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ENERGY EFFICIENCY AUDIT REPORT
CHIMCO COMPANY FERTILIZER WORKS

Vratza, Bulgaria

PREPARED BY:

INTERNATIONAL RESOURCES GROUP, LTD.
Washington, DC

and

ECOTECHPRODUCT, LTD.
Sofia, Bulgaria

U.S. EMERGENCY ENERGY PROGRAM FOR EASTERN & CENTRAL EUROPE

U.S. AGENCY FOR INTERNATIONAL DEVELOPMENT
BUREAU FOR EUROPE
WASHINGTON, DC 20523

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS iv

PREFACE v

1. EXECUTIVE SUMMARY 1

2. PLANT BACKGROUND 5

3. ENERGY MANAGEMENT 10

3.1 Energy Management Structure 10
3.2 Energy Management Seminar 10
3.3 Training Requirements 11

4. ENERGY EFFICIENCY IMPROVEMENT OPTIONS 12

4.1 Low Cost Options 12
4.2 Capital Intensive/Long-Term Options 12

5. RECOMMENDATIONS AND CONCLUSIONS 15

5.1 Improved Energy Management Practices 15
5.2 Improved Operating Practices and Operational Changes 15
5.3 Recommended Capital Investment 16
5.4 Other Recommended Capital Projects 16

APPENDIX I AUDIT RESULTS

APPENDIX II LIST OF PARTICIPANTS

APPENDIX III EQUIPMENT SPECIFICATIONS AND JUSTIFICATIONS

APPENDIX IV TRAINING SEMINAR PRESENTED BY US TEAM

APPENDIX V ADDITIONAL CHARTS AND MEMORANDA

APPENDIX VI AN EXCERPT OF "ENERGY MANAGEMENT PRACTICES" PRESENTATION OF MR. BARRY TUNNAH AT THE ENERGY MANAGEMENT WORKSHOP IN SOFIA, BULGARIA (JANUARY 1992)

LIST OF TABLES AND FIGURES

		Page
Table 1.	Summary of Opportunities for Energy Savings Requiring Capital Investment	3
Table 2.	Major raw materials consumed, 1990	6
Table 3.	Major products, 1990	6
Table 4.	Major consumers of energy, 1990	6
Table 5.	Energy sources and energy consumption (annual data for 1990)	7
Figure 1.	Location of eight industrial plants audited by the IRG team	vii
Figure 2.	Power Station Flowchart	7
Figure 3.	Flowchart of Inter-Plant Connections	8

LIST OF ACRONYMS/ABBREVIATIONS

A.I.D.	U.S. Agency for International Development
atm	atmospheres
GCal	giga calorie
IRG	International Resources Group, Ltd.
kcal	kilocalorie
KWh	kilowatt hours
lv	Levas; currency of Bulgaria; at the time of this report, 15 lv = US $1.
m^3	cubic meters
MM	Million
MW	mega watts
ppm	parts per million
psi	pounds per square inch
t	metric ton

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The Energy Conservation Audit Team of the International Resources Group, Ltd. (IRG) wishes to acknowledge assistance provided by the Ministry of Industry, the Committee on Energy, and its Inspectorate for Energy Utilization in arranging visits to participating facilities. IRG also would like to thank the U.S. Agency for International Development, European Development Resources Section, Office of Energy and Infrastructure for coordinating the entire project.

Work under the A.I.D.-funded Emergency Energy Program at the Chimco Company Fertilizer Works, Sofia, was conducted through a cooperative effort by the factory management and staff; Committee on Energy; Ecotechproduct -- a private sector energy conservation consulting firm; and IRG.

It is IRG's hope that the exchange established through this initiative is maintained and expanded 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.

For Bulgaria, the general atmosphere of crisis in the regional energy sector is compounded by the fact that all of its natural gas and coke and most of its petroleum is imported. Moreover starting in April 1991, the electric power supply imported from the Soviet Union, which previously accounted for a significant amount of Bulgaria's electricity supply, was cut off. Furthermore, domestic electricity production from nuclear power, previously a major source of energy, has been decreasing since the autumn of 1991, as the Kozloduy nuclear power station was taken off-line due to safety concerns. Given these concerns, energy efficiency must play a vital role in transformation of the energy and industrial sectors in Bulgaria.

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 Bulgaria.

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 Bulgaria to which the energy conservation measures developed in this program could be applied.

2) Two Audit Teams went to Bulgaria 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 January 1992 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 Sofia January 27-29, 1992.

The Bulgaria Light and Heavy Industry Audit Teams each audited four plants:

<u>Light Industry</u>
Serdika Dairy Processing Plant - Sofia
Pharmacia Pharmaceutical Company - Stanke Dimitrov
Parvi Mai Cotton Textile Processing Plant - Varna
Dobritch Poultry Processing Plant - Tolbuhin

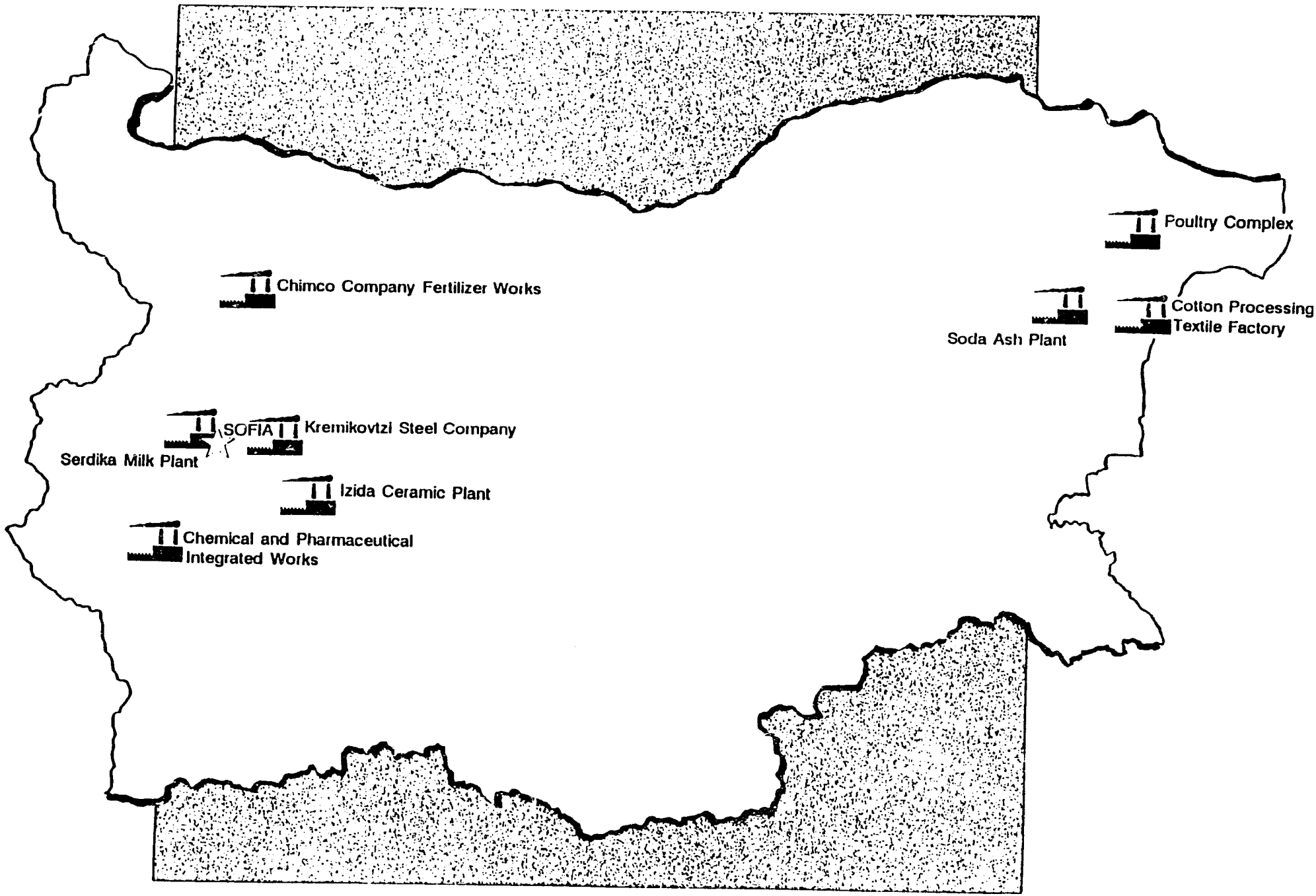


Figure 1. Location of eight industrial plants audited by the IRG team.

Factory

Heavy Industry
Izida Ceramic Facility - Elin Pelin
Kremikovtzi Steel Plant - Sofia
Chimco Ammonia and Urea Facility - Vratza
Sodi Soda Ash Plant - Devnia

The Audit Teams 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 Teams 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.

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 Bulgaria. 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 Bulgaria. 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 Bulgarian 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 Bulgaria 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 Bulgaria, 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 Bulgarian 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

The Chimco Fertilizer Works is a large complex built in sections begining in 1967. It is still being modernized and extended. The main plant produces 500,000 tons/year of ammonia (5 production units), 800,000 tons/year of urea (7 units), and 22,000 tons/year (1 line) of carbon disulfide. In addition, the facility has an air separation unit, argon extraction unit, ammoniacal liquor and ammonium disulfide units, and various catalyst production facilities. The air separation unit and part of the ammonia unit are relatively modern, but vary from current Western standards. They vary insofar as in Western plants there would be fewer units, a higher degree of efficiency, and lower maintenance costs. A significant amount of the facility's products are exported; all chemical installation equipment, except in the Oxygen Plant, were imported from Western countries.

The annual energy consumption of natural gas at Chimco is 703,088 m^3, at a cost in 1990 of 112.36 lv/m^3. The price of natural gas skyrocketed in 1991 to 1725 lv/m^3. In 1990, the plant produced 223,403 KWh of electricity for internal consumption, at a cost of 44.3 lv/kWh. It also purchased 394,850 kWh of electricity from the grid in 1990, at a cost of 52.06 lv/kWh.

One of the major areas Chimco personnel identified as requiring improvement, further study, and investment is the power house. There are serious questions regarding the plant's total natural gas usage, and as such, new meters are being installed by a vendor who claims the plant gas consumption is greater than currently reported by at least 8 or 9%. This is a serious issue for Chimco since its main feed stock is natural gas, the price of which has increased fifteen-fold in the last year from 112 lv/1000 m^3 in 1990, to 1725 lv/1000 m^3 in 1991. This situation is complicated by other external economic factors. For example, the market for CS_2 dropped significantly in the last year, after a major purchaser in Poland went out of business due to ecological problems.

The plant has environmental problems involving atmospheric pollution and aqueous waste streams. Atmospheric pollution consists of emissions of ammonia, urea, and SO_2. Water waste streams can often contain 100 mg/Liter of ammonia and on occasion much higher levels. This aqueous concentration is reduced by dilution with fresh water, an unacceptable long-term solution.

Chimco has an energy conservation committee and all new employees receive a summary course on the importance of energy conservation. The plant has an ongoing energy monitoring program which makes evaluations on a monthly (or shorter term) basis.

The IRG Team provided engineering assistance and advice relating to condensate recovery and heat recovery from reformer furnace flue gas. This applied to the hydrogen sulfide to sulfur conversion in the Claus plant in particular; this process converts hydrogen sulfide gas to sulfur. A brief analysis was conducted to evaluate plant performance and assist in the selection of a H_2S/SO_2 analyzer. This plant is a major source of atmospheric pollution in the region. The IRG Team pointed out that similar plants in other countries have more than two catalyst reactors to achieve lower gaseous sulfur discharge (H_2S and SO_2).

The Team tests on a boilers at the plant indicated efficiency losses of about 1.5%, due to air leaks and possible errors in instrumentation. Test were also conducted on reformer flue gas.

Results of the Emergency Energy Program, Industrial Energy Efficiency

New equipment and instruments were purchased under the Emergency Energy Program. The items purchased were:

- Emissions Gas Analyzers (2)
- Infrared Thermometer
- Portable Temperature Indicator

More capital intensive recommendations have been outlined for the longer term, including projects developed through plant investigations. These are summarized in **Table 1**.

Table 1. Summary of opportunities for energy savings requiring capital investment.

Chimco Company Fertilizer Works

I.	Electric Savings Measures Evaluated	Investment Required (000s lv)	Energy Savings (Gcal/yr)	Value of Savings (000s lv/yr)	Payback Period (years)	Recom's
	1. Checking Instruments in power station relating to Urea and Ammonia	15	17,000	7,500	< 0.1	yes
	2. Installation of waste water dilution line	750	350	154	4.9	no
	3. Install 3rd turbine	75,000	96 MM	60,000	1.25	NEI
	Totals	75,765	96,017,350	67,654		
II.	**Thermal Energy Savings Measures Evaluated**					
	1. Insulation of lines	150	670	150	1	yes
	2. Use of recovered methane from waste Argon gas	-	2,000	452	-	NEI
	3. Use of methane from Argon plant as reformer fuel Buildings	3,000	25,600	5,500	0.5	yes
	4. Repair of underground cooling water valves	150	-	-		NEI
	5. Use of 1.2 bar steam instead of 6 bar steam and use of flash steam at 1.7 bar	30	500	125	0.2	yes

II.	Thermal Energy Savings Measures Evaluated (cont.)	Investment Required (000s lv)	Energy Savings (Gcal/yr)	Value of Savings (000s lv/yr)	Payback Period (years)	Recom's
	6. Flashing of condensate from 1.2 ATM to lower pressure	-	300	-		NEI
	7. Condensate Collection	1,500	700	164	9.1	no
	8. Turbine control systems	60,000	48,000	12,000	5	no
	9. Install 5th Reformer	9,000	7,446	1,860	4.8	no
	10. Reconstruction of urea plants	75,000	-	-	-	NEI
	11. Reconstruction of ammonia plants	15,000	-	-	-	NEI
	12. Repair of boilers	3,000	-	800	3.75	NEI
	13. Reconstruction of carbon disulfide plant	3,000	-	-	-	NEI
	Totals	169,830	85,216	21,051		

Total Potential Electric and Thermal Savings = 88.7 MM leva per year

NEI - Not enough information available about key investment parameters, including management payback requirements, etc. at the time of the audit to recommend implementation of the project. The Team does not suggest that these investments are not sound. However, the Team stresses that a more comprehensive analysis of the return on these investments must be conducted before investment funds are allocated.

2. PLANT BACKGROUND

The Chimco Company Fertilizer Works is a large well-integrated plant with many interconnected process units. For example, carbon dioxide (CO_2) from the ammonia plant goes to make urea, and vent gases from the ammonia converters go to the cryogenic unit for production of nitrogen (N_2), oxygen (O_2), argon, and xenon. In addition, the plant produces carbon disulfide (CS_2) ammonium bisulphide, sodium bisulfite, standard gas mixtures, catalysts, and ferric and nickel oxides. Chimco's data on raw materials, products and energy consumptions are given in **Tables 1 through 4**.

This facility was built in sections begining in 1967, and is still being modernized and extended. The basic plant produces 500,000 tons/year of ammonia (5 production units), 800,000 tons/year of urea (7 units), and 22,000 tons/year (1 line) of carbon disulfide. In addition, the facility has an air separation unit, argon extraction unit, ammoniacal liquor and ammonium disulfide units, and various catalyst production facilities. The air separation unit and part of the ammonia plants are relatively modern but ultimately less efficient than Western plants. A significant number of the facility's products are from the plant. All chemical product equipment except in the Oxygen Plant, was imported from Western countries.

Since natural gas is Chimco's main raw material, its efficient use is vital, especially since the price has increased fifteen fold in the last year from 112 lv/1000 nm^3 in 1990, to 1725 lv/1000 m^3 in 1991. This situation is complicated by other external economic factors. For example, the market for CS_2 has dropped significantly in the last year, after a major client in Poland was shut down due to ecological problems.

The plant also has environmental problems, since it is a major emitter of air pollution and aqueous waste. Air pollution emissions include ammonia, urea, and sulfurdioxide, while waste water streams contain ammonia. Ammonia waste-water levels often reach 100 mg/liter of ammonia, the concentration of which is reduced by dilution with fresh water, clearly a non-sustainable solution.

Table 2. Major raw materials consumed, 1990.

Material	Quantity	Origin	Delivery	Cost
Natural gas	703,088,000 m^3	USSR	pipe line	112 lv/th m^3
Water	12,10,600 m^3	River "Iskar"	pipe line	166 lv/th m^3
Sulphur	21,000 t	Poland	rail	169 lv/t

Table 3. Major products, 1990

Product	Units	Capacity	Production	Values of sales (000s lv)
Urea	t	800,000	794,150	138,783
Ammonia	t	520,000	515,600	10,337
Incl. stock			51,684	
Carb.disulph.	t	20,000	17,250	9,488
Argon	m^3	2,200,000	1,318,415	3,478

Table 4. Major consumers of energy, 1990

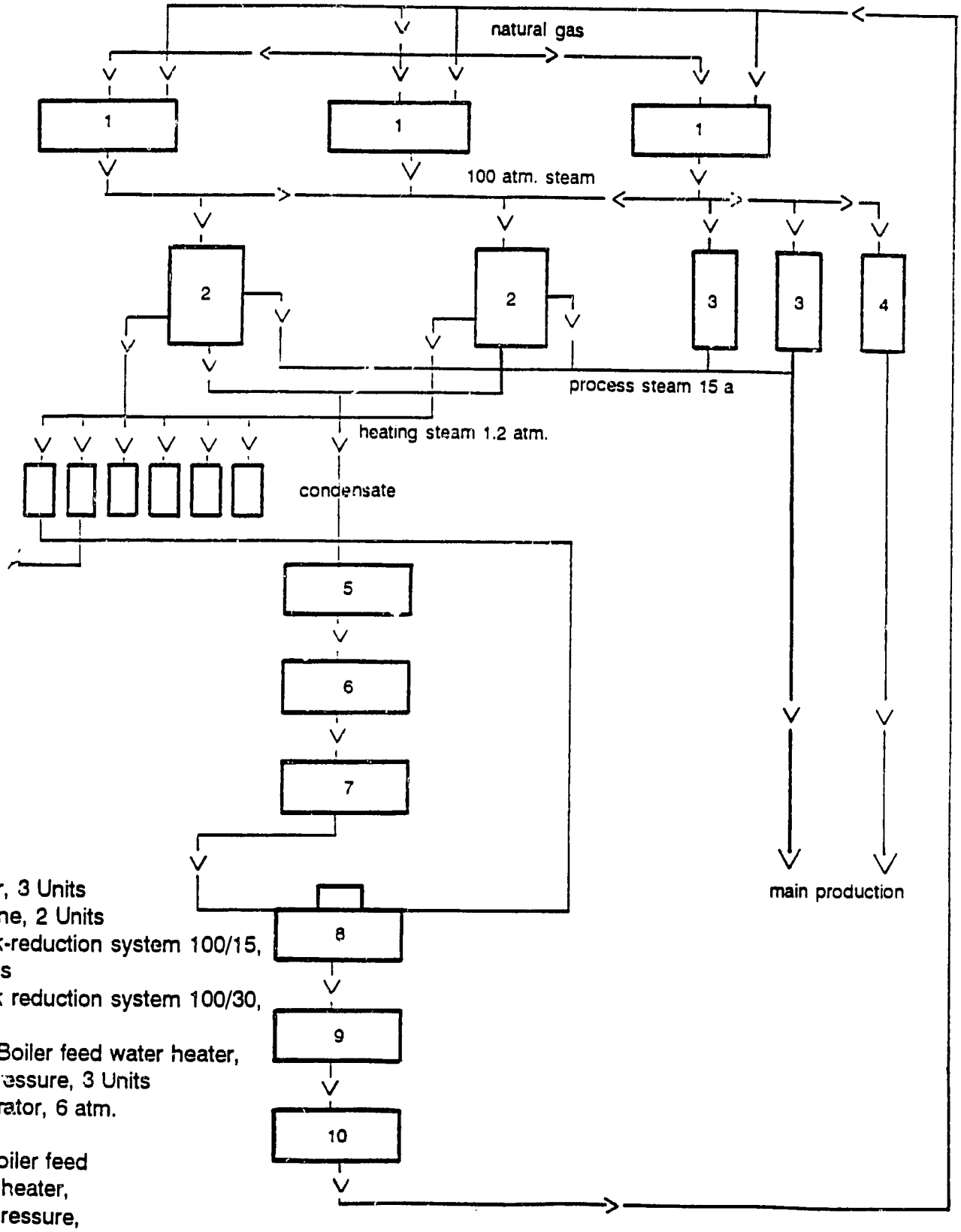
Process unit	Type of energy	Quantity
Urea Plant	Steam	1.146 Gcal/t
	Electric energy	134 KWh/t
Ammonia plant	Electric energy	707 KWh/t

Table 5. Energy sources and energy consumption - annual data for 1990.

#	Type	Unit	Consumption	Price per Units (lv)	Total Cost Per Thousand	Price (1991)
1.	Natural gas	per thousand m^3	703,088	112.36	78,999	1725.28 lv/th.nm^3
2.	Purchased electricity	per thousand KWh	394,850	52.06	20,557	280.0 lv/th.KWh
3.	Produced	per thousand KWh	223,403	44.3	9,897	629.92 lv/th. KWh
4.	Steam & hot water	GCal	1,051,900	27.0	28,000	245.18 lv/Gcal

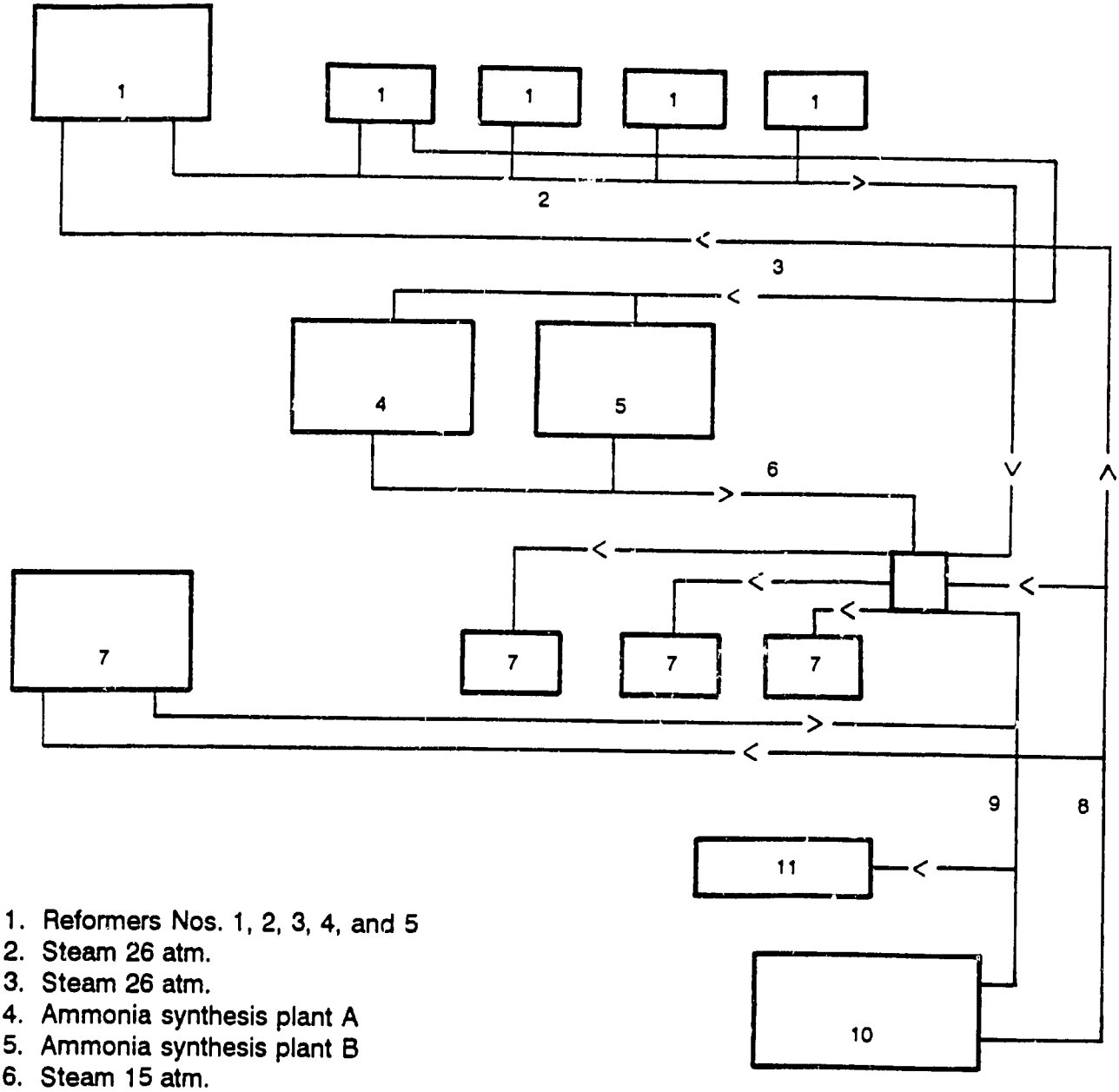
The 1991 audit conducted by the IRG Team involved reviewing Chimco's data, and examining the energy efficiency impacts of lighting, heat, and ventilation, the steam boiler plant, and the process steam distribution station. Specific measurements taken during the audit are included in **Appendix I** of this document. A basic description of operating status of the plant at the time of the audit is included below, along with relevant diagrams. All recommendations made in this report reflect evaluation of measurements taken by the Team, general observations, and discussion with plant managers.

FIGURE 2. POWER STATION FLOW CHART



1. Boiler, 3 Units
2. Turbine, 2 Units
3. Quick-reduction system 100/15, 2 Units
4. Quick reduction system 100/30, 1 Unit
5. 6. 7. Boiler feed water heater, low pressure, 3 Units
8. Deaerator, 6 atm. 1 Unit
9. 10. Boiler feed water heater, high pressure, 2 Units

FIGURE 3. FLOW CHART OF INTER-PLANT CONNECTIONS



1. Reformers Nos. 1, 2, 3, 4, and 5
2. Steam 26 atm.
3. Steam 26 atm.
4. Ammonia synthesis plant A
5. Ammonia synthesis plant B
6. Steam 15 atm.
7. Urea production lines Nos. 1, 2, 3, 4, 5, 6, and 7
8. Steam 28 atm.
9. Steam 15 atm.
10. Power Station
11. CS_2 production

Boilers

Steam and electricity are supplied by the power house and through the purchase of electricity. The power house contains three boilers and two turbine generators. One of the boilers currently is under repair. The details of the boilers are provided below.

Maker:	Barnwell Boiler Factory
Type:	BKZ 160/100 GM
Fuel:	Natural gas, fuel oil
Boiler capacity:	160 tons/hour of steam
Steam pressure:	94 kg/cm^2
Normal fuel consumption:	Natural gas 14,000 nm^3/hour
Estimated excess air:	3%
Inlet air temp:	223 °C
Flue gas exit temp:	125 °C
Hours/day use:	24

These boilers are controlled by a Honeywell TDC 3000 control system, which is 3.5 years old. The boilers themselves were built in the 1960s.

A number of samples were taken by the Audit Team on the flue gas. The induced draft fan has dual inlets, referred to as "right" and "left" in the test results. The complete results of the boiler analysis and flue gas samples are also included in **Appendix I**.

Turbines

In April 1991, only one turbine was operating, while the second was being repaired. The standard mode of operation for the plant's steam supply typically requires 15 atm. steam to be supplied by reductions of 100 atm. steam to 15 atm. Thus, about 500,000 tons/year of energy was lost through this inefficient process which has been in place for around 2 years.

Moreover, the operating turbine had two feed water preheaters out of service (numbers 9 and 10) at the time of the audit, and therefore feed water to the boilers was supplied at only 160 °C, instead of 215 °C, representing another energy loss. These two preheaters were being repaired at the time of the initial audit. It is recognized that without the steam flow to preheaters 9 and 10, not enough additional electricity is being produced to justify the additional energy spent.

Based on power balance figures given in **Appendix I**, it can be seen that with operation of only one turbo-generator, the power factor was lower than the approved level for the energetic system, which for Chimco is 0.930.

3. ENERGY MANAGEMENT

3.1 Energy Management Structure

Chimco has an energy conservation committee, and new employees receive a summary course on the importance of energy conservation. In addition, the plant has an ongoing energy monitoring program which evaluates plant conditions on a monthly basis.

The Deputy Manager of Production, Maintenance and Development is in charge of energy management. The Production and Technical Departments are under his authority, and staff includes one thermal engineer and one electrical energy engineer. The Power Station Manager is subordinate to the Managers of these two departments. Company management is interested in energy consumption reductions.

In addition, the plant has an energy committee which includes:

1.	Eng. M. Mazdrakov	Production and Technical Department Manager
2.	Eng. Nicolov	Energy Department Manager
3.	Physicist B. Cerefeisci	Inst. Department Manager
4.	Eng. I. Crustev	Power Station Manager

The energy committee:

1. Prepares and maintains an energy balance for the company;
2. Monitors raw-material inventories and flows;
3. Monitors energy consumption targets and goals set by management.

Future tasks of the energy committee include monitoring the energy savings obtained through implementation of low-cost energy efficiency measures and verification of estimates previously stated in this audit. This committee will also develop programs to improve the energy awareness of all employees.

3.2 Energy Management Seminar

Recognizing the importance of energy management in determining the overall efficiency of industrial energy use, the Energy Conservation Audit Team presented a seminar at the Chimco plant in April which addressed a number of energy management issues. Recommendations presented in the seminar were designed to provide an overall framework for improved energy management and training related to energy efficiency. The outline of the seminar is included in **Appendix I**.

Issues crucial to any discussion of energy management include:

- Economic Principles - energy costs versus production input costs. In addition, concepts related to the benefits and costs of energy efficiency investments and return on investment must be analyzed.

- Energy Management Programs - the development of specific program to foster an energy ethic within a plant should be encouraged. These programs could include incentive/disincentive, "turn out the lights" campaigns, etc. A comprehensive energy management program also should incorporate an effective mechanism for energy cost accounting.

- Energy Monitoring - successful improvement in energy utilization in an industrial facility is contingent upon continued monitoring of energy use. Increased energy prices in Bulgaria have forced new emphasis on this issue. As such, energy efficiency training must encompass economic justifications for the selection of instruments to monitor energy use.

- Energy Surveys - energy surveys and audits similar to the one conducted under the Emergency Energy Program should be part of an overall energy management framework. In particular, energy surveys should attempt to regularly evaluate such important areas as:

  - steam leaks
  - condensate leaks
  - insulation opportunities (water, steam, refrigeration)
  - electrical opportunities
  - lighting
  - water leaks
  - air leaks

Issues addressed at the April seminar were discussed in further detail at the January 1992 Energy Management Workshop in Sofia, during which a Chimco representative made a presentation.

3.3 Training Requirements

As outlined in the energy management seminar, training in energy awareness, economics, and energy cost accounting are crucial elements in improving plant energy efficiency. At practically every level, improved training in economics, data collection and low cost energy management techniques would yield significant energy savings.

It is particularly important that divisions responsible for overseeing energy utilization and energy efficiency activities receive training in:

- energy cost accounting - this type of training would be particularly useful if it involved practical skills training related to the use of energy cost accounting software packages. Even if it is not possible to purchase and utilize more sophisticated computer accounting programs, plant personnel can learn the basic tools used to maintain solid cost accounting standards within the plant.

- energy efficiency investment planning - training in investment planning would be extremely useful if it included familiarization with the tools used in some energy investment planning programs such as the "Envest" program.

4. ENERGY EFFICIENCY IMPROVEMENT OPTIONS

Listed below are options for improving energy efficiency use at Chimco. Clearly, all of these practices and projects will help conserve energy in the facility. However, given the reality of scarce resources for implementing these projects, the IRG Team recommended that some of these options be given priority. This prioritization is included in **Section 5**. Nevertheless, this section outlines the variety of options available for energy efficiency improvements The ultimate decisions regarding implementation of alternative options will depend upon criteria set by plant management -- including acceptable payback periods, and upon the overall corporate strategy.

Investment requirements, annual energy savings, and their fiscal value were prepared by plant staff, with investments expressed in US dollars.

4.1 Low-Cost Options

"Low cost" items are those which will not require hard currency investments, and may be possible to implement within the existing framework of plant expenditures (ie. through improved utilization of maintenance and housekeeping staff). For purposes of comparison, however, the investment amount is presented in US dollars.

1. **Check flow meters, pressure gauges, and other instruments in the electric power station** as related to the ammonia and urea plants. Investment required is $1,000 maximum, and the energy savings will be 17 million KWh/year, with a cost savings of 7.5 million lv/year.

2. **Take make-up water from a reservoir formed by two rivers to the cooling system through a number of pumps**. They are attempting to reduce the water usage to only 1,400 m^3/hour so that the number of pumps required can be reduced. Savings are projected at 2,000,000 KWh/year.

4.2 Capital-Intensive Options

These are higher capital expenditure items of a longer-term nature intended to increase the profitability of Chimco; investment and saving estimates reflect plant data.

1. **Insulate lines**. A number of insulated lines, ranging from 6 mm to 350 mm in diameter, have defective insulation. Estimated cost to complete insulation repair is $10,000, but incremental savings can be achieved with lower levels of investment. The estimated cost savings of this investment is 150,000 lv/year.

2. **Use recovered methane from waste Argon gas**. Energy savings from this initiative are estimated at 2,000 Gcal/year.

3. **Use methane from Argon plant as a reformer fuel**. Energy savings from this project would be worth approximately 5.5 million lv/year, and would cost approximately $200,000. Recovered low-pressure methane from the argon plant will be burned as fuel in one of the reformers, yielding a savings of at least 400

m^3/hour of natural gas, valued at 5.5 million lv/year at the present cost of natural gas (1,725 lv/ 1000 nm^3). The investment is estimated to require an equivalent of US $200,000.

4. **Repair underwater cooling water valves**. The repair of motor-operated shut-off valves to the underground cooling water system will provide better control. Investment cost is projected at $10,000.

5. **Use of 1.2 bar steam**. Use of 1.2 bar steam instead of 6 bar steam and use of flash steam at 1.7 bar will save approximately 125,000 lv per year, with an energy savings of 500 GCal/year.

6. **Change in flashing of condensate.** If flashing of condensate is altered from 1.2 atm to a lower pressure approximately 300 GCal will be saved annually.

7. **Condensate collection**. Collection of condensate (mostly from urea plant steam tracing) is under study. At present, condensate is wasted. A savings of 10,000 tons/year of condensate at 100 °C is expected. Investment requirements would be approximately $100,000, and the estimated savings would be valued at $10,933 per year.

8. **Install modern control system for turbines**. There are two turbines in the boiler plant. They provide process steam at 15 atm. and 25 MW power each. The controls are dilapidated and a modern control system is required. Steam is fed at 100 atm pressure. The investment required to install a modern control system is estimated at $4 million. Savings are estimated to be 800,000 per year.

9. **Install a third turbine.** It would be desirable to install a third turbine which will provide back-up pressure to convert 100 atm. steam at 540 °C to about 70 t/h of steam at 15 atm. and about 70 t/h of steam at 6 atm. and to generate 12 MW of power. Savings are estimated as 96 million KWh/y, (60 million lv/year or $4 million US $/year). Investment required is estimated as $5 million for the entire installation.

10. **Install a fifth reformer**. A fifth reformer of Topsoe design can provide heat. An induced draft fan on the flue gas has an exit flue gas temperature of 200 - 220 °C. It is proposed to use this flue gas to heat softened water at 100 °C to a temperature that flue gas is cooled to 150 °C. The fan is considered to have ample capacity for the additional pressure drop. A savings of 0.85 Gcal/hour or 7,446 Gcal/year is expected, saving (1.86 million lv/year). An investment of $600,000 would be required.

11. **Reconstruct Urea Plants**. Reconstruction of all urea plants will save energy, reduce pollution, and improve product quality. Investment required by Chimco is about $75 million.

12. **Reconstruct ammonia plants.** Reconstruction of all ammonia plants will conserve energy and substantially improve production economics. Investment required about $15 million # 1 variant; $30 million - # 2 variant.

13. **Repair boilers**. This option requires shutdown for repair of boilers in the power station over the period 1991 - 1993. This actively will be undertaken together with a project to automate the burning units. The estimated cost of this project is $3 million, and the estimated cost savings are $800,000/year.

14. **Reconstruct the carbon disulfide plant**. Under this option, reconstruction of the carbon disulfide plant, including sections for recovery of sulfur from H_2S. The estimated cost of this project is $3 million.

15. **Dilute ammonia waste**. The ammonia concentration in the total waste water from the ammonia and urea plants should be maintained at 100 mg/liter or less. Currently, this is done by diluting wastewater with fresh water from the dam for occasions of operational upset or shut down of a urea line. Installation of a fresh water line to the waste water channel will save pumping costs for 700 hours/year with a savings of 500 KW. This is expected to save 350,000 KWh/year. The investment is estimated at $50,000.

5. RECOMMENDATIONS AND CONCLUSIONS

The following recommendations and conclusions represent those areas which the Audit Team believes should be priorities for the Chimco plant.

5.1 Improved Energy Management Practices

The first priority area for corporate energy management at Chimco should be the establishment of training programs designed to improve energy efficiency awareness, data collection techniques, energy cost accounting, and energy investment planning capabilities.

In conjunction with improved training, the management should establish energy management criteria, including minimum acceptable investment payback criteria and incentive/disincentive schemes for encouraging energy savings. In addition, the management should conduct a comprehensive evaluation of all investment options, both low cost and capital intensive, to determine 1) the cost of the required investment and 2) the payback on the investment (in terms of energy saved, losses avoided or production increases), in order to prioritize investment opportunities.

5.2 Improved Operating Practices and Operational Changes

The following recommendations reflect changes in operating practices, housekeeping, and maintenance which can yield significant energy savings with minimal investment cost. These recommendations include focusing attention on lighting, heating and ventilation for the building, in addition to changes in the operation of the steam boiler plant, and the process steam distribution station.

1.	**Lighting**	Clean up fixtures and reflectors. Replace old incandescent lamps with sodium vapor where possible. Clean all windows to allow natural light to enter, in order to reduce electricity consumption.
2.	**Heating and ventilation**	Consider using condensate to heat buildings before returning it to the power plant.
3.	**Steam boiler plant**	Replace all leaking preheaters and reseal all leaking ducts on induced fan section to increase the air temperature to burners.
4.	**Process steam distribution and condensate return**	Upgrade insulation. Concentrate on recovery of more of the condensate. There were many steam leaks and condensate non-returns noticed during plant visits. This is one very noticeable low cost area of energy savings in the plant, since steam and condensate cost money.

5.	**Use of methane from the Argon Plant as a Reformer Fuel**	With an estimated payback period of only six months, this change in operations will yield significant results.
6.	**Power Station Instruments**	As noted in the "Energy Efficiency Improvement Options" section, careful evaluation of instruments in the power station related to urea and ammonia production will yield energy savings, at a payback of less than two months.

Attention to these energy considerations will yield energy savings of nearly 13 million leva in a year.

5.3 Recommended Capital Investments

Equipment Purchased Under the Emergency Energy Program

1.	**Emissions Gas Analyzers**	Two emissions gas analyzers were purchased on behalf of the Chimco plant for use in improving the efficiency of combustion in plant boilers. The cost of the investment was $11,697, and the annual savings are expected to be $153,333.
2.	**Infrared Thermometer**	This item will be used to identify damaged insulation or heat losses from other sources throughout the plant. The cost of the item was $892 and the estimated savings from the use of this item in conjunction with the temperature indicators are $5,520 per year.
3.	**Portable Temperature Indicator**	The cost of this investment was $1,942 and, with the Infrared Thermometer, this item is estimated to contribute to approximately $5,520 in energy savings per year.

Details on the specifications and justifications for these items of equipment are included in **Appendix III**.

5.4 Other Recommended Capital Projects

■	Repair of 2nd Generator	The continued non-operation of one of the plant's turbo-generators resulted in losses of about 56,000 KWh per month for the company, or 200,000 lv per month. Consequently, it is necessary to ensure that operation of the second turbo-generator recommences, so that energy use will be optimized and the power balance will reach the prescribed optimal power factor.

APPENDIX I.

AUDIT RESULTS

1. Boiler Analysis

	Boiler # 2		Boiler # 3	
	Measured Points		Measured Points	
	Trial 1	Trial 2	Trial 1	Trial 2
Combustion Efficiency, %	82.9	77.1	82.5	77.4
Ambient Temperature, ° C	16	20	17	20
Stack Temperature, ° C	129	251	141	197.5
Oxygen, %	9.6	8.0	9.2	11.2
Carbon Monoxide, ppm	0	0	0	0
Carbon Dioxide, %	6.4	7.3	6.6	5.5
Excess Air, %	76	55	70	102
Oxides of Nitrogen, ppm	152	202	110	120
Sulfur Dioxide, ppm	0	0	0	0
Carbon Monoxide, ppm	50	50	50	50

2. Boiler Station and Steam Turbine

No.	Name, Range and Dimension of the Measured Points	Boiler # 2	Boiler # 3
1.	Fuel Calorific Value, Kcal/nm^3	7,924.0	7,924.0
2.	Flow of natural gas, nm^3/h	10,126.0	8,798.0
3.	Flow of Steam, t/h	122.8	106.0
4.	Pressure of Steam, M Pa	9.5	9.6
5.	Temperature of Steam, ° C	538.6	535.3
6.	Temperature of Water, ° C	164.0	164.0
7.	Pressure of Water, MPa	10.2	10.2
8.	Temperature of Steam in Drum, ° C	315.0	310.0
9.	Pressure of Steam in Drum, MPa	9.8	9.8
10.	Extra Water I Step, t/h	5.1	6.0
11.	Extra Water II Step, t/h	1.5	0.8
12.	Temperature of Extra Water, ° C	315.0	315.0
13.	Flow of Existing Water, t/h	24.4	21.2
14.	Temperature of Existing Water, ° C		
15.	Flow of Hot Air, nm^3/h	111,386.0	96,778.0
16.	Temperature of Hot Air, ° C		225.0
17.	Ambient Temperature, ° C	16.0	17.0
18.	Stack Temperature, ° C	129.0	141.0
19.	Oxygen, point 3, %	4.3	3.2
20.	Turbine Generator Capacity		25.0 MW
21.	Steam Reducing System 100/15 atm.		45.0 t/h
22.	Steam Reducing Steam 100/30 atm.		7.0 t/h
23.	Turbine Sampling Point 15 atm.		55.0 t/h
24.	Turbine Sampling Point 1.2 atm.		37.0 t/h

During the audit, the Audit Team observed that a bypass of the preheater was open which caused the induced draft fan inlet to be 100 °C cooler than it should be.

3. Reformer Analysis

The following are the results from a number of samples that were taken of the ammonia reformer furnace flue gas:

<u>Reformer # 1A</u>

Date: 04-22-91

This analysis was stopped when the CO level reached 2,000 ppm as this is the maximum range of the test instrument.

Reformer # 2A
Time: 10: 58
Date: 04-22-91

Fuel - natural gas:	7,924 Kcal/nm^3
Combustion efficiency	94.8 %
Ambient temperature	19° C
Stack temperature	not measured
O_2	1.2 %
CO	523 ppm
CO_2	11.1 %
Combustible gases	0.05 %
Stack draft	not measured
Excess air	6 %
NOx	229.0 ppm
SO_2	0.0 ppm

Reformer # 3B
Time: 10: 48
Date: 04-22-91

Fuel - natural gas:	7,924 Kcal/nm^3
Combustion efficiency	95.2 %
Ambient temperature	19° C
Stack temperature	not measured
O_2	2.0 %
CO	0 ppm
CO_2	10.7 %
Combustible gases	0.0 %
Stack draft (mm of H_2O)	+ 48.26
Excess air	10 %
NOx	170.0 ppm
SO2	0.0 ppm

Reformer # 2A
Time: 11: 19
Date: 04-22-91

Fuel - natural gas:	7,924 Kcal/nm^3
Combustion efficiency	95.0 %
Ambient temperature	18° C
Stack temperature	not measured
O_2	4.79 %
CO	0 ppm
CO_2	9.1 %
Combustible gases	0.0 %
Stack draft	+ 2.54
Excess air	76 %
NOx	78 ppm
SO_2	0.0 ppm

4. Second Analysis Test Results

Reformer # 1A
TIME: 9:42
Date: 04-23-91

This analysis was stopped when the CO reached 2,000 ppm as this is the maximum range of the instrument.

Reformer # 2a
Time: 10: 58
Date: 04-23-91

Fuel - natural gas:	7,924 Kcal/nm^3
Ambient temperature	19° C
Stack temperature	not measured
O_2	8.6 %
CO	0 ppm
CO_2	6.9 %
Combustible gases	0.0 %
Stack draft (mm H_2O)	+ 7.62
Excess air	63 %
NOx	57.0 ppm
SO2	0.0 ppm

5. Boiler Exit Samples Induced Draft Fan Suction

Boiler # 2 - 1
Time: 10: 07
Date: 04-23-91

Fuel - natural gas:	7,924 Kcal/nm^3
Combustion efficiency	82.4 %
Ambient temperature	17° C
Stack temperature	147 °C
O_2	9.0 %
CO	0 ppm
CO_2	6.8 %
Combustible gases	0.0 %
Stack draft (mm of H_2O)	- 231
Excess air	67 %
NOx	151.0 ppm
SO_2	0.0 ppm

Boiler # 3 - 1
Time: 10: 15
Date: 04-23-91

Fuel - natural gas:	7,924 Kcal/nm^3
Combustion efficiency	80.9 %
Ambient temperature	16° C
Stack temperature	117 °C
O_2	9.2 %
CO	0 ppm
CO_2	6.6 %
Combustible gases	0.0 %
Stack draft (mm H_2O)	- 208.3
Excess air	70 %
NOx	123 ppm
SO_2	0.0 ppm

Boiler # 3 - 2
Time: 10: 24
Date: 04-23-91

Fuel - natural gas:	7,924 Kcal/nm^3
Combustion efficiency	84.1 %
Ambient temperature	16° C
Stack temperature	114 °C
O_2	9.3 %
CO	0 ppm
CO_2	6.6 %
Combustible gases	0.0 %
Stack draft (mm of H_2O)	- 228
Excess air	70 %
NOx	142.0 ppm
SO_2	0.0 ppm

6. Active and Reactive Power and Power Factors
9 O'clock to 11 O'clock

#		Unit	Period of Measurement	
			9-10	10-11
1.	Import from the System			
	1.1 Active Power	MW	52.149	52.913
	1.2 Reactive Power	MVAR	27.326	27.882
	1.3 Power Factor	-	0.880	0.880
2.	Own Production			
	2.1 Active Power	MW	24.392	23.656
	2.2 Reactive Power	MVAR	14.488	15.264
	2.3 Power Factor	-	0.860	0.840
3.	Total for Company			
	3.1 Active Power	MW	76.541	76.569
	3.2 Reactive Power	MVAR	41.814	43.146
	3.3 Power Factor	-	0.878	0.871

NOTE: only generator # 1 of the power station was in operation at the time of the April 1991 audit. Generator # 2 was being repaired at that time.

7. Analytical Data for Sulfur (Claus) Plant
April 22, 1991

Data for section "CLAUS"

Raw gas, °C	36
Pressure, atm.	2
H_2S, kg/h	2,448
CS_2, %	19.00
CH_4, %	29.44
N_2, %	69.16
CO_2, %	2.2
Total	2,600 -+ 15%
Supplied air	5,660 kg/h -+ 15%
N_2, kg/h	4,261
O_2, kg/h	1,238
H_{2O}, kg/h	109

8. Composition of the Tail Before Incineration Gas - % vol.

	Project design	Actual
H_2S	1.06	2.2
SO_2	0.53	~ 1.0
S	0.27	~ 0.6
H_2O	33.36	32-34
CO_2	0.95	~ 2
N_2	63.83	to 100 %

Catalyst alcoa - spherical BASF catalyst in second converter.

APPENDIX II.

LIST OF PARTICIPANTS
TALKS AT CHIMCO - VRATZA

#	Name	Profession and Post	*
1.	D. Kalistratov	Deputy General Director	Yes
2.	G. Andonov	Process Engineer	Yes
3.	V. Cholashki	Power Engineer	Yes
4.	V. Panchev	Chief of RECI **	Yes
5.	S. Vankov	Engineer of RECI ***	Yes
6.	M. Nikolov	Power Engineer	Yes
7.	V. Velchev	Power Engineer	Yes
8.	B. Kerefeiski	Control Engineer	Yes
9.	D. Stoev	Process Engineer	Yes

Note: * - connected with energy conservation
** - Regional Energy Control Inspection - Pleven
*** - Regional Energy Control Inspection - Vratza

APPENDIX III.

EQUIPMENT SPECIFICATIONS AND JUSTIFICATIONS FOR PURCHASE

CHIMCO COMPANY, VRATZA

The recommended equipment is listed in order of priority. All equipment supplied must be in metric units, 220 volts/50 hertz, with a two year supply of consumable and critical parts (spares). In addition, two operating and maintenance manuals and appropriate batteries and/or chargers must also be provided. Complete units with all parts for operation to be supplied for use in Bulgaria. All required equipment to be provided, instrument air at 6.5 Bar (Dry) available and delivered to user at 20 PSI. Quotations should provide a complete installation sketch and description of all equipment supplied.

1. **Portable flue gas and emissions analyzer.** ENERAC 2000 or equivalent, to determine volume % (dry basis) CO_2, CO (to 0.2 % or preferably higher), O_2, SO_2, NOx, soot and combustible hydrocarbons. Unit to indicate, and if possible to print out, results. Also to indicate temperature to at least 1,100 °C and to serve as a draft gauge, reading to plus and minus 100 mm of water relative to atmospheric pressure. Must be durable.

2. **Portable temperature indicator for reading skin and internal temperature** to approximately 1,600 °C. Accuracy 99.8 % over entire range.

3. **Infrared Thermometer**. Davis Instruments or equivalent capable of reading surface temperatures, in order to identify heat losses.

Details on the energy and cost savings associated with these items are included on the following page.

Name of Company: Chimco Ammonia/Urea Plant Location: Vratza, Bulgaria Type of Industry: Industrial Chemical						Total Energy Savings
I. LOW-COST EQUIPMENT	COST	ANNUAL SAVINGS	PAYBACK PERIOD (YRS)	TYPE OF SAVINGS	OIL (tons)	GAS (m^3) COAL (tons) ELECTRIC (kwh)
Emissions Gas Analyzer IR Thermometer (savings est. w/temp indic.) Portable Temperature Indicators	$11,097 $ 892 $1,942	$230,000 $5,520	0.05 0.43	combustion heat loss cumbustion heat loss combustion		20,000.00 48,000.00
EQUIPMENT SUBTOTAL	$14,531	$235,520	0.06			204,480.00
II. NO-COST SAVINGS						
NO-COST SUBTOTAL	$14,531	$235,520	0.06			

(ENERGY COST ASSUMPTIONS)
Natural Gas - 1725 leva/1000 m^3
15 leva = $1 US

APPENDIX IV

TRAINING SEMINAR
PRESENTED BY
U.S. ENERGY AUDIT TEAM

CHIMCO COMPANY FERTILIZER WORKS - BULGARIA

I. Introduction

1.1 Economics - Workers

1.1.1 Why Do These Things
1.1.2 Profitability Cost/Unit of Production

1.1.2.1 Raw Materials
1.1.2.2 Utilities - Steam, Power, Water Sewer, etc.
1.1.2.3 Maintenance
1.1.2.4 Labor
1.1.2.5 Packaging, Shipping
1.1.2.6 Overhead, Mgmt., Taxes, Depreciation
1.1.2.7 Profit

1.1.3 Buying Power
1.1.4 Borrowing Power

2.0 Topics for Discussion
2.1 Boiler
2.2 Steam, Distribution & Condensate Recovery
2.3 Heating and Ventilation
2.4 Lighting
2.5 Water, Hot and Cold
2.6 Refrigeration
2.7 Air Compressors
2.8 Pumps
2.9 Process
3.0 Transportation
3.1 Implementation

2.1 Boilers

2.1.1 Excess Air
2.1.2 Stack Gas Analysis, Draft Gauge
2.1.3 Stack Temp - Prevent Condensation and Corrosion
2.1.2 Preheat Air and Water

2.1.2.1 Air Preheat Increases efficiency 2% with every 100°F, 300°F or more gives 5-10% increases

2.1.3 Steam, Fuel and Stack Temp, Press and Flow Measurement
2.1.4 Hi Efficiency Motors and Fans
2.1.5 Fans Have Capacity Control
2.1.6 Insulation
2.1.7 Cogeneration

2.2 Steam Distribution, Condensate Recovery

2.2.1 Keep Lines Short as Possible and Sized Properly, Low Press. Drop.
2.2.2 Recover as much Condensate as Economically Beneficial
2.2.3 Keep Insulation Repaired and Proper Thickness
2.2.4 Check Steam Traps for Proper Sizing and Operation
2.2.5 Match Distribution System and Users as Closely as Feasible Use Desuperheaters Where Hot Steam not required
2.2.6 Leaks

2.3 Heating and Ventilation

2.3.1 Thermostats
2.3.2 Central Units
2.3.3 Secondary Entrances, Double Windows
2.3.4 Efficient Units
2.3.5 Hot Condensate Usage
2.3.6 Insulation
2.3.7 Idling Engineers

2.4 Lighting

2.4.1 Reflectors
2.4.2 Flood Lights
2.4.3 Halide or Sodium
2.4.4 Conservation - State of Mind

2.5 Water, Hot and Cold

2.4.1 Insulation
2.4.2 Exchange

2.4.3 Recirculate and Heat or Cool
2.4.4 Wash Down, Unnecessary Usage, Leaks

2.6 Refrigeration

2.6.1 Match Demand with Supply Temperature Wise Avoid Large ΔT's

2.6.1.1 Economizers, Pump Liquid

2.6.2 Multi Stage Centrifugal, Utilize Intermediate Stages
2.6.3 Avoid Hi Discharge Pressures

2.6.3.1 Vent Non-Condensibles
2.6.3.2 Use Right Condenser Coolant

2.6.4 Avoid Hi ΔP's and Drops Across Valves
2.6.5 Avoid Hi Press. Drop in Low Press. Lines
2.6.6 Use Low Stage Diffuser Vanes
2.6.7 Insulation
2.6.8 Hi Efficiency Motors
2.6.9 Adequate Liquid in Evaporator
2.6.10 Right Refrigerant

2.7 Air Compressors

2.7.1 Hi Efficiency Motors and Compressor
2.7.2 Capacity Control
2.7.3 Don't Compress Higher Than Necessary
2.7.4 Stop All Leaks, Large and Small
2.7.5 Avoid Unnecessary Usage, Air Hoses
2.7.6 Don't Use Inst. Air For Tools
2.7.7 On P.D. Compressors Keep Valves in Good Shape

2.8 Pumps

2.8.1 Hi Efficiency Motors and Pumps
2.8.2 Match Pump Performance With Needs; Don't Oversize on Volume or Pressure
2.8.3 Stop Shaft Seal Leaks
2.8.4 Right Motor Size and Voltage

2.9 Process

2.9.1 Eliminate Large ΔT's and ΔP's
2.9.2 Save Heat, Cross-Exchange or Steam Generation
2.9.3 Eliminate Bottlenecks and Increase Production
2.9.4 Eliminate Waste by Improving Process or Make Use of Waste
2.9.5 Install Analyzers and Controllers to Give Smoother and Closer Control
2.9.6 Cut Down on Waste, Improve Environment

2.9.6.1 Raw Materials - Quality and Price
2.9.6.2 Recycle Off-Spec Material
2.9.6.3 Improve Quality to Eliminate Problems with Users
2.9.6.4 Change Containers to Reusable
2.9.6.5 Improve Mixing in Reactions that Require
2.9.6.6 Improve Catalyst

2.9.6.7 Improve Distillation Column by Enlarging Part, Adding Trays, Changing Feed Point, Altering Operating Pressure, Preheat Feed, Increase Line Sizes, Improve Control by Automation

2.9.6.8 Condense Vents

2.9.6.9 Eliminate Leaks

2.9.7 Insulation

3.1 Implementation

3.1.1 Measurement

3.1.1.1 Steam, Elec., Util.

3.1.2 Analysis of Streams

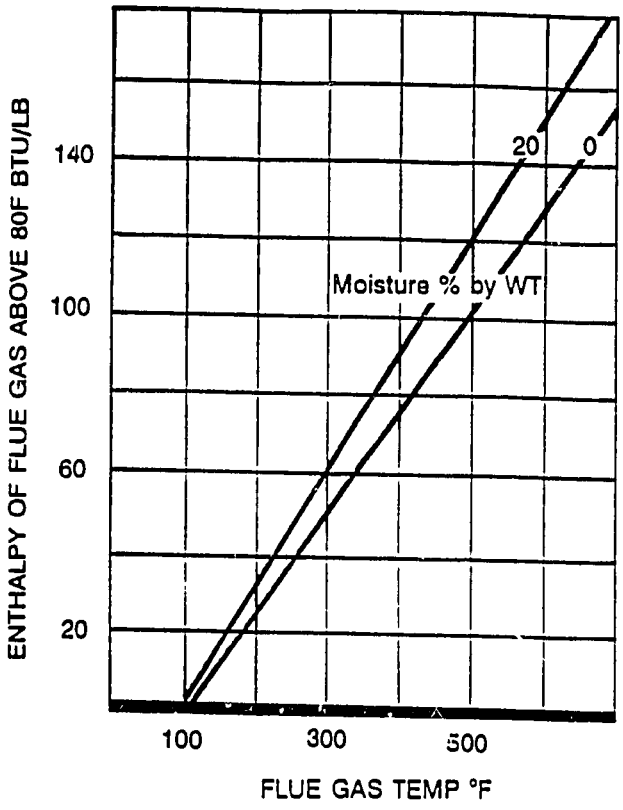
3.1.2.1 Stack Gas, Other Pertinent Losses

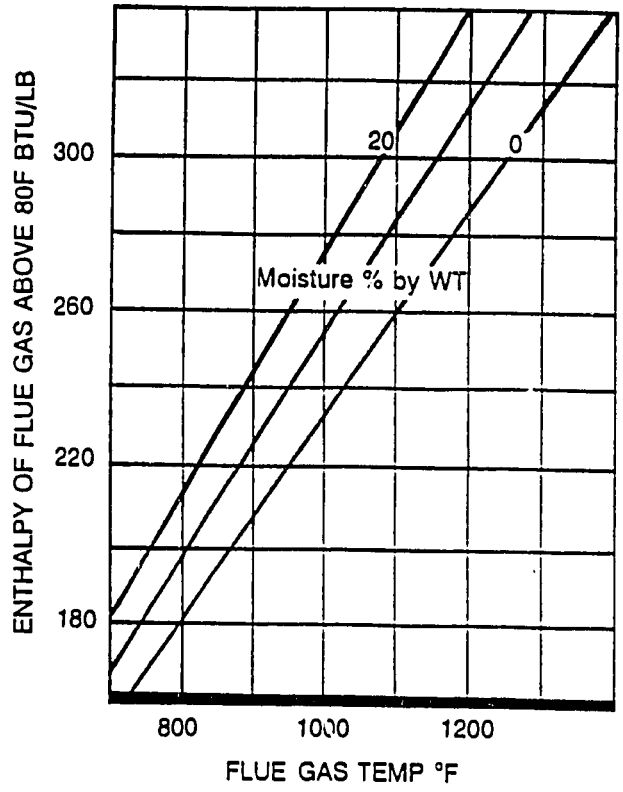
3.1.3 Work on Big User, Losers

3.1.4 Develop Energy Ethic (Everything Costs Money)

3.1.4.1 Energy Committee

3.1.4.2 Contests - Recognition - Rewards


ENTHALPY OF FLUE GAS ABOVE 80F BTU/LB
140
100
60
20
20
0
Moisture % by WT
100
300
500
FLUE GAS TEMP °F


ENTHALPY OF FLUE GAS ABOVE 80F BTU/LB
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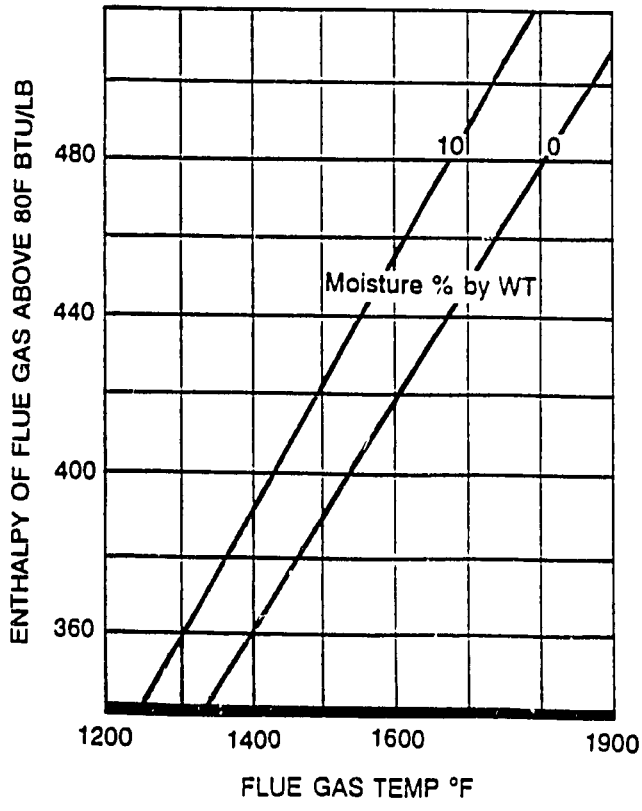
260
220
180
20
0
Moisture % by WT
800
1000
1200
FLUE GAS TEMP °F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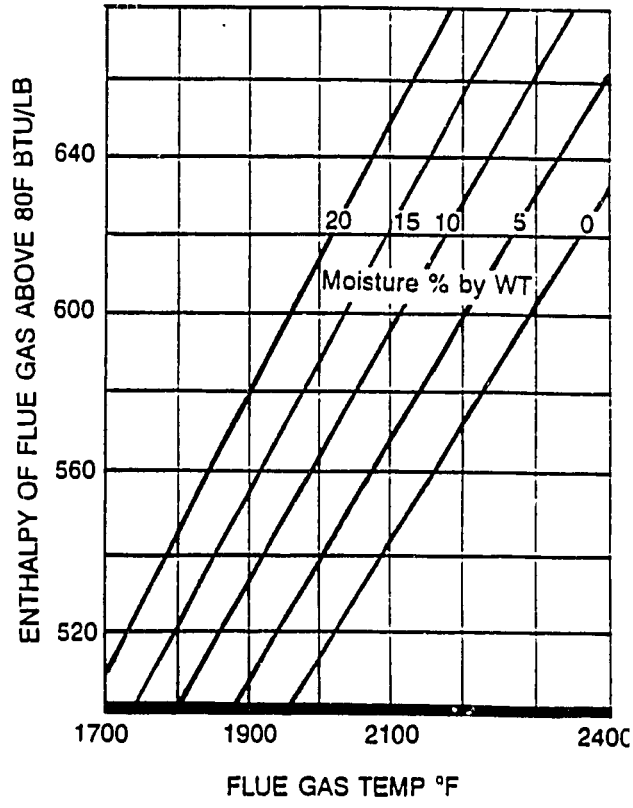
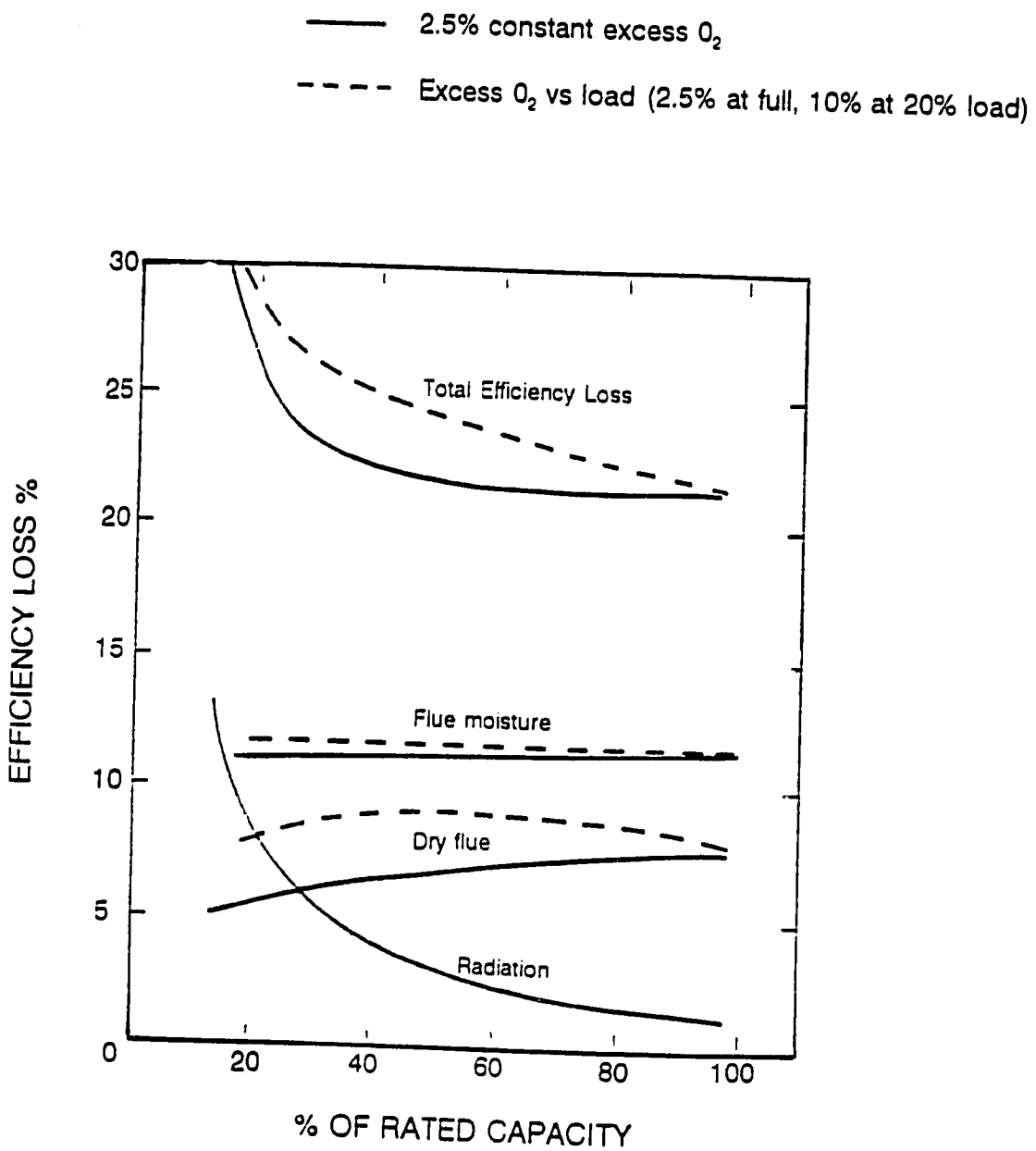
440
400
360
10
0
Moisture % by WT
1200
1400
1600
1900
FLUE GAS TEMP °F


ENTHALPY OF FLUE GAS ABOVE 80F BTU/LB
640
600
560
520
20
15
10
5
0
Moisture % by WT
1700
1900
2100
2400
FLUE GAS TEMP °F

VARIATIONS IN BOILER EFFICIENCY LOSSES WITH CHANGES IN FITTING RATES



APPENDIX V

ADDITIONAL CHARTS AND MEMORANDA

CHIMCO
Tel: (092) 2-22-71, 2-23-81
Telex: 33560, 33530
Telefax: (092) 3-31-18

CHIMCO Company, 3037 Vratza, Bulgaria

MEASURES FOR ENERGY CONSERVATION REQUIRING BARGE INVESTMENTS AND LONG-TERM IMPLEMENTATION

1. Implementation of automized control system for the turbing section of the power station.

2. Mounting of rack-pressure turbine in the power station.

3. Project and implementation of an economizer for utilization for the heat from the flue-cases of the fifth reformer.

4. Reconstruction of the urea production plant with the purpose of savings of energy, improvement of the ecology and the quality.

4.1 It is foreseen that the reconstruction will cover the section for synthesis of urea, the section for concentrating of the urea solution, prilling and the hydrilysis plant.

4.2 Awaited savings

- Decreasing of the consumption of ammonia with 10 Kg/ton or urea or 6,000 tons of ammonia per year.

- Reducing of the consumption of steam with 0.7 Gcal/ton of urea or 420,000 Gcal/year

4.3 Improvement of the quality indices of the urea

	Old Plant	Reconstructed Plant
- Biuret	1.0	0.9
- Moisture	0.5	0.3
- Mechanical Strength	300-400 g/prill	1,400-1,500 g/prill

4.4 Improvement of the ecological indices

4.4.1 Reducing of the emissions of ammonia to the atmosphere and the waste waters from 1,140 kg/h to 450 kg/h or annually they are reduced with 5,520 tons.

4.4.2 Reducing of the quantity of ammonia and urea in the waste waters

	Old Plant	Reconstructed Plant
- Ammonia	70 ppm	To 5 ppm
- urea	200 ppm	To 5 ppm

4.4.3 Reducing of the quantity of urea dust, exhausted to the atmosphere after the prilling towers - below 20 mg/m^3 at world norms 40 mg/m^3.

4.5 The necessary investments are about 25 million US dollars

5. Reconstruction of the ammonia production plant with the purpose of reducing of the consumption of energy.

The reconstruction covers the following sections:

- Replacement of the furnace lining
- Replacement of regenerating heat-exchanger for combustion air
- Saturation of natural gas
- Reducing of process steam consumption
- Replacement of the water-steam system with such at higher pressure and the usage of turbo-generator
- Reconstruction of "synthesis of ammonia" section

I Variant - awaited results

At the realization of complete reconstruction the consumption of energy will be reduced with 1.4 Gcal/ton of ammonia or 700000 Gcal/year.

The necessary investments amount to about 15 million U.S. dollars

II Variant - awaited results

- Reducing of the energy consumption with 1 Gcal/ton of ammonia only by reducing of the natural gas consumption with 117 nm^3/ton of ammonia.
- Reducing of electric energy consumption with 148 KW/t of ammonia.
- Increasing the capacity with 300 t of ammonia per day or 100000 t/year.
- Increasing of the production of CO_2 with 1000 nm^3/h

The awaited investments for this variant are 30 million U.S. dollars.

APPENDIX VI

"ENERGY MANAGEMENT PRACTICES"

EXCERPT OF A PRESENTATION
BY MR. BARRY TUNNAH
AT THE
ENERGY MANAGEMENT WORKSHOP

SOFIA, BULGARIA

JANUARY 1992

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ENERGY MANAGEMENT PRACTICES:
A BRIEF REVIEW

I. INTRODUCTION

Why is energy conservation important? The simplest answer is that it makes a firm more profitable. By practicing good energy management techniques through a well structured and organized company plan, management and employees become more aware of how energy is being used, of the actual costs of energy, and of the methods and equipment that can be used to control and reduce energy waste.

Energy management is a disciplined activity, organized for the more efficient use of energy without reducing production levels or lowering product quality, safety, or environmental standards. The underlying principle is cost effectiveness. Energy management therefore requires both technical and financial evaluations. A systematic and structured approach to energy management is required to identify and to realize full potential savings.

It is apparent that many companies and plants have not identified even simple energy conservation measures with short payback periods, and many who have identified such opportunities fail to implement them. Many studies show that the main barriers to action on energy conservation are:

* lack of knowledge of what is technically possible
* inappropriate financial analysis methods
* management attitudes towards energy efficiency

The greatest successes generally occur at companies where management visibly supports an integrated energy management program.

At the plant level, benefits include:

* lower production costs and higher profits
* better competitive position
* improved ability to withstand future energy cost increases
* improvements in productivity in general
* environmental benefits

The potential benefits of solid energy management are entirely dependent on the nature of the plant concerned. However, savings for a plant which is starting an energy management program are often 20 to 30 percent of present energy consumption, and even more in many cases. For most firms, energy conservation makes very good business sense.

II. THE ENERGY MANAGEMENT APPROACH

2.1 Where To Start

How does a company begin to address the problem of controlling energy consumption and costs? The answer will depend to a great extent on the company concerned -- its current organization and management philosophy. Two points are particularly important.

* top management must be fully committed to controlling energy costs
* the appropriate organization must be set up to implement, and be accountable for, the energy management program

2.2 Top Management Commitment

The decision of company management to control energy costs is a vital first step. This must be clearly stated and understood by all within the company. An important part of top management commitment is to set up the responsible organization for implementing the energy management program. This is commonly at two levels, the Energy Manager and the Energy Committee.

2.3 The Plant Energy Committee

Because energy concerns different departments within a firm, an effective energy management program will involve many people. In some companies, a committee is formed to include representatives of important departments. While unnecessary bureaucracy must be avoided, there are advantages to having an active Energy Committee at the plant:

* it can encourage communications and the sharing of ideas
* it can serve to obtain agreements on energy saving projects which affect more than onE department
* it can provide a stronger voice to top management than a single manager normally could

Membership will depend on existing management structures at the type and quantity of energy used. When should the Committee meet? Normally a monthly meeting is usual, so that monthly production and energy consumptions may be reviewed, including a comparison of actual performance against previously set targets. Other items for the agenda should be a review of the status of energy conservation investments, in progress or planned.

2.4 The Energy Manager

Forming an Energy Committee is not enough: someone is needed to implement the policies and directives of the Committee, and to provide the data needed by the Committee to make decisions. Appointing an Energy Manager is therefore an essential step in implementing an energy management program in most companies. The role will vary from company to company but he will normally be concerned with the following tasks:

* collecting and analyzing energy related data regularly
* monitoring energy purchases

* identifying energy saving opportunities
* developing projects to save energy, including the necessary technical and economic evaluations
* implementing energy saving projects
* maintaining employee communications and public relations

In some companies, particularly the smaller ones, the Energy Manager may report directly to the General Manager or Plant Manager and may be part-time. Larger companies may appoint a full-time Energy Manager and give him one or more technical assistants, thus forming an "energy conservation group". Wherever possible, the Energy Manager or Group should be independent of the main operating departments: reporting to the highest level, such as the Plant Manager, can often give the needed independence and authority.

The skills and experience of the Energy Manager need careful consideration. Technical competence is usually regarded as the primary qualification, although this may not be as important as often thought. In smaller companies, good technical skills may be helpful because the Energy Manager will probably carry out much of the work himself. In a larger company, where technical skills are more readily available, the Energy Manager may well be someone with experience in accounting or general management.

The particular skills that are important for an Energy Manager include administration and communication. Most Energy Managers need to spend much of their time convincing their colleagues and top management to take a specific line of action. Some typical qualifications are:

* familiarity with the plant, processes and quality needs
* ability to collect and analyze data
* knowledge of energy-consuming equipment and factors affecting its efficiency
* engineering skills to size and select equipment, supervise installation and ensure correct maintenance
* ability to communicate and interact well with both plant management and with line operators and maintenance workers
* good judgement to know when to call upon outside help such as consultants or equipment vendors
* proper perspective of the role played by energy in the company, in relation to other elements such as raw materials, capital and labor
* ability to use initiative, a "self starter"

Above all, the Energy Manager needs an open mind to view problems from different perspectives and the skill to convince others that savings are both possible and worthwhile if the right measures are taken.

III. MEASURING ENERGY AND ITS COSTS

3.1 Introduction

Energy management is concerned with the efficient transfer of the energy in fuels and electricity into useful work or heat. It is essential to be able to measure energy inputs and outputs, using various types of meters and instruments, either fixed in the plant or, in some cases, portable. It also requires knowledge of fuel, steam and electricity characteristics to enable comparisons to be made on a common basis.

3.2 The Heating Values of Fuels

An important characteristic of an energy source is the energy contained per unit of mass or volume (the heating value, heat of combustion or calorific value). There are two values associated with fossil fuels, a higher (or gross) heating value and a lower (or net) heating value. The higher heating value includes the latent heat of water vapor formed during combustion as it condenses back to the liquid state. The heating value generally determined in the laboratory is the higher value. The difference between the higher and lower heating values for a fuel is a function of the hydrogen content of the fuel, as this determines the amount of water formed. Some typical ratios of lower to higher heating values are:

	Ratio LHV/HHV
Natural gas	0.90
Fuel oil	0.94
Coal	0.98
Electricity	1.00

In carrying out energy related calculations, it generally makes little difference which heating value is used. The essential principle is to be consistent and use the same basis for all fuels. The convention used should always be clearly stated.

3.3 Unit Energy Costs

An important step to controlling energy costs in a plant is to determine the unit costs of the different energy forms. For example, the cost may be constant, irrespective of the level of consumption (e.g., 150 USD per ton of a specified fuel oil). Some fuels and electricity may have a tariff which varies in accordance with the quantity consumed in a set period of time (e.g., 4.5 US cents per kWh of electricity up to 100 kWh per month, 2.5 cents per kWh thereafter). There may also be other complication factors, such as a "demand charge" for electricity or gas, which is a cost element set by the highest actual level of demand in the period (e.g., 25 USD per kW maximum demand) or even by the maximum contract or maximum allowable connected load. Some forms of energy are also subject to a surcharge for peak period. Electricity consumption may be subject to a "power factor penalty" through which the plant is penalized if it consumes too much reactive power.

For practical reasons, it may often be more meaningful for energy savings calculations for the Energy Manager to compute the **marginal cost** of energy, that is, the cost incurred for consuming one more unit of the particular form of energy (or conversely, the amount saved by consuming one unit less of the particular energy form). A cost-conscious manager will know the unit cost of his energy consumptions and will think in terms of cost savings when he observes operations that are perhaps not optimum or when he suggests priority for a particular maintenance job.

3.4 The Cost of Steam

This is a special case of the unit costs mentioned above. The plant Energy Manager should calculate the cost of steam and advise plant managers. The basic calculation requires the cost of boiler fuel, fuel heating value, water costs, condensate recovery temperature and rate, boiler efficiency and the steam characteristics: these are sufficient for estimating a "marginal" steam cost, one that ignores the labor cost for boiler and steam system operation, maintenance costs and the cost of capital investment. For most practical purposes, the marginal cost is sufficient for making decisions on energy saving actions or investments, as 2these are usually based on differences between costs and savings for various options, and the "excluded" costs are typically the same for all options.

A plant Energy Manager can develop his own graph to show his own plant situation most accurately. A graph provides a simple way of evaluating the relative merits of different fuels, the benefits of improvements in boiler efficiency, or the savings possible from reducing steam use.

3.5 Energy Accounting

Accounting for energy, in its simplest terms, means keeping accounts of energy consumption and energy purchases for the plant. At a more detailed level, it may mean assigning energy costs to different departments. The term "monitoring" is used for maintaining a careful check of energy consumption and, usually, to analyzing energy use.

IV. DATA ANALYSIS

4.1 Graphing the Data

Data should be presented graphically as a better appreciation of variations is almost always obtained from a visual presentation. For example, charts of energy consumption and production against time are drawn at many plants and are usually more enlightening than columns of numbers. However, these graphs tell us little about the relationship between energy and production and therefore are not useful for energy management. Unfortunately, many plants fail to go beyond the drawing of the basic graphs, whereas further simple analysis is needed to give us a great deal more useful information quite quickly.

4.2 Energy-Production Relationships

For a typical plant, a plot of "energy used per month" against "monthly production" can reveal a great deal about energy efficiency. Separate graphs should be drawn from fuel and

electricity use. For most plants, the energy-production graph will be a straight line. There are two components of the energy consumption:

* energy directly related to production (mP)
* energy not directly related to production (e)

The energy used by the plants is the sum of the two components, represented by the basic equation for a straight line:

$$E = mP + e$$

where E is the monthly energy consumption, P is the corresponding monthly production, **m** represents the slope of the line and **e** is the y-axis intercept (daily or weekly data can be used also). Physically, "e" refers to non-production related energy, that is, energy losses or energy used for general plant services:

* lighting, office equipment, ventilation fans
* space conditioning (heating or cooling)
* unnecessary idling of production equipment
* energy in the steam lost in leaks
* radiation and convention heat losses from boilers
* heat losses from steam distribution piping

A graph of **E** against **P** will quickly show the Energy Manager the proportion of energy consumption which corresponds ton non-productive energy (services and losses). If this is high, the Energy Manager can look for ways of cutting down "e", for example:

* replace old lighting units by high efficiency lighting
* eliminate leaks from the compressed air system
* ensure equipment is switched off when not in use

* improve the insulation of the steam distribution system

To cut down on the use of "productive" energy, he might:

* reduce process temperatures to the minimum permissible
* optimize combustion efficiency of boilers and furnaces
* install a heat recovery system

Through such measures, the Energy Manager will seek to reduce the slope of the E-P line as well as reduce "e".

Scattering of points in the E-P graph is a general indication of the level of energy management in the plant. Widely scattered points usually mean that energy use is not properly controlled and operating practices in general are poorly defined and inadequately monitored by supervisors and managers.

4.3 Specific Energy Consumption

Many plants calculate Specific Energy Consumption (SEC) regularly. SEC is the energy used per unit of output, E divided by P. For a typical plant, where the E-P relationship is a straight line, we have:

$$SEC = \frac{E}{P} = m + \frac{e}{P}$$

A graph of SEC against P will therefore be a curve, not a straight line. Figure 4.3 shows a typical SEC-P graph: points lying below the curve represent improved efficiency in energy use relative to the "average performance" represented by the curve itself. Figure 4.3 also shows two points, A and B. The Specific Energy Consumption is certainly lower at B and many engineers think therefore that the point with the highest energy efficiency is B. Indeed, if the energy, production and SEC data are merely shown as a table of numbers (as too many plants do) it is quite easy to draw this erroneous conclusion. When the points are shown on a graph, it becomes clear that B is a point at which energy efficiency is relatively low while A represents a time of good operation at high energy efficiency, albeit at a low production level.

Specific Energy Consumption figures therefore have little meaning unless they are associated with a production rate. Following SEC alone is not the answer to good energy management in any plant where the production rate varies more than a few percent from day to day or month to month.

4.4 The CUSUM Technique

A simple quantitative procedure allows the Energy Manager to evaluate plant performance month by month and to estimate savings made through implementing energy conservation measures (or conversely, the losses occurring due to deficiencies in performance). The method is known as the CUSUM technique, as it relies on calculating "the Cumulative Sum of Differences". The method is applied in the following way:

(1) Plot the E-P graph for a period in which operations were generally similar and during which no major energy conservation measures were introduced.

(2) Find the best fit straight line for the data points.

(3) From each time period, compute the estimated energy use from the straight line equation.

(4) Calculate the differences between calculated energy use and actual energy consumption for corresponding periods.

(5) Compute the cumulative sum of these differences.

If the differences between actual and calculated energy consumption are random, some positive and some negative, then the cumulative sum of these differences should fluctuate around zero. If there are any significant changes in energy efficiency after the "base period" for which the straight line was derived, the differences will accumulate (either positive or negative) and a graph of CUSUM against time will show this clearly.

The Energy Manager can thus determine quantitatively the impact of a change in energy efficiency by examining the CUSUM graph. The procedure may be illustrated by a simple example:

Energy consumption and production data were collected for a plant over a period of 18 months. During month 9, a heat recovery system was installed. Using the plant monthly data, estimate the savings made with the heat recovery system. The plant data are:

	E monthly energy use toe/month	P monthly production tons/month
1	340	380
2	340	440
3	380	460
4	380	520
5	300	320
6	400	520
7	280	240
8	424	620
9	420	600
10	400	560
11	360	440
12	320	360
13	340	420
14	372	480
15	380	540
16	280	280
17	280	260
18	380	500

* Step 1 -- plot the E-P graph for the first 9 months
* Step 2 -- draw the best fit straight line
* Step 3 -- derive the equation of the line

The steps are completed in Figure 4.4 and the equation is:

$$E = 0.4\ P + 180$$

* Step 4 -- calculate the expected energy consumption based on the equation
* Step 5 -- calculate the differences between calculated and actual energy use
* Step 6 -- compute the cumulative sum of differences

These steps are done in the table below:

	E act	P	E calc	Eact-Ecalc	CUSUM
1	340	380	332	+8	+8
2	340	440	356	-16	-8
3	380	460	364	+16	+8
4	380	520	388	-8	0
5	300	320	308	-8	-8
6	400	520	388	+2	-6
7	280	240	276	+4	-2
8	424	620	428	-4	-6
9	420	600	420	0	-6
10	400	560	404	-4	-10
11	360	440	356	+4	-6
12	320	360	324	-4	-10
13	340	420	348	-8	-18
14	372	480	372	0	-18
15	380	540	396	-16	-34
16	280	280	292	-12	-46
17	280	260	284	-4	-50
18	380	500	380	0	-50

* Step 7 -- plot the CUSUM graph -- see Figure 4.5

* Step 8 -- estimate the savings accumulated from use of the heat recovery system

From Figure 4.5, we see that the CUSUM graph fluctuates around the zero line for several months and then drops sharply after month 11. This suggests that the heat recovery system took almost two months to commission and reach proper operating conditions, after which steady savings have been achieved. Based on the graph, savings of 44 toe have been accumulated in the last 7 months. This represents savings of almost 2 percent:

$$\frac{44 \times 100}{\text{energy use in months 12-18 (2352 toe)}} = 1.9\ \%$$

The CUSUM technique is a simple but remarkably powerful statistical method which highlights small differences in energy efficiency performances. Regular use of the procedure allows the Energy Manager to follow his plant performance and to spot any trends at an early date.

4.5 Performance Evaluation

Evaluation of plant performance is best done by regularly comparing the actual energy consumption with the expected consumption. Differences between actual energy use and standards based on past performance will reveal either improvements or a deterioration in performance. The regular data indicate if and where failures have occurred and trigger the necessary remedial action: the data also provide quantified evidence of exactly how successful any energy conservation measures have been.

It is important that performance evaluations be carried out promptly at the end of each month. A review of plant performance is a useful task for the plant Energy Committee. If the analysis is left for too long, it becomes much more difficult to account for any discrepancies that are observed, and of course it is always desirable that corrective measures be taken as soon as possible.

4.6 Monitoring and Targeting

"M & T" is a management approach that enables firms to manage energy as a controllable resource in the same way as they manage other resources such as raw materials and manpower. M and T helps companies eliminate waste and also provides the incentive for further improvement by giving concrete evidence of successful energy conservation activities, from which the economic benefits of energy management become evident.

Central to the success of M and T is the establishment of "energy accountable centers" for which targets can be set. A center might consist of an individual machine, a process department or even the entire site. Recording and reporting procedures for the centers should be set up. Each center should correspond to a nominated individual responsible for operational achievements in that area. Tying resource consumption to those responsible for operational achievement is a key factor in the M and T system since it focusses attention on those with authority to effect improvements in performance. It is also essential that those held accountable for energy performance should be able to assess that performance and have the pertinent information on which to base judgements, decisions and actions to bring about improvements.

Targets may be set using a detailed engineering analysis of operations, or can be developed using historical data such as that described earlier. Graphs of E-P and SEC-P will reveal the occasions when energy efficiency are particularly high, and thus it would be reasonable to use the best historical performance (or something close to that) as a challenging but attainable target.