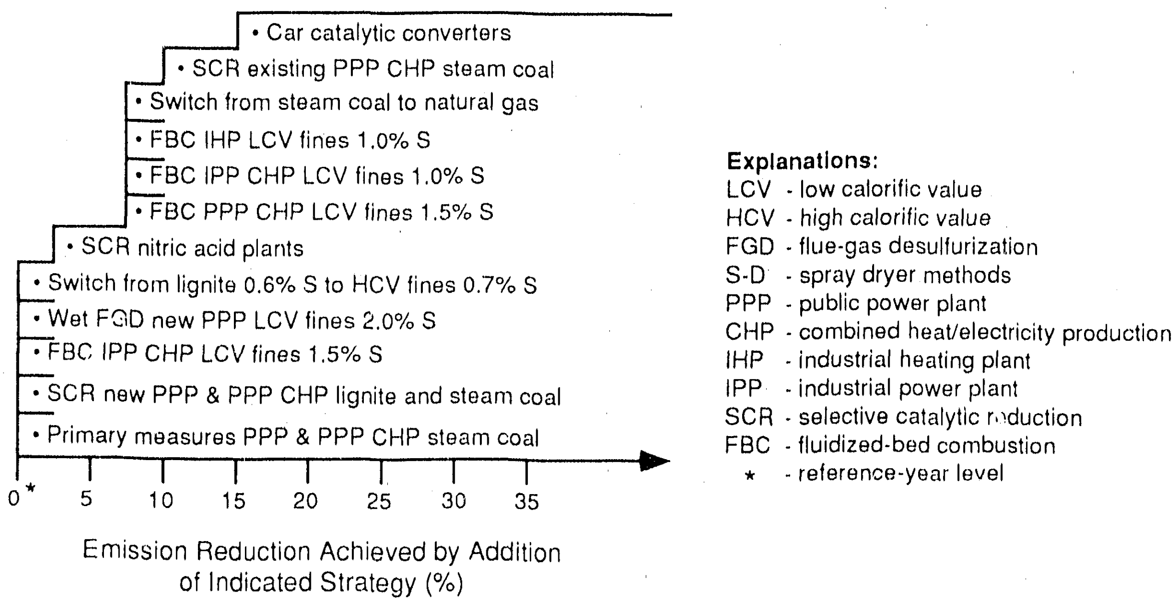

FIGURE 26.4 Cost-Efficient Strategies for SO_2 and NO_x Reduction

At present, Poland is at a turning point. The period is one of deep-reaching changes that are affecting its whole economic system as it changes from a centrally planned to a free-market economy. The introduction of consistent and reasonably coherent reform measures in the national economy was, in fact, started only in the middle of 1989. This effort clearly revealed a far-reaching imbalance in all realms of the national economy. Because of it, almost all the numbers cited in this chapter (economic growth projections, energy sector expansion, and the resulting SO_2 and NO_x emissions) are already out of date. Thus, the step functions shown in Figs. 26.2-26.4 should be worked out for the new economic and energy projections as well as the reduction cost curves. The differences in SO_2 and NO_x emission estimates between the latest results (Cofala, Parczewski, and Umer 1990) and results obtained in past investigations (Cofala, Balandynowicz, and Parczewski 1989) are significant.

It should be noted that the SPSEK-E model set is fairly aggregated and does not use plant-specific data. This fact is of special importance wh n one is analyzing the retrofit of existing plants with emission control equipment. Therefore, the results of the model should be treated as a first approximation only. More detailed studies should be performed on a plant-by-plant basis for major energy consumers. Such a study for public utilitie. has been proposed by the World Bank; as of yet, the work is not very advanced.

27 FINANCING OPTIONS

No matter how strong the desire and incentives to control emissions of air pollutants are, unless financial resources are available to implement these controls, they will not be initiated. With the Polish economy in the grave state that it is in at present, financial considerations will likely be the major impediment to controlling air pollution. Because Poland is faced with an enormous foreign debt ($40 billion) and skyrocketing inflation, pollution controls have to compete with more basic and essential goods and services. In addition, most of the more effective emission-control technologies must be purchased from Western nations, which require payment in hard currency. Such currency is in extremely short supply in Poland and must be generated through exports of Polish goods to Western countries. Generating hard currency will therefore have to be a major endeavor if pollution controls are to be used.

Financial assistance from Western nations may be one way for Poland to obtain the pollution-control technology it needs. This aid could be in the form of direct monetary aid, pollution-control devices provided at zero or reduced costs, technology transfer and/or expertise that would enable Poland to fabricate pollution-control equipment within the country, and debt-for-nature or debt-for-pollution reduction trade (with neighboring countries). As discussed in Chap. 23 and earlier, the U.S. DOE has already agreed to retrofit a power plant in Krakow with U.S.-supplied coal-related control technology. The money for this project (expected to total $10 million for the first year) is to be provided by A.I.D. as part of President Bush's overall aid package to Eastern Europe. This package, known as the SEED Act of 1989, is expected to provide a total of $100 million for fiscal year 1991 for environmental programs in Eastern Europe (Atlas 1990).

Pledges for environmental assistance from other countries have also been made in the past year, including $65 million from 24 OECD countries, $45 million from Sweden, and $30 million from the Netherlands (JAWMA 1990). Much of this aid has been promised not just on humanitarian grounds but also for the benefit of the purveyor, since emission reductions in Poland would yield far greater returns on investment than would implementing further emission controls within these Western European countries.

Japan, although not providing any direct financial aid, has been studying various pollution-control strategies that might may be applicable to Poland. Norway has recently (1989) entered into a formal agreement to cooperate in research endeavors relating to environmental issues in Poland. In addition, the World Bank is currently considering a $20 million loan to improve the management of Poland's environment, including the monitoring of pollutants and restructuring of the energy sector. In preparation for the latter, energy prices were increased by 600% in January 1990 (Pape 1990).

Although further assistance of this nature would definitely help Poland to improve the quality of its environment, the level of this aid is extremely small relative to the total amount needed to address Poland's environmental problems. This total amount has been estimated to be $20 billion (JAWMA 1990). Thus, other financial measures must be considered if the Polish environment is to be improved. These measures include adopting market-based prices for energy and raw materials through the removal of subsidies. The savings thus generated could be used to subsidize and/or finance pollution-control equipment. This strategy would have the added benefit of encouraging conservation and energy efficiency, thus further reducing emissions of pollutants. Another method to finance pollution-control endeavors would be to heavily tax and fine emissions. This practice would encourage the use of control technologies and provide an incentive for increasing efficiency and conservation. In addition, the revenues generated by these fines and taxes could be used by the government to acquire and/or subsidize pollution-control equipment.

Another manner in which revenue, particularly hard currency, could be generated to obtain pollution-control technology would be to increase exports to Western nations. This increase could involve the production of higher-grade coals to be sold to the West at higher prices or an increase in energy efficiency and conservation efforts, which, in addition to improving environmental quality, would enable Poland to use less coal for domestic consumption and thus have more to export. Also, Poland could supplement its traditional exports (agricultural products, coal, textiles) with new products. One of these products could be electricity generated from coal-fired plants equipped with pollution-control devices. These latter controls could be purchased through loans that would be repaid in the form of electricity exports to the loan-granting country or by hard currency generated through the sale of this power.

As already described, such a financing strategy involving Sweden and Poland has recently been conceived; Sweden could provide Poland with the expertise and/or loans for power plant control equipment and, in return, could buy the electricity generated by these power plants carried by underground cable across the floor of the Baltic Sea to Sweden. Poland could then use the hard currency generated by the sale of this power to repay its loans. Expansion of such endeavors could eventually increase Poland's hard-currency reserves and allow it to install a significant number of advanced pollution-control devices. This situation would allow Poland to generate power for domestic use without threatening the environment.

Another method whereby Poland could obtain assistance in improving the quality of its environment is through the expansion of private sector investment in its economy. Poland has already initiated a series of programs aimed at restructuring its industries, reforming its monetary system, and adopting a more free-market-oriented economy. It is currently considering a law that would ensure equal treatment of privately owned and state-owned companies. In addition, one of the major objectives of the 1989 SEED Act is to develop the private sector in Eastern Europe and encourage U.S. private-sector involvement in these nations. For fiscal year 1991, the U.S. Congress has appropriated a significant amount of funds specifically for such private-sector development. A variety of programs, agencies, and institutions are involved in this private-sector-related funding; short descriptions of some of these are given below.

1. The Polish-American Enterprise Fund is to receive (along with the Hungarian-American Enterprise Fund) $72.5 million (as mentioned in Chap. 2). This money, to be administered by the U.S. A.I.D., is to be used to provide loans, equity-investment, feasibility studies,

and technical assistance and training to private-sector groups in Poland (and Hungary). This fund represents the primary source of U.S. assistance to the emerging private sector in these countries (Layman and Anderson 1990; U.S. House 1990b).

2. The Overseas Private Investment Corporation (OPIC), an independent government agency, is involved in providing assistance to U.S. businesses investing in Eastern Europe by insuring investment projects against political risks and by financing investment projects through direct loans and loan guarantees. One of OPIC's projects involves managing the Eastern European Growth Fund, which aims to mobilize new economic activity in these nations by stimulating private-sector growth (U.S. Senate 1990).

3. The Trade Credit Insurance Program has been allocated $200 million for the purpose of guaranteeing medium-term loans to Eastern Europe through the Export-Import Bank, also called Eximbank (U.S. Senate 1990). Eximbank finances export sales of U.S. firms and provides direct loans to public and private enterprises in Poland to purchase U.S. goods (Layman and Anderson 1990).

4. An additional $65 million has been appropriated by the U.S. Congress for other private enterprise activities in Eastern Europe (as mentioned in Chap. 2), with much of this funding targeted to "technical assistance and training for development of market-oriented policies, restructuring and creation of financial institutions . . ., creation and management of private business organizations and privatization of State business organizations" (U.S. House 1990b).

All of these programs are designed to foster private initiatives and competition in Poland from both domestic and foreign (U.S.) businesses, with the ultimate goal of enhancing the ability of private enterprise to make its full contribution to the development process. Although some risk is probably involved, particularly in the short term, to investors in Eastern Europe, there is little doubt that these nations offer tremendous opportunities for U.S. businesses, and, in turn, such private-sector investment provides viable financing options for these countries.

28 POLICY IMPLICATIONS

The proposed regulatory changes, and those which have had a place in Poland since the beginning of 1990, are rapidly shifting Poland's economic system to market-based mechanisms. (This process was initiated with measures involving price liberalization, wage controls, exchange-rate liberalization, and the abandonment of output planning and controls.) An eminent feature of this economic system is competition, which generally produces performance that is superior in terms of economic outcomes to that achieved by alternative methods. A major reason for this verdict is that competition generates the appropriate price signals in output and capital markets; these signals, in turn, provide almost all the information needed by competing agents to act optimally.

The new economic policy in Poland has had a dramatic effect. Inflation has been sharply reduced (although has not yet been brought under complete control), while real wages and thus living standards have fallen significantly (approximately 30%), and the unemployment rate has increased to 8% (in some regions, 12-15%). However, internal and external markets are starting to function and economically viable levels of output are being established within the economy. The macroeconomic implications of this new economic policy are as follows:

- Promotion of efficient resource allocation, with prices and competitive behavior as primary tools;
- Reduction of price inflation;
- Release and mobilization of internal and external capital resources; and
- Establishment of mechanisms for the proper reflection of external costs.

This policy's influence on energy sectors allows for these results:

- Achievement of an efficient and secure energy supply;
- Achievement of efficient energy use because opportunity costs are properly reflected in prices;
- Transition to retail price levels, which reflect broader prices for energy;
- Establishment of autonomous enterprises with hard budgets and divestment from state ownership where possible; and
- Inclusion of environmental and social costs of energy production and use in economic decisions.

Of course, this is only the beginning of economic changes in Poland. It must be emphasized that all statistics related to the future of the Polish energy system are very uncertain and can only form a basis for the qualitative strategies being formulated. Because the trends observed in the past are unlikely to continue to prevail in the future, it is impossible to predict the future on the basis of past assumptions. The essence of the current social and economic situation in Poland resides in it breaking with such trends of the past while it passes from a centrally planned to a free-market economy. Yet there is no experience or sound theoretical background throughout the world in that area. Therefore, it is impossible to formulate any sufficiently credible predictions for the future macroeconomic development of Poland, a crucial factor to those who have an influence in determining the demand for power and fuel. Despite that fact, however, any effort to develop scenarios may prove helpful in the formulation of qualitative strategies.

PARTING THOUGHTS

It is hoped that this report will influence the manner in which U.S. government agencies and departments, private industry, and individuals view Poland and its Eastern European neighbors -- not only as an environmental catastrophe in need of urgent attention but also as a challenge and an opportunity to create a prototype of what might be accomplished in the environmental realm in that region by world leaders and others heeding requests for assistance.

It is also expected that this report will demonstrate the magnitude and severity of the current Polish situation (Polska situacja) environmentally and reinforce an intuitively obvious truth -- i.e., that no single entity, group, or government can offer enough assistance (financial, technical, but most importantly, human resources) to Poland and other countries facing similar plights, needed to correct the tragic environmental and health problems that continue to assail these countries.

It is further hoped that this report will help to catalyze a working relationship between U.S. human and technical resources and the great number of educated, talented, and concerned Polish experts -- academicians, analysts, researchers, technologists, engineers, scientists, bureaucrats, and technocrats -- in specific collaborative endeavors to apply modern energy and environmental knowledge.

With the recent passage of the Foreign Assistance Appropriations Act of Fiscal Year 1991, the U.S. A.I.D. Office of Energy is expected to take the lead in a U.S. global warming initiative, which will include expanded programs in energy efficiency, renewable energy, and "least-cost" energy planning. It is hoped that this report will provide a foundation on which the U.S. A.I.D. and its Office of Energy (among others) could build in developing an energy and environmental strategy for Poland. In addition, the authors of this report hope that it will be only one of a number of individual efforts that will spearhead and make up this initiative.

As Poland takes unprecedented steps to become a democratic, market-oriented society, new opportunities are emerging to assist this country in reclaiming its environmental heritage and resource base, which is vital to its successful economic and political transition. With the overwhelming need and potential demand for assistance in Poland, as demonstrated in this report, it is hoped that this report will serve to encourage private investors to leverage their commitment risk and yet participate in expanding trade and investment opportunities in Poland.

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APPENDIX:

PUBLIC POWER STATIONS IN POLAND IN DECEMBER 1986*

*The source of information for this appendix is Buehring (1987).

TABLE A.1 Public Fossil-Fueled and Non-Fossil-Fueled Power Stations

Region and Power Station	Plant Type	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Pro-duction (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
North											
Olowianka	CHP	Coal	29	10 9	2 1	1895	42	17	9,783	9,272	37
Golynia-1	CHP	Coal	30	10	3	1936	35	13	7,530	7,137	48
Golynia-2	CHP	Coal	33	12 10 1	1 2 1	1942	32	11	6,662	6,314	54
Elblag	CHP	Coal	72	25 12 10	2 1 1	1928	161	26	9,631	9,128	37
Bydgoszcz-1	CHP	Coal	14	10 4	1 1	1928	31	25	6,782	6,428	53
Bydgoszcz-2	CHP	Coal	170	55 50 32.5	1 1 2	1974	684	46	4,718	4,472	76
Bydgoszcz-3	CHP	Coal	33	15 12 6	1 1 1	1957	43	15	13,710	12,995	26
Gdansk-2	CHP	Coal	187	55 22	3 1	1970	622	38	5,908	5,600	61
Gdynia-3	CHP	Coal	55	55	1	1975	271	56	5,310	5,033	68
Total North			623		28		1,921	35			

TABLE A.1 (Cont'd)

Region and Power Station	Plant Type	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Production (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
Central											
Zeran	CHP	Coal	250	35 25 15	1 8 1	1954	1,118	51	6,147	5,826	59
Siekierki	CHP	Coal	655	125 120 50 30	1 3 1 4	1961	1,827	32	7,389	7,003	49
Powisle	CHP	Coal	42	32 10	1 1	1904	95	26	5,782	5,480	62
Pruszkow	CHP	Coal	11	11	1	1914	12	12	5,862	5,556	61
Lodz-1	CHP	Coal	60	22 20 18	1 1 1	1907	81	15	6,588	6,244	55
Lodz-2	CHP	Coal	189	32.5 30 25.5 25	1 1 3 2	1958	442	27	6,132	5,812	59
Lodz-3	CHP	Coal	198	55 33	3 1	1968	600	35	4,683	4,439	77
Lodz-4	CHP	Coal	110	55	2	1977	492	51	4,488	4,254	80
Ostroleka-A	CHP	Coal	112	40.5 31 9.5	1 2 1	1956	124	13	10,958	10,386	33
Ostroleka-B	Elec.	Coal	600	200	3	1972	2,375	45	11,512	10,911	31

TABLE A.1 (Cont'd)

Region and Power Station	Plant Type	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Production (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
Bialystok-1	CHP	Coal	2	2	1	1910	>1				
Bialystok-2	CHP	Coal	118	63 55	1 1	1968	455	44	6,216	5,892	58
Belchatow[c]	Elec.	Lignite	3,240	360	9	1981	17,493	62	10,968	10,396	33
Total Central			5,587		57		25,114	51			
<u>South</u>											
Bedzin	CHP	Coal	55	55	1	1913	174	36	7,462	7,073	48
Chorzow	CHP	Coal	92	45 2	2 1	1898	326	40	13,820	13,099	26
Laziska	Elec.	Coal	1,040	200 120	4 2	1917	5,191	57	11,574	10,970	31
Miechowice	Elec.	Coal	165	55	3	1954	321	22	16,865	15,985	21
Szombierki	CHP	Coal	69	35 25 9	1 1 1	1921	87	14	16,524	15,662	22
Zabrze	CHP	Coal	106	35 25 11	2 1 1	1898	311	33	15,181	14,389	24
Halemba	Elec.	Coal	200	50	4	1963	948	54	14,118	13,381	25

TABLE A.1 (Cont'd)

Region and Power Station	Plant Type	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Pro-duction (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
Jaworzno-1	Elec.	Coal	226	35 20 13 88	3 1 1 1	1952	239	12	15,757	14,935	23
Jaworzno-2	Elec.	Coal	350	50	7	1953	916	30	15,129	14,339	24
Jaworzno-3	Elec.	Coal	1,290	215	6	1977	6,139	54	11,501	10,901	31
Lagirza	Elec.	Coal	840	120	7	1963	3,474	47	12,254	11,615	29
Skawina	Elec.	Coal	550	100 50	4 3	1957	2,616	54	13,278	12,585	27
Rybnik	Elec.	Coal	1,600	200	8	1972	9,780	70	11,135	10,554	32
Bielslo Biala	CHP	Coal	126	37 32 25	1 2 1	1960	404	37	8,599	8,150	42
Blachownia	CHP	Coal	281	55 32.5 28.5	4 1 1	1957	1,028	42	13,654	12,941	26
Siersza	Elec.	Coal	740	130 120	2 4	1962	2,820	44	12,392	11,745	29
Krakow Leg	CHP	Coal	510	150 120	1 3	1970	1,611	36	9,531	9,034	38
Total South			8,240		85		36,385	50			

TABLE A.1 (Cont'd)

Region and Power Station	Plant Type	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Production (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
West											
Czechnica	CHP	Coal	142	55	2	1955	804	65	6,789	6,435	53
				32	1						
Wroclaw	CHP	Coal	192	125	1	1962	655	39	6,194	5,871	58
				55	1						
				12	1						
Szczecin	CHP	Coal	55	25	2	1947	116	24	5,342	5,063	67
				5	1						
Pomorzany	Elec.	Coal	120	60	2	1960	463	44	11,214	10,629	32
Gorzow	CHP	Coal	89	32	2	1951	339	43	14,322	13,575	25
				14	1						
				6	1						
				5	1						
Poznan Garb	CHP	Coal	20	13	1	1929	54	31	7,572	7,177	48
				7	1						
Poznan Karolin	CHP	Coal	50	50	1	1975	296	68	5,359	5,079	67
Kalisz	CHP	Coal	10	5	1	1932	8	9	8,047	7,627	45
				3	1						
				2	1						
Dolna Odra	Elec.	Coal	1,880	235	8	1974	7,537	46	10,598	10,045	34
Zielona Gora	CHP	Coal	10	10	1	1974	37	42	5,977	5,665	60
Palnow-1	Elec.	Lignite	1,200	200	6	1967	7,219	69	10,978	10,405	33
Palnow-2	Elec.	Oil	400	200	2	1943	0	0			

TABLE A.1 (Cont'd)

Region and Power Station	Plant Type	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Pro-duction (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
Adamow	Elec.	Lignite	600	120	5	1964	2,742	52	12,954	12,278	28
Konin-1	Elec.	Lignite	343	55	3	1958	1,636	54	14,423	13,670	25
				50	3						
				28	1						
Konin-2	Elec.	Lignite	240	120	2	1964	1,454	69	11,732	11,120	31
Turow	Elec.	Lignite	2,000	200	10	1962	12,001	68	12,453	11,803	29
Total West			7,351		63		35,361	55			
East											
Kozjenice	Elec.	Coal	2,600	500	2	1972	10,127	44	10,716	10,157	34
				200	8						
Stalowa Wola	Elec.	Coal	385	120	2	1938	1,440	43	9,890	9,374	36
				60	1						
				35	1						
				20	2						
				10	1						
Polaniec	Elec.	Coal	1,600	200	8	1979	8,244	59	10,780	10,217	33
Total East			4,585		25		19,811	49			

TABLE A.1 (Cont'd)

Region and Power Station	Plant Type	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Production (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
Nonfossil											
Solina	Hydro/ pumped		136	47 21	2 2	1968	101	8			
Zar	Pumped		500	125	4	1979	694	16			
Dychow	Hydro/ pumped		79	27 26	1 2	1936	81	12			
Zydowo	Pumped		150	50	3	1970	275	21			
Wloclawek	Hydro		163	27.8 24	5 1	1969	636	45			
Zarnowiec	Pumped		680	170	4	1982	1,208	20			
Others			302				758	29			
Total nonfossil			2,010		24		3,753	21			
All plants			28,396		282		122,345	49			

[a]Capacity factor = MWh electricity produced/(MW electricity capacity × 365 days × 24 hours).

[b]Efficiency = heat rate/(3600 kJ/kWh). Note that in some CHP plants, where production of the thermal energy is the primary function and electricity is generated as a by-product and is delivered to the electrical grid, the efficiency associated with the electrical generation can be as high as 80%.

[c]By 1988, the full complement of lignite-fired units at Belchatow became operational, with 12 units at 360 MW each.

TABLE A.2 Public Fossil-Fueled Electricity-Generation Stations

Region and Power Station	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Production (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
Central										
Ostroleka-B	Coal	600	200	3	1972	2,375	45	11,512	10,911	31
Belchatow[c]	Lignite	3,240	360	9	1981	17,493	62	10,968	10,396	33
Total Central		3,840		12		19,868	59			
South										
Laziska	Coal	1,040	200 120	4 2	1917	5,191	57	11,574	10,970	31
Miechowice	Coal	165	55	3	1954	321	22	16,865	15,985	21
Halemba	Coal	200	50	4	1963	948	54	14,118	13,381	25
Jaworzno-1	Coal	226	35 20 13 88	3 1 1 1	1952	239	12	15,757	14,935	23
Jaworzno-2	Coal	350	50	7	1953	916	30	15,129	14,339	24
Jaworzno-3	Coal	1,290	215	6	1977	6,139	54	11,501	10,901	31
Lagirza	Coal	840	120	7	1963	3,474	47	12,254	11,615	29
Skawina	Coal	550	100 50	4 3	1957	2,616	54	13,278	12,585	27
Rybnik	Coal	1,600	200	8	1972	9,780	70	11,135	10,554	32

TABLE A.2 (Cont'd)

Region and Power Station	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Pro-duction (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
Siersza	Coal	740	130 120	2 4	1962	2,820	44	12,392	11,745	29
Total South		7,001		60		32,444	53			
<u>West</u>										
Pomorzany	Coal	120	60	2	1960	463	44	11,214	10,629	32
Dolna Odra	Coal	1,880	235	8	1974	7,537	46	10,598	10,045	34
Palnow-1	Lignite	1,200	200	6	1967	7,219	69	10,978	10,405	33
Palnow-2	Oil	400	200	2	1943	0	0			
Adamow	Lignite	600	120	5	1964	2,742	52	12,954	12,278	28
Konin-1	Lignite	343	55 50 28	3 3 1	1958	1,636	54	14,423	13,670	25
Konin-2	Lignite	240	120	2	1964	1,454	69	11,732	11,120	31
Turow	Lignite	2,000	200	10	1962	12,001	68	12,453	11,803	29
Total West		6,783		42		33,052	56			
<u>East</u>										
Kozjenice	Coal	2,600	500 200	2 8	1972	10,127	44	10,716	10,157	34

TABLE A.2 (Cont'd)

Region and Power Station	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Production (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
Stalowa Wola	Coal	385	120	2	1938	1,440	43	9,890	9,374	36
			60	1						
			35	1						
			20	2						
			10	1						
Polaniec	Coal	1,600	200	8	1979	8,244	59	10,780	10,217	33
Total East		4,585		25		19,811	49			
All plants		22,209		139		105,175	54			

[a]Capacity factor = MWh electricity produced/(MW electricity capacity × 365 days × 24 hours).

[b]Efficiency = heat rate/(3600 kJ/kWh).

[c]By 1988, the full complement of lignite-fired units at Belchatow became operational, with 12 units at 360 MW each.

TABLE A.3 Public Fossil-Fueled Combined Heat and Power (CHP) Stations

Region and Power Station	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Production (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
North										
Olowianka	Coal	29	10 9	2 1	1895	42	17	9,783	9,272	37
Golynia-1	Coal	30	10	3	1936	35	13	7,530	7,137	48
Golynia-2	Coal	33	12 10 1	1 2 1	1942	32	11	6,662	6,314	54
Elblag	Coal	72	25 12 10	2 1 1	1928	161	26	9,631	9,128	37
Bydgoszcz-1	Coal	14	10 4	1 1	1928	31	25	6,782	6,428	53
Bydgoszcz-2	Coal	170	55 50 32.5	1 1 2	1974	684	46	4,718	4,472	76
Bydgoszcz-3	Coal	33	15 12 6	1 1 1	1957	43	15	13,710	12,995	26
Gdansk-2	Coal	187	55 22	3 1	1970	622	38	5,908	5,600	61
Gydnia-3	Coal	55	55	1	1975	271	56	5,310	5,033	68
Total North		623		28		1,921	35			

TABLE A.3 (Cont'd)

Region and Power Station	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Pro-duction (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
Central										
Zeran	Coal	250	35	1	1954	1,118	51	6,147	5,826	59
			25	8						
			15	1						
Siekierki	Coal	655	125	1	1961	1,827	32	7,389	7,003	49
			120	3						
			50	1						
			30	4						
Powisle	Coal	42	32	1	1904	95	26	5,782	5,480	62
			10	1						
Pruszkow	Coal	11	11	1	1914	12	12	5,862	5,556	61
Lodz-1	Coal	60	22	1	1907	81	15	6,588	6,244	55
			20	1						
			18	1						
Lodz-2	Coal	189	32.5	1	1958	442	27	6,132	5,812	59
			30	1						
			25.5	3						
			25	2						
Lodz-3	Coal	198	55	3	1968	600	35	4,683	4,439	77
			33	1						
Lodz-4	Coal	110	55	2	1977	492	51	4,488	4,254	80
Ostroleka-A	Coal	112	40.5	1	1956	124	13	10,958	10,386	33
			31	2						
			9.5	1						

TABLE A.3 (Cont'd)

Region and Power Station	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Production (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
Bialystok-1	Coal	2	2	1	1910	>1				
Bialystok-2	Coal	118	63 55	1 1	1968	455	44	6,216	5,892	58
Total Central		1,747		45		5,246	34			
South										
Bedzin	Coal	55	55	1	1913	174	36	7,462	7,073	48
Chorzow	Coal	92	45 2	2 1	1898	326	40	13,820	13,099	26
Szombierki	Coal	69	35 25 9	1 1 1	1921	87	14	16,524	15,662	22
Zabrze	Coal	106	35 25 11	2 1 1		311	33	15,181	14,389	24
Bieslo Biala	Coal	126	37 32 25	1 2 1	1960	404	37	8,599	8,150	42
Blachownia	Coal	281	55 32.5 28.5	4 1 1	1957	1,028	42	13,654	12,941	26
Krakow Leg	Coal	510	150 120	1 3	1970	1,611	36	9,531	9,034	38
Total South		1,239		25		3,941	36			

TABLE A.3 (Cont'd)

Region and Power Station	Fuel	Site Size (MW)	Unit Size (MW)	No. of Units	Year of Station Commission	Production (GWh)	Capacity Factor (%)[a]	Heat Rate (kJ/kWh)	Heat Rate (Btu/kWh)	Efficiency (%)[b]
West										
Czechnica	Coal	142	55 32	2 1	1955	804	65	6,789	6,435	53
Wroclaw	Coal	192	125 55 12	1 1 1	1962	655	39	6,194	5,871	58
Szczecin	Coal	55	25 5	2 1	1947	116	24	5,342	5,063	67
Gorzow	Coal	89	32 14 6 5	2 1 1 1	1951	339	43	14,322	13,575	25
Poznan Garb	Coal	20	13 7	1 1	1929	54	31	7,572	7,177	48
Poznan Karolin	Coal	50	50	1	1975	296	68	5,359	5,079	67
Kalisz	Coal	10	5 3 2	1 1 1	1932	8	9	8,047	7,627	45
Zielona Gora	Coal	10	10	1	1974	37	42	5,977	5,665	60
Total West		568		21		2,309	46			
All plants		4,177		119		13,417	37			

[a] Capacity factor = MWh electricity produced/(MW electricity capacity × 365 × 24 hours).

[b] Efficiency is the heat rate/(3600 kJ/kWh). Note that in some CHP plants, where production of the thermal energy is the primary function and electricity is generated as a by-product and is delivered to the electrical grid, the efficiency associated with the electrical generation can be as high as 80%.

[c] By 1988, the full complement of lignite-fired units at Belchatow became operational, with 12 units at 360 MW each.

The Office of Energy

The Agency for International Development's Office of Energy plays an increasingly important role in providing innovative approaches to solving the continuing energy crisis in developing countries. Three problems drive the Office's assistance programs: high rates of energy and economic growth accompanied by a lack of energy, especially power in rural areas; severe financial problems, including a lack of investment capital, especially in the electricity sector; and growing energy-related environmental threats, including global climate change, acid rain, and urban air pollution.

To address these problems, the Office of Energy leverages financial resources of multilateral development banks such as The World Bank and the InterAmerican Development Bank, the private sector, and bilateral donors to increase energy efficiency and expand energy supplies, enhance the role of private power, and implement novel approaches through research, adaptation, and innovation. These approaches include improving power sector investment planning ("least-cost" planning) and encouraging the application of cleaner technologies that use both conventional fossil fuels and renewable energy sources. Promotion of greater private sector participation in the power sector and a wide-ranging training program also help to build the institutional infrastructure necessary to sustain cost-effective, reliable, and environmentally-sound energy systems integral to broad-based economic growth.

Much of the Office's strategic focus has anticipated and supports recently-enacted congressional legislation directing the Office and A.I.D. to undertake a "Global Warming Initiative" to mitigate the increasing contribution of key developing countries to greenhouse gas emissions. This strategy includes expanding least-cost planning activities to incorporate additional countries and environmental concerns, increasing support for feasibility studies in renewable and cleaner fossil energy technologies that focus on site-specific commercial applications, launching a multilateral global energy efficiency initiative, and improving the training of host country nationals and overseas A.I.D. staff in areas of energy that can help to reduce expected global warming and other environmental problems.

To pursue these activities, the Office of Energy implements the following seven projects: (1) The Energy Policy Development and Conservation Project (EPDAC); (2) The Biomass Energy Systems and Technology Project (BEST); (3) The Renewable Energy Applications and Training Project (REAT); (4) The Private Sector Energy Development Project (PSED); (5) The Energy Training Project (ETP); (6) The Conventional Energy Technical Assistance Project (CETA); and (7) its follow-on Energy Technology Innovation Project (ETIP).

The Office of Energy helps set energy policy direction for the Agency, making its projects available to meet generic needs (such as training), and responding to short-term needs of A.I.D.'s field offices in assisted countries.

Further information regarding the Office of Energy's projects and activities is available in our Program Plan, which can be requested by contacting:

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