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ENERGY EFFICIENCY AUDIT REPORT
WLOCLAWEK NITROGEN PRODUCTION FACILITY
COGENERATION PLANT

Zaklady Azotowe "Wloclawek"
Wloclawek, Poland

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List of Acronyms/Abbreviations

A.I.D.	U.S. Agency for International Development
BTU	British Thermal Unit
IRG	International Resources Group
GJ	giga-joule
kWh	kilowatt hours
MPa	millipascale
MW	megawatts
MWh	megawatt hours
m^3	cubic meters
PPM	parts per million
psi	pounds per square inch
PVC	poly vinyl chloride
zł	złotys; unit of Polish currency

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The IRG Industry Energy Audit Team for Poland wishes to express sincere thanks to the plant management and technical personnel for the valuable time and effort spent in preparing for the audit visit to the plant. The cooperation shown by the plant facilitated the communication and exchange of ideas and experiences in the area of energy management. IRG also would like to thank the U.S. Agency for International Development, European Development Resources, Office of Energy and Infrastructure for coordinating the entire project.

It is the hope of the Audit Team that the exchange established through this initiative be maintained in the future.

PREFACE

In the wake of the political and economic collapse of the Soviet Union, the nations of Central and Eastern Europe confront an energy situation for which there is no historical precedent. Overnight long-standing supply agreements for oil, natural gas and electricity supplies from the Soviet Union have been curtailed or discarded with attendant dramatic increases in the prices of these commodities. In addition, as the veil of secrecy has been lifted in these nations, the devastating legacy of years of neglect of coal and other fossil fuel pollution and an aging, largely unsafe, and unregulated nuclear power industry are vital issues that need to be addressed in light of the fundamental structural reform of these Central and Eastern European economies. Democracy for these countries means change amidst great political and economic uncertainly.

To support the transition from Soviet-based dependence to democracy, based on free market principles, the United States, in 1989, instituted a program to assist the countries of Central and Eastern Europe with humanitarian aid, technical assistance and direct economic aid. The U.S. focused initially on Poland and Hungary, where this transition was in its most advanced stages. Since that initial commitment to Poland and Hungary, the U.S. has expanded its focus to include Czechoslovakia, Bulgaria, Romania and Yugoslavia as technical assistance recipients in Eastern and Central Europe. In the future, large scale assistance is likely to be given to the Baltic States, Estonia, Latvia and Lithuania, as well as the republics of the former Soviet Union -- and possibly Albania.

Grants and other assistance to Central and Eastern Europe already account for a U.S. commitment of $1.5 billion since 1989. In Fiscal Year 1991, alone, grant assistance to the region totaled about $450 million. Many of these special assistance grants were funded through the U.S. Agency for International Development, with implementation assistance by various U.S. agencies and private sector organizations.

One important initiative under the U.S. technical assistance program was the U.S. Agency for International Development Emergency Energy Program for Eastern and Central Europe, Component #1: Industrial Energy Efficiency Improvement. This program was designed to address regional energy sector problems on a short-term basis and to identify and implement energy efficiency initiatives. This effort combined in-plant, on-the-job training with identification and implementation of energy management practices and low-cost measures to be implemented during the period of the contract work. This report outlines the activities of the Industrial Energy Efficiency Improvement project in one plant in Poland.

The purpose of the Industrial Energy Efficiency work was to improve in the short-term the efficiency of energy use by industry. Specific objectives included:

1) fostering improved management of energy use in industrial plants by identifying and implementing immediately cost-effective "low cost/no cost" energy efficiency improvements;

2) transferring energy auditing and management techniques including financial and economic analysis techniques; and

3) providing equipment to implement low-cost options, to improve monitoring and energy management, and to identify additional energy efficiency opportunities.

To accomplish these objectives the following actions were undertaken:

1) Eight industrial facilities were selected as target plants for audits. The plants were selected on the basis of:

- potential for significant energy savings;
- the likelihood that the plants will continue operating in the new economic climate;
- applicability of results to similar plants in Poland to which the energy conservation measures developed in this program could be applied.

2) Two Audit Teams went to Poland on two separate occasions, each Team visiting four or five plants to perform energy audits and conduct training.

3) The Teams identified, specified, and procured energy efficiency equipment to be used by the plants to implement short-term energy efficiency improvements.

4) Representatives of the Audit Teams returned to the plants in October 1991 to assist in implementation of the audit recommendations, and to monitor the energy improvements actually achieved.

5) The Teams presented a wrap-up workshop for plant managers and technical staff of the participant plants and other similar plants throughout the country. The seminar was held in Warsaw October 8-9, 1991.

The Industry Audit Team audited four plants **(Figure 1)**:

Huta Ostrowiec, Steel Plant - Ostrowiec-Swietokrzyska
Zaklady Azotowe Wloclawek, Nitrogen Plant - Wloclawek
Zaklady Azotowe Kedzierzyn - Kedzierzyn-Kozle
Cement Plant Wierzbica - Wierzbica

The Audit Team collected data at every plant on the costs of producing steam and electricity, primarily using plant records, audit measurements, and interviews with plant officials. In some cases, the Audit Team counselled the plants in the establishment of systems for cost accounting in the plant, particularly where it related to energy costs per unit of output. The Industrial Energy Efficiency activities had tremendous success and generated letters of support from several plant managers.

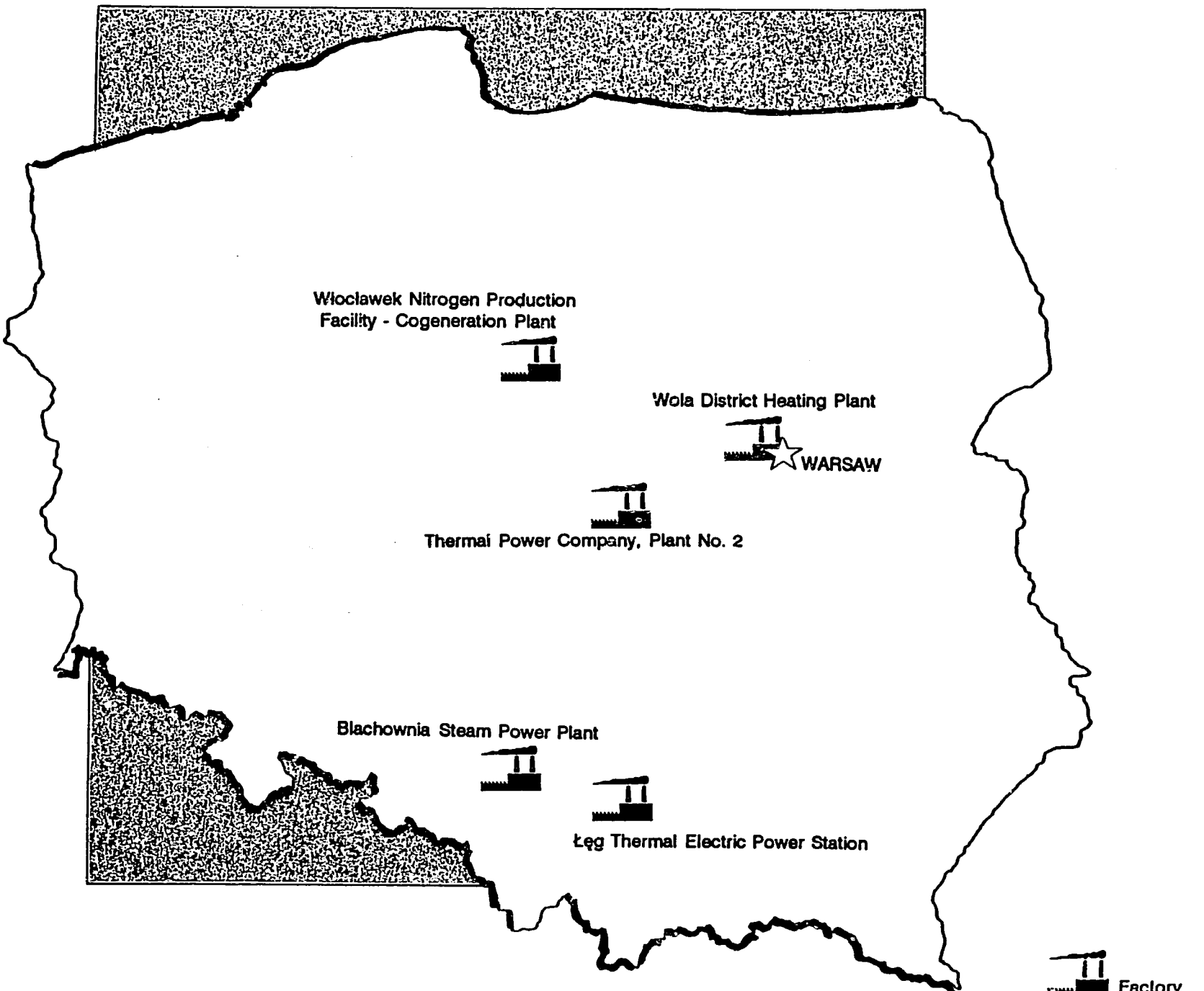

Figure 1 Location of plants audited by the IRG team

Program Rationale

While this program was clearly a logical starting point for improved energy use patterns, it is only a beginning. Although all activities under the Industrial Energy Efficiency project were conducted using a relatively small budget for equipment purchases, the energy savings results were significant. Thus, the program demonstrated the tremendous potential for energy savings through low cost and no cost mechanisms. Moreover, these programs represented important energy savings initiatives that were implemented on a timely basis, within a matter of months.

These initiatives should serve as a cornerstone for a new way of approaching energy savings in Poland. They represent the lowest cost and most readily implemented energy savings initiatives available. Furthermore, the energy savings techniques/measures identified and implemented in this Emergency Energy Program should be applicable to other similar facilities and process units throughout Poland. As a result, these low cost techniques for improving energy efficiency, and thereby improving economic efficiency in industrial facilities, should serve as a model for restructuring energy use in the Polish industrial sector.

The project also highlighted a number of issues that fundamentally affect the ability of industrial entities to solve energy problems. Basic issues such as industrial energy pricing, environmental regulation, legal reforms, corporate organization and management structure, personnel training, and the overall economic environment all affect the ability of industrial concerns to implement energy savings opportunities. Thus, the Industrial Energy Efficiency Improvement project attempted to address issues of micro-level plant organization and management, training, and economic evaluation at each of the plants. In addition, the IRG Team has outlined key macro-level issues which must be addressed by the Government of Poland before comprehensive energy efficiency initiatives are enacted. These issues are addressed in this report as well as in Industrial Profile Report and the Policy and Institutional Analysis Report for Poland, both prepared as part of the Industrial Energy Efficiency Improvement project.

Ultimately, the IRG Team is convinced that the overwhelming potential for energy and cost savings in the Polish industrial sector will provide sufficient incentive for plant managers and industrial executives to actively promote the need for reforms that encourage energy conservation and improved economic efficiency.

1. EXECUTIVE SUMMARY

As part of the U.S. Agency for International Development (A.I.D.)-funded Emergency Energy Program for Eastern and Central Europe, the International Resources Group (IRG) Cogeneration Audit Team visited Poland in April 1991 to conduct an energy efficiency audit of the cogeneration plant at the Wloclawek Nitrogen Production Facility. The overall purpose of the audit was to assist plant personnel in identifying low- and no-cost opportunities for improving energy efficiency. In addition, the Audit Team trained key plant personnel in modern methods of energy management as practiced in the United States.

The Wloclawek Nitrogen Production Facility was chosen for the Industrial Energy Efficiency Improvement project based on assessments by the project definitional team, which included IRG Vice President Charles Ebinger and IRG Team Leader Gerald Decker. The Team evaluated the following issues to decide which plants to include in the project:

- potential for energy savings, from low cost or no cost activities;
- overall economic status (i.e., would the plant survive removal of price subsidies and/or privatization?); and
- replicability of the project activities and experiences at similar plants throughout Poland.

Because the Nitrogen Plant was perceived to be an outstanding model for how to operate a successful industrial facility with a cogeneration power facility, both the IRG Industrial and Cogeneration Audit Teams visited this plant. This report includes the audit results of the cogeneration plant at Wloclawek, while results of the production facility audit are presented in a separate document.

Following the April 1991 visit, the IRG Cogeneration Audit Team returned to the U.S. and arranged the procurement of equipment to be used by Wloclawek to implement the low-cost/no-cost energy efficiency initiatives identified. After the equipment was ordered and shipped, the Team returned to Poland in October 1991 to learn what progress Wloclawek had made in implementing the recommendations. Discussions focused on some of the no-cost/low-cost recommendations made by the Team.

The Team's overall goal in conducting these activities was to identify short-term and longer-term energy conservation opportunities; develop estimates of the quantities of energy that could be saved; estimate the costs of energy lost; conduct a seminar on energy conservation for plant staff; and to train seminar participants in the use of the energy measurement instruments brought from the United States.

To accomplish these objectives, Team members attempted to accumulate sufficient data at each plant visited to make informed decisions regarding opportunities for improving energy efficiency. Data were collected from several sources, including plant instrumentation, field measurements (using a portable Enerac 2000 stack gas analyzer purchased for the project), plant records, independent reports, and interviews of plant operating personnel. Detailed information regarding measurements taken during the audit and general plant statistics are presented in **Appendix III**.

1.1 Plant Background

Wloclawek is a large chemical complex built between 1971 and 1983 which produces chlorine, ethylene dichloride, chlorinated solvents, vinyl chloride monomer, polyvinyl chloride, ammonia, nitric acid, and ammonium nitrate. This integrated plant also produced a number of finished products for use within the plant, including polyethylene bags, oxygen, nitrogen, electricity, thermal energy, and carbon dioxide for refrigeration.

At the time of audit, the price of electricity from the Polish grid was so low [250 złotys (zł) per kilowatt hour (kWh)] that Zakłady Azotowe bought most of its electricity from the grid, despite the fact it had the capacity to produce all its own electricity needs.

In 1990, the cogeneration plant consumed 149,274 tons of fuel oil No. 3, 24,093 tons of coal tars, and 18,907,200 cubic meters (m^3) of natural gas. During this same year, the plant produced 4,417,600 GJ of thermal energy (about 47% of boiler capacity), and 190,000 MWh of electricity (about 22% of turbine capacity). In addition, Zakłady Azotowe purchased 390,000 MWh of electricity from the Polish grid.

Low-cost opportunities for energy conservation principally involved improvements in combustion efficiency, thermal energy use, steam recovery, and general plant housekeeping and maintenance. In addition, the Team recommended strategic, operational, and management changes, to improve the plant's overall economic status.

Since the five plants visited by the Cogeneration Audit Team had many similarities, it was useful for the Audit Team to develop comparative information on the plants; tables presenting this data are included in **Appendix III**. These tables outline boiler operating conditions, distribution of costs of production, specific heat consumption to produce electricity and thermal energy, coal pricing, fuel oil pricing, and personnel/functional structures.

1.2 Results of the Emergency Energy Program

As part of the audit process, the Team recommended several prices of equipment be purchased under the Emergency Energy Program. Items included:

- Infrared Thermometer
- In-Situ Oxygen Analyzer
- Steam Traps

These recommendations are summarized below in **Table 1**; this table also summarizes the estimated energy savings for each item, a key criterion used in recommending the purchase of specific equipment. Given the need for high impact energy savings results, all equipment purchased had payback periods of one year or less. In addition, special attention was given by the IRG Team to procuring equipment that would produce energy savings results that could be replicated in plants throughout Poland. Thus, the Team focused on steam systems, combustion systems, and heat losses, areas in which most plants in Poland would be deficient.

Table 1. Equipment Procured under the A.I.D. Emergency Energy Program

Equipment Item	Cost	Annual Savings	Type of Savings	Payback Period (yrs)	Fuel Oil * (tons)
Infrared Thermometer	$427	$1,700	steam	0.25	23
In-situ O_2 Analyzer	$28,197	$77,400	combustion	0.36	1045
Steam Traps	$2,619	$34,000	steam	0.08	460
TOTAL	$31,243	$113,100			1528

* In October 1991, the price for Polish fuel oil no. 3 was approximately $74/ton.

Unlike many other technical assistance projects, the Industrial Energy Efficiency Improvement project was an action-oriented initiative designed to demonstrate the potential for energy savings in Poland by actually implementing energy efficiency projects in selected facilities. This report, prepared as a part of the Industry Energy Efficiency project, is intended to provide the reader with a background against which to view the actions implemented under this report project. Thus, this outlines the observations, comments, and recommendations of the Audit Team gathered during the initial plant audit in April 1991, and from subsequent discussions with plant managers.

To allow a more comprehensive evaluation of the results, specific project results will be presented in the summary reports for the project. This Energy Efficiency Audit Report focuses on the costs, benefits, and problems associated with each energy efficiency option. In addition, the report briefly outlines management, training, policy, and institutional factors that affect the ability of plants to achieve energy efficiency improvements.

2. PLANT PERSPECTIVE

2.1 General Background

Wloclawek is a large chemical complex located on a 1,100-acre site outside Wloclawek, Poland. Principal products manufactured at this plant are caustic and chlorine, ethylene dichloride, chlorinated solvents, vinyl chloride monomer, polyvinyl chloride (PVC), ammonia, nitric acid, and ammonium nitrate. Approximately 80% of the PVC produced is exported to Germany, England, and the Far East, bringing significant amounts of hard currency to the plant.

The plant is well integrated and also produces a number of products for internal use. These include polyethylene bags, made by extrusion; oxygen and nitrogen; electricity; thermal energy; and carbon dioxide (CO_2) for refrigeration. Supporting operations at the facility include extensive waste treatment facilities, a cogeneration plant, large maintenance shops, drilling station, boiler water treatment, and de-mineralized water production. Plant management also plan to add a urea-production facility in the future.

In addition to the cogeneration plant, Wloclawek has eight small turbines and four waste heat boilers which utilize waste heat and process steam to generate electricity or thermal energy for use in the individual production plants. These smaller units are located in various chemical production units, and operate independently of the cogeneration plant.

Wloclawek was the best-managed and operated plant the Audit Team encountered in Poland. All facilities were well maintained, and the housekeeping was quite good. Personnel were well-trained and had strong technical backgrounds; at the time of audit, the plant employed 4,100 people, 290 of whom work in the cogeneration plant.

In October 1991, the price of electricity from the Polish grid was so low (250 złotys/kWh) that Wloclawek purchased most of its electricity from the grid, even though it had the capacity to produce all its own electricity needs. This audit report focuses on the cogeneration aspects of the facility, while the IRG Industry Audit Team report focuses on its nitrogen-production facilities.

2.2 Plant Statistics

The fertilizer plant was built in 1971, the PVC complex was added in 1977-83, and the cogeneration plant was constructed in 1979. The cogeneration facility included three boilers with a total capacity of 750 tons/hour of steam and three turbine/generator sets with a total capacity of 125 MW. There were also plans to add a fourth boiler with capacity to produce 230 tons/hour of steam.

No electricity from this facility was sold to the Polish grid at the time of audit, nor had any electricity sales occurred historically. Although no thermal energy was ever supplied to the local district heating system, a small quantity of steam had been sold to a few industrial customers located near by.

In 1990, the cogeneration plant consumed 149,274 tons of fuel oil No. 3, 24,093 tons of coal tars, and 18,907,200 cubic meters (m^3) of natural gas. Natural gas consumption comprised less than 10% of the total heating value of the fuel consumed, however.

In 1990, the cogeneration plant produced 4,417,600 giga-joules (GJ) of thermal energy, or approximately 47% of the boiler capacity, and 190,000 megawatt hours (MWh) of electricity, 22% of turbine capacity; in addition, Wloclawek purchased 390,000 MWh from the Polish grid. The low price of electricity from the Polish grid (250 zł/kWh) created a serious anomaly -- Wloclawek, due to its efficient operations, produced electricity as cheaply as any facility in Poland at the time of the audit. Yet in 1990, plant turbines operated at only 22% of capacity since it was cheaper to buy from the grid than to produce electricity at the complex. Subsidies provided for electricity contribute significantly to inefficient energy use in Poland's industrial sector.

2.3 Operating Status of the Nitrogen Plant

The Technical Director of the plant welcomed the Audit Team during their October 1991 visit and thanked them for their previous efforts. The Director commented that the Audit Team recommendations matched Wloclawek's own internal assessments. The most profound effect of the IRG Cogeneration Audit Team visits was that the plant's energy management program subsequently received much stronger support from upper-level staff. Staff intend to continue this energy efficiency program and make it an important part of plant performance indices.

The recession in the Polish economy affected Wloclawek seriously. The nitric acid/nitrogen fertilizers division of the plant was shut down due to lack of demand, since fertilizer use dropped throughout Europe. Sales of PVC resins have also decreased since 1990, with no significant turn-around in the economy foreseen. Thus, the plant will continue to emphasize cost efficiency in all operations, and will be ready to take advantage of any improvement in the economy.

The Chief Power Engineer informed the Audit Team that, on October 1, 1991, the price of electricity from the Polish National Grid increased to 480 zł/kWh for industrial customers and 300 zł/kWh for residential customers. Fuel oil prices in October were about $74.00 per ton. In April 1991, however, the fuel oil price was only $63.00 per ton.

2.4 Supply of Thermal Energy to Wloclawek District Heating System

The plant continued to explore the possibility of supplying a major share of the thermal energy demand of the city of Wloclawek. The 1991 demand on the cogeneration plant was very low -- between 20-25% capacity; at full capacity, the cogeneration plant can produce 200 thermal MW of energy -- equivalent to 680 million BTU/hour. Thus, there is plenty of available capacity to supply the city. At present, Wloclawek operates two small old boilers to provide hot water to the district heating system. The boilers operate at very low efficiency (reported to be less than 60%), and have no pollution controls.

The Chief Power Engineer reported that in August 1991 the plant commissioned a study of the feasibility of supplying thermal energy to Wloclawek; this study was subsequently carried

out by Energoprojekt, a process-design enterprise located in Gliwice. Preliminary results were very good, showing a potential pay-back period of one year. It would be technically simple to tie the city system into the Wloclawek system; however, the present municipally-owned system provides employment to a significant number of people in the city, so changes will be resisted by most of the workers. The political and social problems will undoubtedly be more difficult to resolve than any technical problems.

2.5 Measurements

The IRG Cogeneration Audit Team obtained operating data at Wloclawek by the following means:

a) Visiting control rooms and recording operating data displayed on the various instruments.

b) Using a portable Enerac gas analyzer to measure concentrations of oxygen (O_2), carbon dioxide (CO_2), sulfur dioxide (SO_2), and nitrogen oxide (NO_x) in the flue gas.

c) Using an Omega Infrared Temperature Monitor to spot-check surface temperatures of insulated pipe, exposed surfaces, and operating equipment.

d) Interviewing plant personnel.

e) Observing plant operations.

Measurements on the turbine/generator sets and boilers are included in **Appendix III.** These measurements were used to calculate boiler excess air levels, turbine/generator efficiency, estimated air leaks, heat losses due to inadequate insulation, and operating levels as percent of capacity; this information became the basis for the recommendations proposed by the Audit Team.

Analysis of the measurements and calculations resulted in the following general conclusions:

1. Boilers were operating at excess air levels of 30% to 40%, depressing boiler efficiency by 1% to 2%.

2. Turbine/generator sets were operating at 72% to 76% of total internal thermal efficiency, which a fairly good level.

3. Measurements of O_2 concentrations increased from 3.2% before the pre-heaters to 8.1% after the pre-heaters. This indicates significant air leaks into the system around the preheated area. These concentrations amount to 35-40% by volume of the flue gas. This, in turn, reduces the temperature of the flue gas, resulting in much less transfer of heat to the in-coming air.

4. There were a few instances of inadequate, damaged, or missing insulation throughout the plant.

3. ENERGY MANAGEMENT

3.1 Energy Management Program

Although there was no formal energy committee at Wloclawek, Team members observed a strong commitment to energy conservation on the part of the plant management. Specific energy management initiatives in existence at the plant prior to the Audit included:

- A manager assigned specific responsibility for energy management in each department.
- Specific unit energy and fuel consumption ratios set as annual goals for each product, with progress measured monthly.
- Computers to track energy demand and to balance supply with demand among departments.
- Plant-wide "watt-less power program" to compensate for low power factors, and decrease energy costs.
- Energy consumption continually audited, and the decision to buy or produce electricity determined to maintain the least cost.
- Supervision and staff throughout the plant participating in energy meetings and symposia on a regular basis.
- Hydrogen from the chlorine cells being piped to the ammonia plant for use as a raw material.
- Heat recovery between ammonia reactors improved.

Team members suggested a "theoretical" unit value of energy consumption be calculated for each product to determine the minimum energy necessary. This will help the plant focus efforts on those products where the largest potential energy efficiency gain exists.

3.2 Training and Energy Management Requirements

1. <u>Economics and Project Evaluation</u>

Personnel at Wloclawek, unlike those at most other plants visited by the Audit Team, had some understanding of methods commonly used in the U.S. to evaluate the economic efficacy of energy investment projects. These methods include calculating:

- Return on investment;
- Net present values;
- Discounted cash flow; and
- Sensitivity.

Further training of key personnel in the use of these techniques will help management analyze investment alternatives and prioritize projects.

2. Long-Range Strategic Planning

The officials of Wloclawek had given a good deal of attention to developing a long-range strategic plan. The IRG Cogeneration Audit Team believes additional formal training in strategic planning would enable these plant managers to develop improved and more useful strategic plans. Development of a truly comprehensive long-term strategic plan will require:

- Forecast of demand for electric and thermal energy;
- Analysis of corporate strengths and weaknesses;
- Analysis of competitive influences;
- Definition of alternative possible long-range courses of action; and
- The ability to evaluate alternatives.

Due to the range of operations at Wloclawek, there is a unique opportunity for plant managers to benefit substantially from continued training in strategic planning.

3.3 USAID Sponsored Energy Management Workshop

During his October 1991 visit to Wloclawek, the IRG Team Leader described the Energy Management Workshop to be held in Warsaw on October 8 & 9, 1991. The Workshop was sponsored by the U.S. Agency for International Development with strong support from the Polish Ministry of Industry (Mr. Roman Łuczkiewitz) and the World Bank (Mr. Ian Hume). Three representatives of the Wloclawek plant participated. Upon request of the Team Leader, the Technical Director, agreed to make a brief presentation summarizing the plants experiences with the energy management techniques and equipment purchased through the Emergency Energy Program.

4. ENERGY EFFICIENCY IMPROVEMENT OPTIONS

Opportunities for energy conservation were identified by the Team as a result of Team observations and audit measurements, plant inspections by other organizations (ie. the Institute for Heat Engineering), or through discussions with plant technical personnel and managers. Listed below are options to improve energy efficiency use within the plant. Clearly, all these practices and projects will help conserve energy in the facility. Given the reality of scarce resources for implementing these projects, the IRG Cogeneration Audit Team recommended some be given priority; this prioritization is included in **Section 5**.

This section presents various options discussed during the course of the Industrial Energy Efficiency Improvement Project. These include options proposed by the IRG Team, officials at the plant, and in some cases, those proposed by outside organizations. In this section, the Team intends to present the merits and deficiencies of each proposal. Since the Team did not recommend each proposal be implemented, this section includes caveats about projects the Team did not endorse. Ultimate decisions regarding implementation of alternative options will depend upon the criteria set by the plant management -- including acceptable payback periods -- and upon the overall corporate strategy.

4.1 Short-term Options

For the purposes of this report, "short-term" options refer to "no-cost" items which will not require hard currency, but may require small scale local currency investments, which "low-cost" items may require limited amounts of hard currency. Each of these initiatives should be possible within the existing framework of plant expenditures (ie. zloty purchases, small hard currency purchases, improved maintenance, and housekeeping) and will have rapid payback periods.

1. Increase Fuel Oil Temperature

The temperature of the fuel oil feed to Boiler No. 2 was measured at 125 °C, and the coal tar feed to Boiler No. 3 was measured at 85-90 °C during the audit; the optimum feed temperature is 145 °C. One option would be to have these feed temperatures be increased closer to optimum to use more exhaust heat. This option would not require any investment, and would cause the boiler to operate more efficiently.

2. Identify and Eliminate Excess Air in the Furnaces

The boilers at Wloclawek operate at excess air levels in the range of 25-30%, while efficient operation is usually between 12-20%. Each 5% increase in excess air results in a 0.35% decrease in boiler efficiency. These air levels are high due to unreliable oxygen analyzers. To compensate, the plant is operating on the "safe" side of optimum excess air levels. **Appendix IV** details estimates of costs, benefits, and payback periods that can be realized through the installation of reliable oxygen analyzers.

In addition Team members recommended one continuous oxygen analyzer be purchased and installed on Boiler No. 3 at Wloclawek.

3. install Dew Point Monitor

Due to the high sulfur content of the fuel oil (about 2%), there is a high concentration of SO_2 in the flue gas. Measurements made by the Audit Team on April 25, 1991 were:

Boiler #2:	681-825 ppm SO_2 (before air heater)
	606-611 ppm SO_2 (after air heater)
Boiler #3:	204-210 ppm SO_2 (before air heater)
	30-50 ppm SO_2 (after air heater)

Boiler No. 2 used Polish fuel oil No. 3, and coal tar was used for Boiler No. 3. In Boiler No. 2, the stack gas temperature was 123 °C after the air heater, and in Boiler No. 3 it was 142 °C. At these temperatures, the high concentrations of SO_2 can be corrosive as a result of water vapor in the stack gas.

The Technical Team recommends a device to measure the dew point of the stack gas be installed in Boiler No. 2. The stack gas temperature could then be adjusted to be high enough above the dew point to prevent serious corrosion. The costs, benefits, and estimated payback period for a dew point analyzer are outlined in **Appendix IV**. Briefly, the purchase cost plus installation of one dew point analyzer at Wloclawek is estimated to be less than $25,000; the savings in fuel costs should be at least $63,000/year, with a payback period of five months. Since the three boilers usually burn the same fuel, one dew point analyzer can be used to measure all three stacks, and operating conditions can be adjusted accordingly.

4. Purchase and Install Steam Traps

Wloclawek experiences little difficulty with leakage and failure of steam traps in use on higher pressure steam lines. The present traps were made in Poland, however, and most other plants have experienced leakage problems with them.

The IRG Cogeneration Audit Team believed high quality U.S.-made traps will yield lower maintenance costs and reduced losses; therefore the Team recommended 15 stainless steel inverted bucket steam traps be purchased and installed on appropriate steam lines. The performance of these traps should be monitored; if the improvement is as expected, Wloclawek should begin replacing all questionable steam traps. **Appendix IV** details trap sizes, costs, and estimated payback periods.

5. Repair and Maintain Insulation

Although the insulation throughout the plant appeared to be in good condition, there were a few instances of deteriorated insulation and uninsulated pipes. In one case, surface temperature of exposed pipe and fittings was measured at 180 °C. This can result in losses of about 800-1,000 BTU/hour per square foot of exposed surface, or roughly 4 tons/year of steam per square foot. Effective insulation should reduce this loss by 80-90%.

The Audit Team recommends one Infrared Thermometer be purchased for use in detecting sources of potential heat loss.

6. Eliminate Air Leaks around the Air Pre-Heaters

Measurements indicated there were significant air leaks into the system around the air pre-heaters on Boiler No. 3; these leaks were estimated to be 35-40% of the flue gas, by volume. Similar leakage probably occurs around all air pre-heaters, and may be significantly reducing boiler efficiency.

The Audit Team recommended the plant modify pre-heaters to reduce leaks during regularly scheduled overhauls of the boiler systems. Calculations of benefits should be made prior to implementing this option. However, no additional investments would be required to implement this option.

4.2 Long-term/Capital Intensive Options

1. Install New Boiler No. 4

Wloclawek management plans to add a fourth boiler to the cogeneration plant in the near future. There are no plans to add turbine/generator capacity. The boiler will supply thermal energy only; capacity will be about 230 tons/hour of steam.

The purpose of the new boiler will to:

- assure supply to the Wloclawek nitrogen facility during peak demand periods.
- supply steam and heat (hot water) to industrial customers. Zakłady Azotowe plans to solicit industry to locate nearby.
- supply heat (hot water) to the District Heating System in Wloclawek.

To supply heat to the District Heating System, a significant investment in piping and controls to connect the systems will be required.

The Wloclawek Nitrogen Production Facility's Cogeneration Plant has the managerial and operational skills needed to carry out this program, and could likely finance the project internally if necessary. The project will yield benefits for the city of Wloclawek, since some of the smaller boilers now supplying heat can be shut down.

Team members recommended a thorough economic study be conducted to define and evaluate this project. If the benefits are as great as expected, the project should be supported.

2. Install Oxygen (O_2) Analyzers for all Boilers

If the O_2 Analyzer recommended for purchase under **Section 4.1** has the beneficial results expected and enables the cogeneration plant to operate at lower levels of excess air, O_2

Analyzers should be installed on all boilers in the cogeneration plant--including the planned Boiler No. 4.

Johnson-Yokogawa manufactures a multiprobe analyzer that uses one panel-mounted instrument to service several boilers. The IRG Cogeneration Audit Team recommended the following purchase of:

One panel-mounted instrument ($6,600)
Eight probes ($1,300 each)

Two probes should be installed in each stack. The purchase cost will total $17,000, plus transportation, duties, installation, and other costs. The total should not exceed $30,000 and the benefit should be at least $50,000 (see **Appendix IV**), providing a payback period of about seven months.

3. Supply Electricity to the National Grid

In the long-term, this cogeneration plant may have the option of supplying electricity to the national grid, since it is an efficient producer of electricity. Although current electricity prices are still subsidized, future prices are expected to rise enough to justify increased electricity production. As an efficient and economical producer of electricity, the plant could make some money, and the city would benefit from receiving cheaper electricity. In addition, this option would have environment benefits by eliminating old boilers as sources of pollution. Clearly, however, implementation of this option will involve a number of significant policy decisions, as well as financial investment.

5. RECOMMENDATIONS AND CONCLUSIONS

After the April and October visits to the plant, the only major recommendation of the Audit Team was that international donors such as A.I.D help provide the necessary assistance to link the plant up with the district heating system. The requisite help is largely financial, although costs are relatively low. As soon as the Energoprojekt study is available, A.I.D. and the World Bank should determine if the project qualifies for their funding programs. If it does, funds should be made available as quickly as possible. In the interim, installation of the equipment mentioned in **Section 5.1** below should further improve energy efficiency in the plant.

5.1 Implementation Priorities

Members of the IRG Cogeneration Audit Team recommended the items listed in **Section 4.1** and summarized below be purchased for installation in the cogeneration plant at Wloclawek as part of the Emergency Energy Program. These items include:

	Estimated Purchase Cost	Estimated Savings	Estimated Payback Period*
One Continuous Oxygen Analyzer	$4,437	$16,000/yr.	8 months
One Dew Point Monitor	16,831	$63,000/yr.	5 months
Ten Steam Traps	1,300	$12,000/yr.	3 months
Five Steam Traps	1,590	$12,000/yr.	3 months
One IR Thermometer	895	$ 2,000/yr.	6 months
TOTAL	$25,053		

* Note that the Payback Period is based on an estimate of the installed cost of the equipment, including transportation, inspection, installation, and other expenses, as well as the purchase cost.

Because these items involve relatively short payback periods, Team members recommended all equipment be installed as quickly as possible. There is no particular advantage to be gained by emphasizing one item to the detriment of others.

5.2 Conclusions After Second Visit

As reported in April 1991, Wloclawek is a well-managed and operated plant, comparing favorably with almost any U.S. facility. The managers are competent, workers are knowledgeable and well-trained, and the plant has well-defined objectives for every part of the operation; Funds invested in this facility will be used productively. In addition, the plant had a

good energy conservation program before visits by the IRG Cogeneration Audit Team, and has redoubled its efforts since that time.

Although the plant is suffering from the general recession in the Polish economy, it is efficiently dealing with the downturn, and should be in a good position to take advantage of the turn-around when it comes.

There is little the IRG Team can recommend to this plant that Wloclawek management has not already considered. The primary problem in Wloclawek, as in much of Polish industry, is the lack of capital to finance economically sound investment projects. It is unlikely the plant will be able to generate needed funds domestically in the near future (one to three years). Thus, outside help will be necessary if this excellent plant is to stay abreast of international competition.

APPENDIX I

AUDIT ACTIVITIES

APRIL 1991

At each plant, the Audit Team followed approximately the following procedure:

Day 1 — Presentation by Team of program objectives and goals to plant management and administrators.

- Detailed discussion of plant responses to questionnaire given them in February.
- Quick "get acquainted" tour of facilities.

Day 2 — More detailed tour and inspection of facilities.

- Extensive collection of operating data, both from plant instruments and from portable instruments carried by the Audit Team.

Day 3 — Preparation of preliminary report of findings and recommendations.

Day 4 — Presentation of seminar on "Energy Conservation" by Gerald Decker to 10 - 20 representatives of plant management and operating supervision.

- Presentation and discussion of preliminary report with plant management.
- Transfer to the next facility.

APPENDIX II

MEETING PARTICIPANTS
April, 1991

Zaklady Azotowe Wloclawek

Mr. Ryszard Ścierzyński	Production Director
Mr. Kazimierz Dobisz	Chief of Energy
Mr. Andrej Markiewicz	Technical Director
Mr. Zdzisław Razmuk	Deputy Manager of the Cogeneration Plant
Mr. Edward Cwojdziński	Manager of the Cogeneration Plant
Mr. Wlodzimierz Nowakowski	Plant Engineer

International Resources Group

Mr. Gerald Decker	IRG Team Leader
Dr. Richard Heiny	Engineer
Mr. John Pangborn	Engineer

Energopomiar

Mr. Adam Zemla
Mr. Zdzislaw Gieras

Kompekon Consulting/Independent Consultant

Mr. Boguslaw Pieczyiski	President
Mr. Julian Fortunski	Consultant

Polish Foundation for Energy Efficiency

Dr. Slawomir Pasierb	Assistant Director

APPENDIX III

AUDIT MEASUREMENTS AND COMPARATIVE STATISTICS

From April 23-26, 1991, the Audit Team visited the cogeneration plant of the Wloclavek Nitrogen Production Facility in Wloclawek, Poland. Control measurements taken at the cogeneration plant that are summarized below, specifically referencing to the boilers and turbines in operation. There were two boilers (No. 2 and 3) and one turboset (No. 3.) in operation. The plant was operating in the cogeneration mode, producing both heat and electricity.

AUDIT MEASUREMENTS

A. BOILERS

Boiler Number		K-2		K-3	
Date		24.04	25.04	24.04	25.04
Boiler Output	t/h	110	110	180	175
Feed Water:					
pressure	MPa	14.2	13.6	13.5	13.5
temperature	oC	242	240	200	200
Steam output:					
pressure	MPa	9.4	9.3	9.2	9.2
temperature	oC	500	510	520	500
Before air heater:					
CO_2	%	-	-	13.0	13.6
O_2 L/R	%	-	-	2.8/3.6	3.0/3.2
gas temperature	oC	340/280	350/300	340/400	330/380
After air heater:					
O_2	%	-	-	7.8/8.5	7.5/8.4
gas temperature	oC	140/130	140/140	145/148	140/140
Fuel consumed	t/h	7.2	7.0	14.0	14.2
Number of burners in operation		5	5	6	6
Oil temperature before burners	oC	125	125	90	85
Draft from output	Amps.	-	-	22/22	21/22
gas flow	%	-	-	90/85	72/65
Stack draft	mm/H_2O	+20	+20	-150	-150
Inlet air fan	Amps.	24/32	25/30	148/138	142/138
governing flap	% open	30/35	30/35	85/74	80/72
air flow	10^3 m^3/hr.	56/68	56/66	98/75	80/72.5

B. TURBINES

TURBOSET NO. 3			
Date		24.04.91	25.04.91
Power output	MW	20	20
Inlet steam:			
pressure	MPa	8.8	8.8
temperature	oC	520	500
flow	t/h	170	170
Extracted steam:			
pressure	MPa	1.9	1.9
temperature	oC	260	260
flow	t/h	132	140
Steam temperature after turbine	oC	39	39
Condensate after condenser	oC	38	39
Cooling water temperature:			
inlet	oC	24	25
outlet	oC	30	30.5

Table 1. Boiler Operating Conditions

	Blachownia (Kędzierzyn - Kozle)		Łęg (Kraków)		Plant No. 2 (Łódź)		Wola[1] (Warsaw)		Zakłady Azotowe (Włocławek)	
	Boiler #8	Boiler #12	Boiler #1	Boiler #3	Boiler #3	Boiler #5	Boiler #2	Boiler #4	Boiler#2	Boiler#3
STEAM PRODUCTION:										
Capacity, T/hr.	120	215	380	430	120	140	116 MW_{th}	116 MW_{th}	260	230
Measured, T/hr.	98	158	365	355	100	110	2,450 (68.2 MW_{th})	2,250 80.9 MWth	110	180
Pressure, MPa	8.2	9.5	12.3	12.2	9.6	8.5	1.75	1.81	9.3	9.2
Temperature, °C[2]	480/505	500/495	533/536	535	490	500	103	105	505	510
STACK TEMPERATURE:										
Before heater, °C			540°C	370/390	310°C	290°C			268°C	327°C
After heater, °C	195/185	138/140	135	160/150	207/211	180/182	188	215	123	148
FLUE GAS ANALYSIS (before air heater)										
O_2 [2]	5.2%	3.9%	6.3/4.9	5.5%	5.3%	7.5/6.1	4.7%	7.4%	5.5%	4.8%
CO_2 [2]	12.7%	12.5%	12.5/14.5	15.7%	-	-			12.5%	12.9%
SO_2	10 ppm	77 ppm	-						753 ppm	207 mgm
NO_x	110 ppm	92 ppm	215 ppm						233 ppm	485 mgm
EXCESS AIR LEVEL	31%	23%	37%	35%	34%	48%	29%	54%	35%	29%

(1) Wola capacity is stated in Thermal Megawatts (MW_{th}).
(2) In many boilers there were separate measurements for the left- and right-hand sides of the stacks. In those cases, the two sides are reported as left/right.

Table 2. Distribution of Costs of Production

	Blachownia (Kędzierzyn - Kozle)		Łęg (Kraków)		Plant No. 2 (Łódź)		Wola (Warsaw)		Zakłady Azotowe (Włocławek)	
	Electrical Energy	Thermal Energy	Electrical Energy	Thermal Energy	Electrical Energy	Thermal Energy	Electrical Energy	Thermal Energy	Electrical Energy	Thermal Energy
Fuel	48.3%	50.9%	49.2%	49.2%	35%	35%			60% (?)	54.7%
Electricity	-	7.8%							-	17.7%
Supplies	0.9%	0.8%								
Wages	3.5%	2.9%			5%	5%			1.6%	1.5%
Overhauls	29.8%	23.5%								
Depreciation	5.2%	3.5%							4.9%	10.4%
Environmental	8.6%	7.9%								
Overhead	3.6%	2.7%							0.7%	0.5%
Total	100.0%	100.0%								
Total Cost zł/kWh zł/GJ	230		87		246		351 (purch from grid) 30454		400 (est) 250 (purchased from grid)	
Sales Price zł/kWh	178.5		99		152					
zł/GJ								40,333		

Table 3. Specific Heat Consumption[1] to Produce Electricity and Thermal Energy

	Blachownia (Kędzierzyn - Kozle)	Łęg (Kraków)	Plant No. 2 (Łódź)	Wola[2] (Warsaw)	Zakłady Azotowe (Włocławek)
Unit Energy/kWh	12,516 kj/kWh	9,602 kj/kWh	4,810 kj/kWh[4]		12,210 kj/kWh
Unit Energy/kWh	(11,865 BTU/kWh	9,103 BTU/kWh	4,560 BTU/kWh		11,547 BTU/kWh
Efficiency	28.8%	37.5%	74.8%		29.5%
Unit Energy/GJ	[3]	1,229 MJ/GJ	1,169 MJ/GJ	1,150 MJ/GJ	1,197 MJ/GJ

NOTES:

[1] Data were calculated from average results for 1990.

[2] Wola produces no electricity.

[3] 1990 data were not available

[4] This data for Łódź may be incomplete.

Table 4. Coal Pricing

	Blachownia (Kędzierzyn - Kozle)	Łęg (Kraków)	Plant No. 2 (Łódź)
1990 Price (Average)	73,993 zł/Ton	91,958 zł/T.	
Consumption	771,124 tons	1,156,941 tons	592,680 tons.
Source		6 collieries	3 mines
Heating Value	16,000 - 18,000 kj/kg. (6880 - 7740 BTU/lb.	(17,000-22,000 kj/kg range 19,590 kj/kg average 8760 BTU/lb.)	20-21,000 kj/kg (8,600-9,030 BTU/lb.)
Sulfur Content	0.8%	0.7-0.8%	<1.0%
Ash Content		27.9% (average) (10-32% range)	18%
1991 Prices	200,000 zł./T	139,000 zł/T (Jan.) 160,000 zł/T (Apr.) +35,000 zł/T delivery cost	230,000 zł/T (Feb.) (delivered)
Comments on Purchasing	Prices are increasing about 5% per month. Supply options are limited.	Monthly price increases. Price depends on H.V., % Ash, % S Theoretically, can buy wherever they want. Really, limited choice.	Coal price is increasing about 5%/month

NOTE: These prices were obtained in April, 1991. At that time the conversion rate was about 9,500 zł/$1.00 U.S. By October, 1991, the conversion rate had risen to about 11,100 zł/$1.00 U.S.

Table 5. Fuel Oil Pricing

	Blachownia (Kędzierzyn - Kozle)	Łęg (Kraków)	Plant No. 2 (Łódź)	Wola (Warsaw)	Zakłady Azotowe (Włocławek)
1990 Price (Average)	824,215 zł/T	795,115 zł/T	-	720,349 zł/T (delivered)	800,000 zł/T.
1990 Consumption	4,755 T.	4,825 T.	990 T.	85,157 T.	149,240 T.
Source				Plock	Plock, Gdansk
Heating Value	-	40,328 kj/kg (17,350 BTU/lb.)	40,160 kj/T. (17,270 BTU/lb.)	40,700 kj/kg (17,500 BTU/lb.)	40,700 kj/kg (17,500 BTU/lb.)
Sulfur Content				2%	2%
Pricing history: Sept. 1990 Oct. 1990				400,000 zł/T 1,100,000 zł/T	
Pricing forecast: Feb. 1991 April 1991 Projected			1,380,000 zł/T 800,000 zł/T	1,300,000 zł/T 800,000 zł/T (+ 120,000 zł/T frt.) 700,000 zł/T	1,300,000 zł/T 600,000 zł/T
Possible Future sources	Coal is the primary fuel; fuel oil use is small and not critical	Coal is the primary fuel; fuel oil use is small and not critical	Coal is the primary fuel; fuel oil use is small and not critical	Negotiating with: Astra (U.S.) Netherlands Co. Brokers in Poland $70/T fob port in Poland	Amsterdam proposed $60-70/T.

NOTE: Conversion rate - $1.00 = 9,500 zlotys (April, 1991).

Table 6. Personnel/Functional Structure
(Number of persons employed in each function)

	Blachownia (Kędzierzyn - Kozle)			Łęg (Kraków)			Plant No. 2 (Łódź)			Wola (Warsaw)			Zakłady Azotowe (Włocławek)		
	Total	S	U	Total	S	U	Total	S	U	Total	S	U	Total	S	U
Prod'n Op'ns	200	23	7	435	66	27				63		1	81	8	0
• Turbine							80	9	3						
• Boilers							140	9	4						
• Coal Hdlg.							63	12	2						
• Water Trt.							42	8	1						
Elect. Maint.	97	16	6	146	16	12	82	8	4	26		1	66	7	2
• Elect. Prot.							11	2	1						
Mech. Maint.	153	23	8	520	109	42				15		2	62	7	1
Contr. & Env.	6	-	3				22	2	1	12		1	67	8	1
Transport	15	1													
Purch., Etc.	3		3							14		1			
Institute	5														
Management	3	3	3	15	3	3				6	6	4			
Unaccounted	88			197			250			4			10		
Totals	620	65	30	1,355	213	100	690	50	16	150	?	10	286	30	4
MW Capacity	1220 Th MW (est'd)			2000 Th MW			1050 Th MW (est'd)			580 Th MW			655 Th MW (est'd)		
Pers./MW	0.57			0.68			0.66			0.26			0.44		

S = Supervisory personnel

U = University-trained professionals

APPENDIX IV

JUSTIFICATION FOR PURCHASE OF EQUIPMENT

CONTINUOUS OXYGEN (O_2) ANALYZERS FOR STACK GAS

The Team recommended the installation of reliable continuous O_2 analyzers on boiler stacks so that operating conditions can be adjusted to keep excess air supplied to the boilers at optimum levels. Presently, the boilers at Zakłady Azotowe are operating at excess air levels in the range of 20-30%, when the optimum level is about 15%. With reliable O_2 analyzers the excess air level can be reduced by 5%, resulting in 0.4% improvement in efficiency of boiler operation. At Zakłady Azotowe, fuel consumption per boiler was:

Boiler No. 2	-	7 tons/hour
Boiler No. 3	-	14 tons/hour

Total consumption in 1990 was about 145,000 tons of Fuel Oil No. 3

Current (April, 1991) price for fuel oil was 800,000 zlotys/ton ($84/ton). (When this price is adjusted for quality and heating value, it is within 10% of current U.S. prices). A 5% reduction in excess air level will result in the following estimated savings for Zakłady Azotowe:

0.4% x 145,000 tons/year x $84/ton = $49,000/year

(These are believed to be minimum savings; Zakłady Azotowe may realize more).

Reliable O_2 analyzers including remote reading instruments are available from several U.S. suppliers at prices of $6,000 or less per boiler stack, depending upon the exact model purchased. Shipping and installation will bring the total cost up to a maximum of $10,000 per boiler stack. At $10,000 per stack, the payback period at Zakłady Azotowe is about 7 months.

In addition to the direct economic benefit, there will be a significant environmental benefit, because emissions of NO_x and SO_2 will be reduced. The fuel oil used at Zakłady Azotowe contained 2% sulfur. The savings described above will reduce SO_2 emissions by about:

0.4% x 145,000 x 2% = 12 tons per year of sulfur
or 24 tons per year of SO_2.

The reduction in NO_x emissions will be similar.

Preliminary quotes (not firm or final) for O_2 analyzers suitable for use at Zakłady Azotowe are:

Johnson-Yokogawa	$4,437.00*	
Bailey Controls	3,129.00	
Ametek, Thermox Div.	3,570.00	or
	5,700.00	
Land Combustion	5,092.00	

The Audit Team recommends that one continuous Oxygen Analyzer be purchased for installation in Zakłady Azotowe.

Because of the flexibility of their instruments and the apparent extent of their European service network, the Audit Team recommended that Johnson-Yokogawa be the preferred supplier. However, in the judgment of the Audit Team all the listed suppliers manufacture O_2 analyzers suitable for the intended use in Poland.

* The price given for the Johnson-Yokogawa oxygen analyzer was the basic price for the model recommended. Additional probes and terminals will increase the price.

DEW POINT ANALYZERS FOR STACK GASES:

A number of boilers in Poland are being fired with coal or fuel oil that has a high sulfur content (1% for coal; ≥2% for fuel oil). In those boilers the concentration of SO_2 in the stack gas is so high (in the range of 600 ppm) that condensation may occur at stack gas temperatures reached when trying to operate the boilers at optimum conditions by recovering the maximum amount of heat from the stack gas. When condensation occurs, it is very acidic and corrosive because of the presence of the SO_2.

In order to avoid corrosive conditions, the stack gas temperature must be maintained above the dew point. No plants had dew point measuring instruments, so all were operating with excessively high stack gas temperature which caused a lot of heat to be lost with the stack gas.

If the stack gas temperature is reduced by 10°C., by recovering useful heat, the boiler efficiency is increased by about 0.5%.

On the three boilers at Zakłady Azotowe, a 0.5% improvement in efficiency will result in using 750 tons less fuel oil per year. At current prices ($84/ton), this will effect a savings of about $63,000/year on all three boilers together.

Only one instrument is needed since all three boilers normally burn the same fuel.

Land Combustion manufactures a suitable dew point meter, and has quoted a price of $16,831 (including recommended spare parts). If shipping and installation brings the total cost up to $25,000, the payback period is 5 months.

Land Combustion provides Sales/Service to the European area from a facility in Sheffield, England. Land Combustion has quoted prices for the following instruments:

Land Model 200-04 Portable Dewpoint Meter with Operating Manual and Detector Element Assembly	$9,726.00

Land Model 410 Continuous Dewpoint Monitor with Operating Manual and Detector Element Assembly $16,831.00

The vendor is:

Land Combustion (A Division of Land Instruments International, Inc.)
2525-B Pearl Buck Road
Bristol, PA 19007-6807
(215) 781-0810

The Audit Team recommends that one Land Continuous Dewpoint Monitor be purchased for Zakłady Azotowe in Wloclawek, Poland.

STEAM TRAPS

Present steam traps (manufactured in Poland) allow significant leakage of steam and condensate, and are a maintenance problem. Recommended steam traps are produced by the Armstrong Machine Works in Three Rivers, Michigan.

The Dow Chemical Company is a very large user of steam traps; based on extensive investigation and years of experience, the Dow experts strongly recommended to the Audit Team that only Armstrong inverted bucket traps be considered. The Audit Team supported this recommendation. In addition to being a manufacturer of high quality steam traps in the U.S., Armstrong has a strong presence in Europe. They have a manufacturing facility in Liege, Belgium, and Sales/Service offices in many cities including Warsaw.

Steam losses through defective steam traps vary depending on steam pressure, trap size, and trap condition. Maximum losses are in the range of:

Small traps:	20 lbs./hr. at 30 psig; 70 lb./hr. at 150 psig
Medium traps:	120 lbs./hr. at 30 psig; 450 lb./hr. at 150 psig
Large traps:	1000 lbs./hr. at 30 psig; 3,700 lb./hr. at 150 psig

Armstrong suggested that an "average" maximum loss would be about 200,000 lb./month, and that an "average" installed cost of a steam trap is about $300. Using a typical steam value in the U.S. of $5.00 per 1,000 pounds, each $300 investment in steam traps should yield the following benefits:

100% failure	-	$12,000/year
50% failure	-	6,000/year
10% failure	-	1,200/year (three-month payback)

The Audit Team recommended that fifteen (15) stainless steel traps be purchased for installation on appropriate steam lines at Zakłady Azotowe.

The trapes recommended for purchase were:

- Ten (10) medium-sized traps:

  Armstrong Stainless Steel Trap Model No. 1811
  Pipe connection = 3/4"
  Orifice diameter = 1/4"

- Five (5) larger traps:

  Armstrong Stainless Steel Trap Model No. 1812
  Pipe connection = 1"
  Orifice diameter = 1/4"

Armstrong has the following list prices for these traps:

Model 1811	=	$130
Model 1812	=	$318

The Armstrong representative indicated that discounts may be available for the quantities indicated.

INFRARED THERMOMETERS:

At Zakłady Azotowe all exposed hot surfaces appeared to be insulated adequately, and the insulation appeared to be well-maintained. Despite this, however, there were a few instances of inadequate, damaged, or missing insulation.

At the energy costs levred by the old regime, it was not regarded as worthwhile to make sure that all hot surfaces were insulated and that the insulation was maintained well. At world prices for energy, however, good insulation definitely pays. For example, 200 meters of poorly insulated 10 cm. diameter steam line can lose heat equivalent to about 340 Tons/yr. of steam. This is an economic loss of about $1,700/year. The cost of insulating the steam line properly is certainly less than $2,000, so the minimum return on investment is 85%.

The easiest way to detect heat losses is by using an IR (Infrared) thermometer to measure the surface temperatures. When "hot spots" are observed, a maintenance crew can be assigned to check them and to repair or replace the insulation if appropriate.

Hand-held battery-operated IR thermometers are available from Omega Engineering, Inc. (Stamford, Connecticut) for $895 each. Two were used by the Audit Teams in Poland, and were left -- one with Energopomiar, and one with The Polish Foundation for Energy Efficiency.

The Audit Team recommended that one IR thermometer be purchased for use at Zakłady Azotowe to locate "hot spots" where significant heat losses may be occurring

RECOMMENDED VENDOR:

Omega Engineering, Inc.
One Omega Drive
Box 4047
Stamford, CT 06907-4047

MODEL: No. 0571C Infrared Thermometer-C display

PRICE: $895.00 each

APPENDIX V

PARTICIPANTS IN DISCUSSIONS
October, 1991

The discussions during the return visit took place in the conference room of the main administration building at Zakłady Azotowe. The participants included:

ZAKŁADY AZOTOWE WŁOCŁAWEK:

Mr. Andrzej Markiewicz	Technical Director
Mr. Kazimierz Dobisz	Chief Power Engineer
Mr. Eugeniusz Wesniuk	Power Engineer
Mr. Edward Cwojdzinski	Manager of Power Plant
Mr. Włodzimierz Nowakowski	Chief Interpreter

IRG AUDIT TEAM:

Mr. Gerald Decker	IRG Country Leader
Dr. Richard Heiny	Cogeneration Audit Team Leader
Dr. Frank Wang	Industry Audit Team Leader

LOCAL SUPPORT:

Mr. Zdzisław Gieras	Head of Boiler Guarantee and Operation Testing Division, Energopomiar
Mr. Edward Magiera	Turbine Engineering Specialist, Energopomiar
Mr. Marian Warachim	Senior Engineer, Energopomiar
Mr. Adam Zemła	Kierownik Działu Turbinowego, Energopomiar
Mr. Julian Fortunski	Senior Design Engineer, Kompekon Consulting
Dr. Bogusław Pieczyski	President, Kompekon Consulting
Mr. Pawel Pytel	Interpreter,Kompekon Consulting
Mr. Aleksander Bajan	Engineer, Kompekon Consulting

APPENDIX VI

EQUIPMENT PURCHASED FOR ZAKŁADY AZOTOWE WLOCLAWEK

The following items of equipment and instrumentation were purchased in the U.S. and shipped to Zakłady Azotowe Wloclawek:

OXYGEN ANALYZER:	one Johnson-Yokogawa in situ zirconia type oxygen analyzer with four probes, four probe protectors, one averaging convertor, and one recorder.
ACID DEW-POINT MONITOR:	one Land Combustion Model 410 Continuous Dew-point Monitor, with electronic control unit, twin air filters, four-foot operating probe, and the necessary interconnecting hose and cable, plus accessories.
STEAM TRAPS:	ten Armstrong Model 1811 stainless steel inverted bucket type steam traps with 3/4-inch pipe connections and 1/4-inch orifices. Five Armstrong Model 1812 stainless steel inverted bucket type steam traps with 1-inch pipe connections and 1/4-inch orifices.
INFRA-RED THERMOMETER:	one Model 550 portable infra-red temperature measuring instrument with service manual and case.

APPENDIX VII

DISCUSSION OF THE EQUIPMENT

ACID DEW-POINT MONITOR: The plant indicated that they were prepared to install the monitor as soon as it was delivered. This meter will enable the plant to adjust operations to maintain the stack gas temperature as low as possible and yet be above the temperature at which the SO_2-laden gas will condense. The condensation of this acid gas stream can cause severe corrosion throughout the stack gas lines. In practice, a small safety margin should be allowed, but the Audit Team could not state what this margin should be. A "guesstimate" is 5-10°C. It was recommended that the plant should adopt a "trial and error" approach by starting at something like 30°C above the dew-point and then reducing the temperature of the stack gas in 5°C increments to see if there is any indication of condensation. As soon as condensation is observed, the temperature should be increased by 5-10°C, and operations should continue at that level unless further condensation is observed.

IN SITU OXYGEN ANALYZER: The new analyzer will be installed so that two probes can be installed in the flue gas spaces on Boilers No. 1 and 2. During the discussion, plant personnel asked what level of excess air was considered desirable. The Audit Team responded that, in the U.S. it was usually regarded as good operating practice to maintain the excess air level at 12% or a little below. Ten percent is regarded as a very good operational standard.

During the April visit, Boiler No. 2 was operating at 35% excess air, and Boiler No. 3 was operating with 29% excess air. (Boiler No. 1 was not operating at the time of the visit). Each 5% reduction in the excess air level results in about 0.35% increase in boiler efficiency. If both boilers can operate at 12% excess air, efficiency will be increased by about 1.5% on Boiler No. 2 and 1.2% on Boiler No. 3 Boiler No. 2 consumes about 7 tons/hour of fuel oil, and Boiler No. 3 consumes about 14 tons/hour. If each boiler operates 6,000 hours per year, the savings will be about 1,638 tons of fuel oil per year. At the October price of about 800,000 zł/ton (about $73/ton), the annual savings will be about $120,000 per year.

It was pointed out that, as excess air level is reduced, it becomes more important to control any air leakage into the combustion space and the stack prior to the air pre-heaters. Plant personnel were aware of this, and assured the Audit Team that they will take precautions.

STEAM TRAPS: The Audit Team pointed out that the Armstrong stainless steel traps are designed to operate at pressures no higher than about 450 psi (about 3 MPa). Plant personnel stated that they would like to have traps that could be used on their high pressure steam lines, which are at about 9-10 MPa (about 1300 to 1450 psi). Following the visit, the Audit Team contacted Armstrong Specialty Products in Three Rivers, Michigan, and learned that the trap for this duty is:

- Forged steel inverted bucket type
- Model 315 fw
- 1 1/2 inch flange fittings
- Orifice to be specified later
- Weight: 103 pounds (47 kilograms) each

The Audit Team does not recommend purchasing such traps with the funds that are presently available for this project. Zakłady Azotowe does have numerous locations for use of the stainless steel traps, and will put them into service as soon as they are received.