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ENERGY EFFICIENCY AUDIT REPORT "POULTRY COMPLEX"

Dobritch, Bulgaria

PREPARED BY:

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Washington, DC 20005

and

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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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ENERGY & INFRASTRUCTURE DIVISION
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LIST OF ACRONYMS

A.I.D.	U.S. Agency for International Development
Baumé	measures of specific gravity
BTU	British thermal unit
GCal	giga-calories
IRG	International Resources Group, Ltd.
Kwh	kilowatt hours
lv	levas; Bulgaria currency - at the time of audit, 15 lv = U.S. $1
lx	lux (lumens per square meter)
m^3	cubic meters
mm	millimeter
MWH	Megawatt hours
ppm	parts per million
ROI	return on investment
t	tons

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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 "Poultry Complex", Dobritch, 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 **(Figure 1)**:

<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

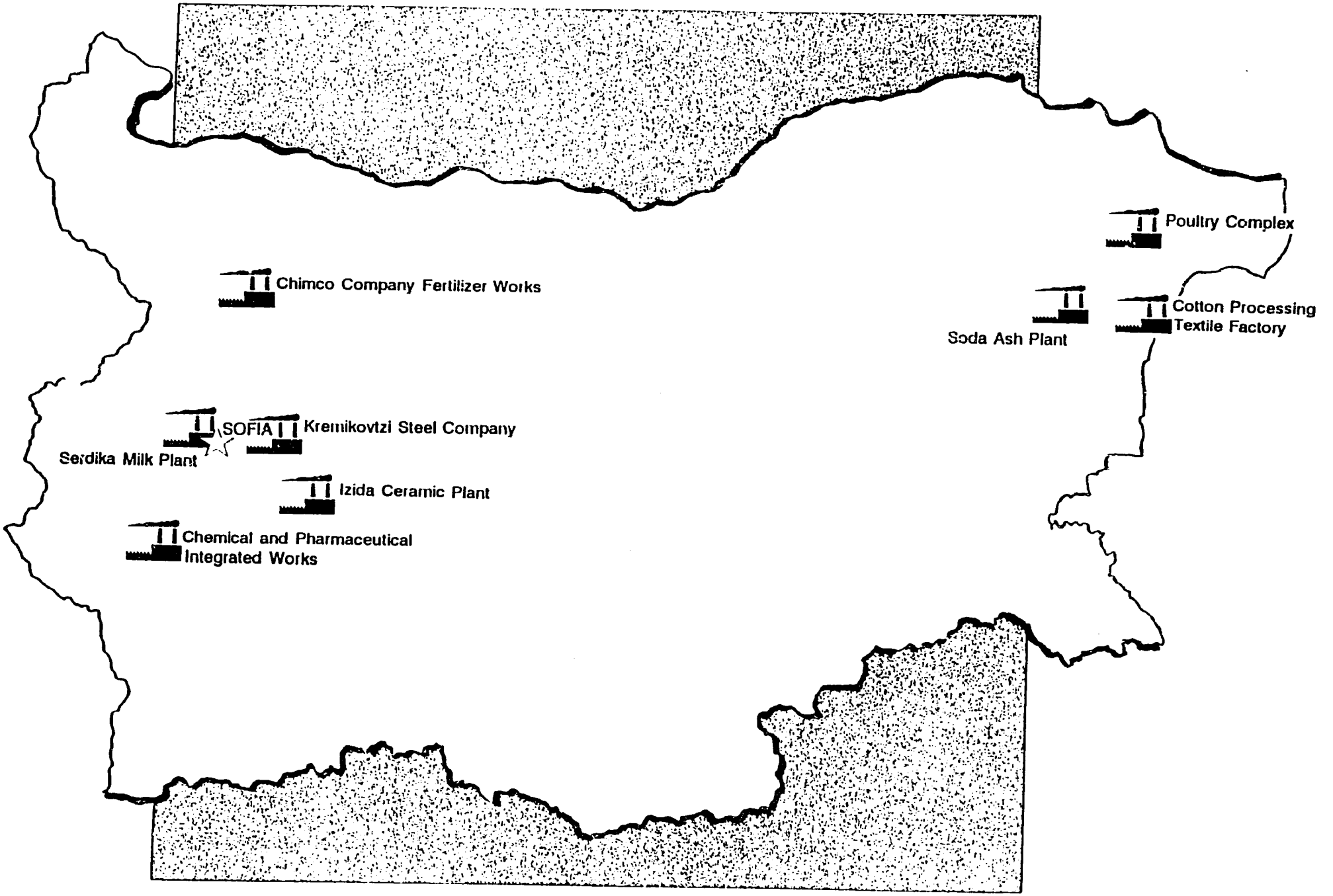


Figure 1. Location of eight industrial plants audited by the IRG team.

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 reforms that encourage energy conservation and improved economic efficiency.

EXECUTIVE SUMMARY

The Tolbuhin Poultry Complex is a vertically integrated poultry processing facility that includes an egg-laying farm, hatchery, broiler farm, and a slaughterhouse, primarily dedicated to chicken processing. Total energy consumption in the plant averages 27,000 tons of mazut (fuel oil) and 18,000 megawatt hours (MWh) of electricity annually.

The plant has a wide range of energy- and production-related concerns, including quality of equipment (e.g. steam traps), high oil consumption at the broiler farm, manure disposal, water supply shortages, and food supply for poultry. Since 1990, the "Poultry Complex" has been drastically affected by a ten-fold increase in fuel costs, a shortage of corn (maize) and an increase in other input costs, as well as changing market demand. All these factors contribute to increase the complex's energy cost per unit of product.

The International Resources Group (IRG) Energy Conservation Audit Team determined that low-cost energy conservation opportunities can provide an estimated savings of more than 1,000,000 leva (lv) per year at a cost of 200,000 lv; all projects recommended by the IRG Audit Team have payback periods of less than one year. These projects include:

- refrigeration improvements
- intensive leak-repair programs
- water conservation efforts
- boiler instrumentation
- condensate return improvements.

In addition, establishment of an Energy Management Program for the plant should be a priority, since it has the potential to yield significant energy savings at a minimal cost. The program should focus on the use of economic investment criteria for evaluating investment options, including broiler farm investments and a water conservation program for the slaughterhouse.

Other short-term recommendations include installing additional instrumentation and condensate recovery equipment, purchasing automatic control systems for the refrigeration units, and providing key energy-training programs at the plant. The U.S. Agency for International Development (A.I.D.) will assist with the financing for some of these recommendations as part of the Emergency Energy Program.

Longer term recommendations include examining current U.S. technologies in manure utilization and an engineering and economic evaluation of broiler-farm heating alternatives identified for the Tolbuhin facility.

Results of the Emergency Energy Program, Industrial Energy Efficiency

As a contribution to the improvement of energy efficiency in this plant, new equipment and instruments were purchased by IRG through the A.I.D.-funded Emergency Energy Program. Items purchased include:

- Portable Infrared Thermometer
- Oxygen Analyzer (3)
- Fluorescent Light Fixtures (various)
- Industrial Stethoscope
- Steam Traps
- Pipe Fittings
- Electric Power Monitor
- Portable Temperature/Humidity Meter
- Pressure Recorder

A summary of additional opportunities for energy savings is included in **Table 1**.

Table 1. Summary of Opportunities for Energy Savings - Dobritch "Poultry Complex".

I. No Cost/Low Cost Measures Evaluated	Investment (lv)	Energy Savings (KWh/year)	Cost Savings (lv/year)	Payback (years)	Recom's
Energy management program	-	3,448,300	1,000,000	0.3	yes
Repair condensate system	50,000	689,700	200,000	0.4	yes
Install 02 & T instrumentation	90,000	344,800	100,000	0.9	yes
Install watt meter & remote demand monitor	-	-	-	-	NEI
Replace incandescent vacuum lamps	36,000	*	72,000	0.5	yes
Replace std. incandescent lamps w/fluorescent lamps	240,000	*	290,000	0.8	yes
Lighting	20,000	-	-	-	NEI
Repair hatchery timers	5,000	69,000	20,000	0.4	yes
Implement & use chemical treated closed water circulation cycle	14,000	237,900	69,000	0.33	yes
Repair insulation	2,400	25,500	7,400	0.4	yes
Change outside insulation of cold storage chambers	12,000	24,500	7,100	1.7	NEI
Provide for regular defrosting	7,600	669,000	194,000	0.08	yes

I.	No Cost/Low Cost Measures Evaluated (continued)	Investment (lv)	Energy Savings (KWh/y)	Cost Savings (lv/year)	Payback (years)	Recom's
Repair cold storage chamber doors		8,000	120,700	35,000	0.25	yes
Purge non-condensables & repair existing purge point		8,800	575,900	167,000	0.08	yes
II.	**Capital Intensive Measures Evaluated**	**Investment (lv)**	**Energy Savings (KWh/y)**	**Cost Savings (lv/year)**	**Payback (years)**	**Recom's**
Install water sprays, clean ammonia coils & close side watering space		12,000	379,300	110,000	-	NEI
Install & use shell-tube condensers		180,000	575,900	167,000	1.1	NEI
Develop a chicken manure utilization process/system		-	-	-	-	NEI
Replace incandescent lamps with compact fluorescent lamps		1,600,000	-	384,000	4.2	no
TOTAL			2,285,000	2,076,500	2,822,500	

NEI - Not enough information available about key investment parameters, including management payback requirements, to recommend implementation of the project. The team does not suggest that these investments are not sound, but stresses that a more comprehensive analysis of the return on these investments should be undertaken before investment funds are allocated.

NOTE - Where necessary for currency conversions, an exchange rate of 15 leva = U.S. $1 has been used in this report, since it was the exchange rate in effect at the time the audit work was conducted. In January 1992, the exchange rate value was closer to 25 leva = U.S. $1.

* - estimated; either through the use of other related estimates, or derived to be an indirect result of another energy conservation measure.

2. PLANT BACKGROUND

The Tolbuhin Poultry Complex includes an egg laying farm, a hatchery, a broiler farm, and a slaughterhouse. Production and energy consumption statistics for the period proceeding the International Resources Group (IRG) energy audit are included in **Appendix II**. These statistics cover the period between April 1990 and March 1991.

Table 2. Plant energy consumption and production statistics, April 1990-March 1991.

Division	Mazut (Tons)	Electricity MWh			Production
		Peak	Mid	Off	
Egg-laying hens & hatchery		1,336	4,076	2,054	
Broiler farm	5,380	800	2,100	1,236	2,270,000 thou
Slaughterhouse	21,800	1,067	3,716	1,306	14,142 tons

Some of the plant divisions began operating in 1962, and the vertically integrated combine was formed in 1975. The Divisions of the facility are located in Dontchevo, Tzarevetz, and Dobritch.

Energy- and production-related problems of concern to management include:

- **Manure disposal** - many experiments have been conducted (except gasification) with no economic success. They now are considering pumping the manure into large earthen tanks about four kilometers away.

- **High oil consumption at the broiler farm** - buildings are located as far away from the boiler house as four kilometers; they also have high ceilings and ventilation-design flaws, causing high oil consumption. This problem is of particular concern since fuel oil prices have increased dramatically since 1990.

- **Water supply shortages** - some wells are 1,200 meters deep and six others are 800 meters, and the water level is reportedly receding. Pumping costs are estimated to be 1.2 lv/m^3 and city water, at 2.3 lv/m^3.

- **Food supply** (corn or maize) is scarce and costly; substitutes result in longer growth periods and decreased profitability.

- **Quality of Bulgarian equipment**, such as steam traps, is poor.

2.1 Boiler Operations

The Audit Team noted boiler sets appeared to be well maintained throughout the complex. The Team examined boilers at various sites throughout the facility, including the broiler farm, slaughterhouse, and the egg laying farm.

Boiler #3 at the Broiler Farm at (Tzarevetz) was operating at approximately 4 tons (t)/hour steam during the first day of the energy audit; Boiler # 1 at the slaughterhouse was also operating at the same steam production level. Since the boilers were not equipped with metering devices, analyzers, or in-situ instrumentation, they operated with considerable excess air and high stack temperatures, particularly Boiler # 1, resulting in low efficiency.

All PKM-4 boilers had an electrically-driven damper with two position possibilities, depending on steam pressure. At position No. 1, one fuel nozzle was operating, and at position No. 2, both fuel nozzles were operating. Tests conducted by the Audit Team included varying damper positions and analyzing stack gases, the results of these tests are presented **Appendices IV and V**. In all test cases, the fuel pressure was held constant.

Subsequent tests were conducted on Boilers #1 and #2 at the egg-laying farm in Dontchevo and Boiler #2 at the slaughterhouse. Unfortunately, the damper of Boiler #2 had to be repaired during the tests, limiting the Team's ability to take measurements. Data for these tests are shown in **Appendices VI, VII and VIII.**

During testing, stack gases were analyzed at various damper positions to provide operators a guide for more efficient settings, until such time as oxygen and temperature measurement equipment could be installed.

2.2 Condensate Systems

The plant had a low level of condensate return, and the condensate system was in general disrepair at the hatchery and the slaughterhouse. Poor-quality condensate pumps, low-quality steam traps, and areas of contamination contributed to inefficient operation of the condensate system at this facility.

Approximately 35% of the condensate from the slaughterhouse was returned from heating and production lines when the steam was not contaminated. Additional data regarding the slaughterhouse condensate system is included in **Table 3**.

Table 3. Slaughterhouse condensate system data, 1990/1991.

Department	Summer April to September 1990				Winter October 1990 to March 1991			
	Steam, Tons		Ret. Cond.		Steam, Tons		Ret. Cond.	
	Cont.	Ind.	Tons	%	Cont.	Ind.	Tons	%
Sausages	230	915	824	72.0	225	898	808	72.0
Smoked Chicken	62	248	224	72.2	40	160	144	72.0
Scald. Tanks								
chickens	1,094	-	-	-	720	-	-	-
hens	547	-	-	-	360	-	-	-
geese	-	7	7	-	-	13	13	-
Heat exchange	-	1,320	500	-	-	1,320	500	37.9
Heating	-	-	-	-	-	2,800	2,200	79.3
Total	1,933	2,490	1,555	35.5	1,345	5,191	3,685	48.5

Due to the lack of automatic level control of the condensate (heat station in building for office use and heat station in storage) and the non-return of condensate from two heat exchangers steam, leaks in the slaughterhouse were about 1,850 tons/year. The temperature of the condensate returned from the space heating systems and sausage and smoked chicken departments was 100-120°C at the time of the audit due to faulty steam traps. Overall losses at this site are about 160 GCal annually.

Analysis of the steam consumption of each department suggested that 16.8% more of the condensate could be recovered than April 1991 practices were achieving. Promotion of more rational use of the condensate heat, instead of steam, through a new heat exchanger for heating water would undoubtedly yield significant energy savings. The potential savings are 54,200 lv/year at an investment cost of about 28,200 lv.

The total potential value of the non-returned condensate from the Poultry Complex was over 1,000,000 lv/year at the time of audit. As explained in the Audit Team's seminar, discussions, and in the meeting with plant management to discuss audit results, the condensate was worth in April 1991 ten times what it was worth the previous year, and should be given a commensurate level of maintenance and operation attention.

Plant personnel were encouraged to repair the systems according to recommendations outlined in this report.

2.3 Electrical Distribution

The egg-laying and hatchery sites were connected to one electricity meter, while the broiler farm and slaughterhouse were each on separate meters. The primary electricity source is 20,000 volts and the secondary is 900 volts through transformers as shown **Appendix XI**. Energy consumption profiles are shown in **Table 2** above as well as in **Appendices I, II, and III**.

2.4 Electricity Demand

Electricity demand was only sporadically monitored, but some attention had been given to taking advantage of the Time-of-Day rate schedule that the Poultry Complex currently utilizes.

The Time-of-Day tariff is as follows:

PEAK - 8 to 10 AM & 6 to 10 PM - 0.56 lv/kWh (approximately 4 c)
MID - 6 to 8 AM & 10 AM to 6 PM - 0.28 lv/kWh (approximately 2 c)
OFF - 10 PM to 6 AM - 0.12 lv/kWh (approximately 9 mills)

Four possible options for taking advantage of the lesser rate period were recommended, including:

1) shifting chick on/off periods (see **Appendix I**)
2) shifting egg laying hen on/off periods.
3) shifting slaughterhouse work hours when on short shift.
4) Adding water storage capacity.

Technicians began evaluating prospects 1) and 2) after conclusion of the April audit; similarly, management considered option 3). The additional water storage project (option 4) was also initiated after the April 1991 audit.

2.5 Electric Motors

In April 1991, there were 545 induction motors at the Poultry Complex with an installed capacity of 3,675 kW. Twelve of these motors had a capacity of 132 kW each, and three had capacities of 160 kW each. The remaining 530 electric motors had a capacity of only 7.5 kW each.

Typically, about five electric motors with capacities of more than 100 kW failed to operate during previous years, due to accidents, breakages, or other failures. Approximately ten low-capacity electric motors failed to operate each month, totalling approximately 120 electric motor failures per year.

Due to the poor-quality repairs, all electric motors decreased in efficiency after repairs, increased their specific power consumption (kWh), and shortened their productive life spans.

Consequently, the IRG Energy Conservation Audit Team recommended new, high-efficiency electric motors be installed, assuming suitable domestic manufacturers can be identified.

2.6 Lighting

During the audit, the IRG Team examined lighting conditions throughout the complex, but the Team only took detailed measurements of lighting fixtures and conditions at the broiler farm and slaughterhouse.

At the Broiler Farm, electric energy costs averaged approximately 0.29 lv/kWh in April 1991. This facility operated approximately 5,600 hours/year. The installed lighting capacity of the broiler farm facility was 379 kW, with approximately 7,785 lamps. Of these, 7,190 lamps were of the 294 kW incandescent type, and were primarily found in working departments. Lighting at this site was timer-controlled, and remained switched on from 12 to 6 p.m., depending on the chickens' stage of growth. The lighting level (in lx) was changed smoothly by a rheostat, and was adjusted depending on the chickens' growth. **Table 4** outlines these adjustments.

Table 4. Chicken growth and lighting levels.

growth	lighting level
0 - 2 weeks	80 lx
2 - 4 weeks	15 - 20 lx
4 - 20 weeks	10 - 15 lx
Egg-laying growth	20 lx

After reviewing conditions at the broiler farm, the Team recommended several ways to reduce energy consumption through low-cost investments and operational changes. These recommendations are outlined in **Sections 5 and 6.**

At the slaughterhouse, the installed lighting capacity was 101 kW. There were 130 three-tube fixtures in the working departments with a total capacity of 26 kW. Approximately 35% of these lamps did not work at the time of the audit, and were burned out or had been removed.

Lighting measurements taken in two working departments suggested that levels were far below standards. For example, in the Packaging Department for hearts, livers, and gizzards, measurements registered from 20 to 100 lx, far lower than standard norm of 600 lx. Similarly, in the Sausage Department the measured intensity of light ranged between 20 and 250 lx, again lower than the standard norm of 450 lx. These results indicate that lighting levels in these departments were sufficiently below standard, resulting in a decrease of personnel productivity between 5 and 8%, and ultimately affecting output and quality of the product.

In the slaughterhouse, power consumption of one line of lamps was measured before and after replacement of burned out bulbs. The results demonstrated that consumption before replacement was 76 watts per lamp, whereas after replacement, specific consumption was

reduced to 56 watts/lamp, showing losses of 20 W for each burned-out lamp. Based on this, the Team recommended burned out lamps be replaced or the entire fixture disconnected.

2.7 Heat Balances - Steam

Again, there was little statistical information available in the plant on heat balances for the component plants in the Poultry Complex, a situation which appeared to be fairly common in Bulgaria. Time did not permit comprehensive heat balance assessments of the four plants during the brief audit. However, steam leak, condensate leak, and insulation surveys were conducted. These surveys indicated savings potential for the Slaughterhouse alone was very high. These also include:

- Condensate system reconstruction
- Steam leak repairs
- Insulation replacement
- Process design investigations

All these opportunities are significant, but the condensate, system initiatives represent the best opportunities for increased efficiency, since approximately 52% of the condensate appeared to be recoverable at that time.

The balance of heat losses due to steam leaks, lost condensate and non-insulated surfaces is shown in **Table 5**.

Table 5. Balance of heat losses.

Losses	Heat Power		Losses/Savings
	Gcal/hr	mln BTU/hr	lv/yr
Steam Leaks	0.156	0.393	150,000
Non-Insulated Surface	0.033	0.083	15,800
Lost Condensate	0.078	0.197	40,000
TOTAL	0.267	0.673	205,000
Note: The savings are calculated on the base of fuel price of 1,200 lv/t.			

Rough estimations of losses were 20.9% for fuel oil consumption (Mazut), which was approximately 930 tons/year. The boiler efficiency was about 79%, and the specific heat of fuel was 9.5 Gcal/t.

The heat balance of the factory included:

- 6 - 7% losses from to steam leakages
- 3 - 4% losses due to lost condensate

- 1 - 2% losses due to non-insulated surfaces
- 0.5 - 1% losses for mazut preheating in rail-way tanks
- 2% losses from distribution heating system

The total amount of losses varied between 10 - 13%. During average steam production of 2.38 GCal/hour, the useful energy for plant processes was between 2 - 2.13 GCal/hour to 3 and 3.5 T/hour steam.

The total condensate return was about 35 - 45%, but only 6 - 16% had the enthalpy between 60 - 70 kcal/kg. Almost 29% of the condensate was within a 100 - 110°C temperature range, and the heat of evaporatization was not fully used. This suggested the need for pressure and temperature measurement equipment to be installed at the significant steam stations in the plant.

2..8 Heat Balances - Refrigeration

The Slaughterhouse has quick freeze and cold storage systems that are critical to operations. These systems also offer substantial savings opportunities. Poor operating conditions in these systems also prompted some recommendations for training listed in **Section 3**.

The principal scheme for the refrigeration station installation is shown in **Figure 2**.

There were 10 compressors, 2V8-200 type, and 2 compressors, V5-200 type, with 132 kW power, and a cooling capacity of 125,000 kcal/hr per compressor. The number of working compressors in the summer and winter and the objects of cooling are listed in **Table 6**.

Table 6. Number of Working Compressions

	Quick freezing tunnel	Freezing tunnel "Rodopa"	Storage for freezing production	Total
Summer	6	1	1	8
Winter	4	1	1	6

The daily consumption of electricity for the refrigeration installation, under average production conditions, was estimated to be 10,000 kWh/day or 3,500,000 kWh/yr. There were 12 KIK-250 type ammonia condensers. These were fan spread, water-cooled ammonia condensers; each included three fans, two water spread tubes, an ammonia coil, and bottom-type water collector.

Construction of the condenser is shown in **Figure 3**.

FIGURE 2. Refrigeration station scheme.

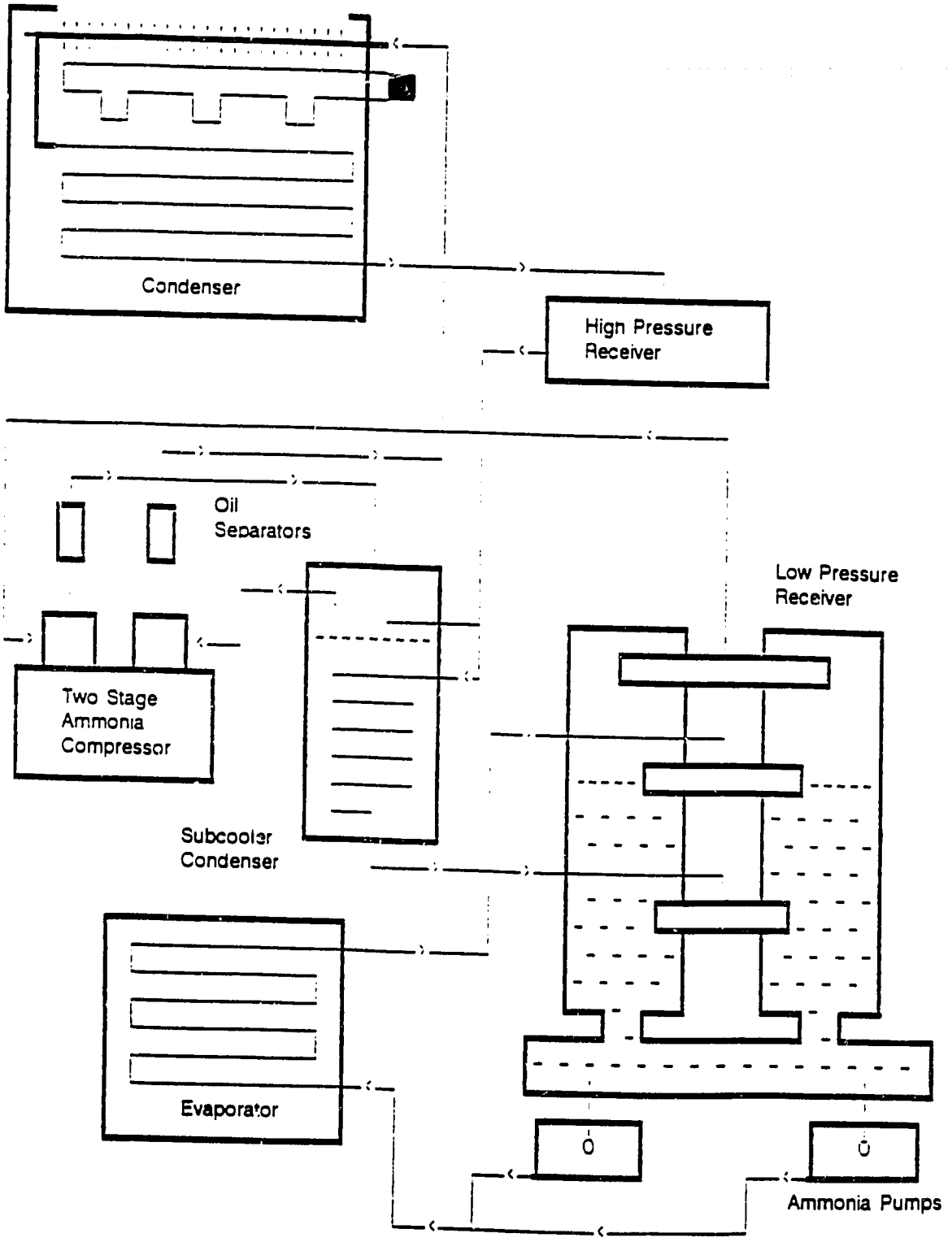
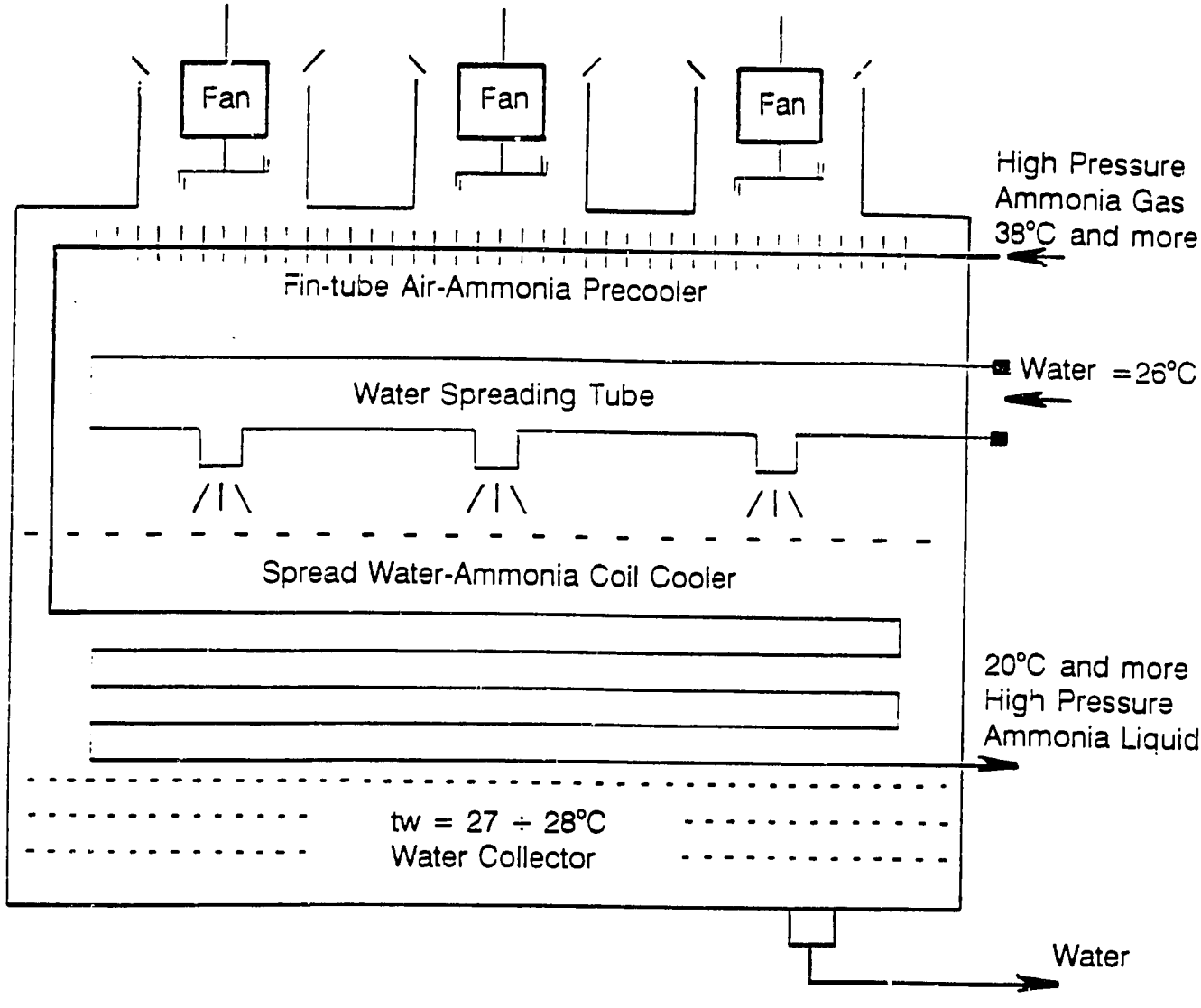


FIGURE 3. Schematic diagram of the Poultry Complex ammonia condenser.



Inspection of the refrigeration system showed that there were 30 fans in place, although only 21 of them were working. The outside surface of the heat exchanger was covered with 1 - 2 mm organic hard layer, because the cooling water was very hard with usually high levels of calcium carbonate ($CaCo_3$) and magnesium carbonate ($Mg\ CO_3$) (21° Baumé). Due to the build up of the calcium carbonate scale only 30 - 50% of the ammonia coil surface had been cooled. In addition, there was evidence of poor cooling, since the temperature difference of inlet/outlet cooling water was 1 - 2°C. There was high oil consumption of about 10 - 12 Tons/yr.

The inspection also revealed high temperature and pressure of condensation. The desired pressure of condensation is 12 kg/cm^2, but the real pressure of condensation was between 14.5 - 17 kg/cm^2. This 30% excess pressure led to an approximately 30% increase in compressor electricity consumption. In this case, calculations showed additional electricity consumption due to the high pressure of condensation was 1,120,000 kWh/year. At a price of 0.28 lv/kWh, this energy was valued at about 310,000 lv/year.

The evaporators of the refrigeration installation were located in freezing tunnels and cold storage chambers. All tunnels had fan-air circulation. The project air temperatures are given below in **Table 7.**

Table 7. Air temperature - refrigeration system.

	Quick freezing tunnel	Freezing tunnel "Rodopa"	Storage for freezing production
Number pcs	1	2	4
Temperature °C	-30 to -40	-25 to -35	-25

The Audit Team also observed there was no temperature evaporation measurement equipment in any of the plants. Moreover, the tunnel evaporators were manually defrosted once or twice per week, because there was no automatic defrost cycle system. Storage evaporators were defrosted once per year, and all evaporators were covered with layers of ice 25 - 35 cm thick. These conditions are not conducive to efficient energy use.

Almost all doors to the cold storage chambers were inefficient. There were 30 - 100 cm^2 openings at each door. These openings resulted in a high infiltration and additional cooling load of about 1 - 2%. In addition, the insulation of cold storage chambers was badly deformed and wet. The area was about 100 m^2, and the surface temperature was about 7°C. At an ambient temperature of 12°C, cooling losses totalled 5,000 kcal/hr.

At a COP of 1.5 for this kind of compressor, additionally consumed electricity is 3.3 kW, or for 24 hours about 80 kWh. The additional electricity consumption is 25.000 kWh/year or 7,100 lv/yr. Due to abnormal defrosting cycle in the cold storage chambers, it is estimated that 3 to 10 times more electricity is consumed. Currently, the electricity consumption is about 1,050,000 kWh/yr with minimal losses of about 690,000 kWh/year worth 194,000 lv/year.

3. ENERGY MANAGEMENT

3.1 Energy Management Structure

Prior to the April 1991 audit, the management of the Poultry Complex did not have an Energy Management Program, nor did it have staff members with appropriate technical and economic training to institute a comprehensive energy conservation program. The plant had no formal procedures or organizational structure for identifying and implementing energy savings or other investment projects. Moreover, due to lack of measurement instruments, little actual energy consumption data had ever been collected in the plant. Similarly, the management had no formal system for using economic criteria to evaluate investment projects. However, the management's cooperation with the Emergency Energy Program Team and local energy consultants demonstrated a clear concern for energy management issues. Consequently, the establishment of an Energy Management Program and appropriate personnel training to facilitate the implementation of the Program are high management priorities.

3.2 Energy Management Seminar

Recognizing the importance of energy management in determining the overall efficiency of industrial energy use, the Energy Audit Team presented a seminar at the Poultry Complex 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.

Issues crucial to any discussion of energy management include:

Economic Principles - it is important in any energy management regime to view energy costs as production input costs. In addition, concepts related to the benefits and costs of energy efficiency investments and return on investment must be analyzed. The in-plant seminar also attempted to define the economic benefits and the costs of conservation opportunities. This was coupled with an introduction, explanation and the determination of the Return on Investment (ROI) along with the pay-out time of individual opportunities as tools for ranking and prioritizing projects.

Energy Management Programs - specific programs which could help 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. Such a mechanism might require the purchase of and training in the use of computer accounting software, etc.

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
- boiler operations
- refrigeration
- air conditioning

Issues addressed at the April seminar were dealt with in more detail at the January 1992 Energy Management Workshop in Sofia, at which a representative of the Poultry plant made a presentation. The excerpt of a presentation on Energy Management Practices given at the January seminar is included in **Appendix VI**.

3.3 Training Requirements

Training requirements for this plant vary by personnel category. At a minimum, all plant personnel should receive basic training in energy awareness. Technical and managerial personnel should receive more extensive training in economic and technical areas through seminars, training retreats, and where feasible, outside training courses at technical institutes.

Moreover, 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 such key areas as:

- energy cost accounting - this type of training would be particularly useful if it involved practical skills training related to 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 - again, training in investment planning would be extremely useful if it included familiarization with the tools used in some energy investment planning programs such as "Envest".

Refresher courses and subsequent programs for all plant personnel should focus on specifics of the plant's energy management program; key energy waste areas; energy

conservation opportunity identification and solutions; and energy conservation monitoring and incentive schemes. In addition, training initiatives for managers should address economic issues (with varying degrees of specificity depending on job requirements) including investment evaluation tools, plant profitability, export benefits and principles, employment issues. Finally, training programs for department heads, engineers and technical specialists should address a variety of technical issues including thermodynamics (as applied to both steam and refrigeration systems), engineering economics, and detailed energy management techniques.

4. ENVIRONMENTAL CONSIDERATIONS

The manure disposal issue potentially has both environmental and energy implications since gasification and subsequent use of manure as a fuel could be a viable solution to this environmental problem. Unfortunately the Dontchevo facilities use large volumes of water as a part of the manure removal process. As is known from experience with wood and sludge disposal and gasification projects, mechanical or thermal removal of water is usually not economic.

The IRG Team recommended a brief review of recent U.S. technical literature for the plant managers to evaluate current solutions to the manure issue.

Other environmental issues were not apparent. It was interesting to note that the Slaughter House Director is a Doctor of Veterinary Medicine. Also notable was the fact that the Dobritch Combine had passed the health and sanitation tests and inspections of numerous countries to permit the plant to export the products.

5. ENERGY EFFICIENCY IMPROVEMENT OPTIONS

Listed below are options for improving energy efficiency use within the plant. Clearly, all these practices and projects will help conserve energy in the facility. However, given the reality of scarce resources for implementing these projects, the IRG Audit Team recommended some be given priority; this prioritization is included in **Section 6**. Nevertheless, this section outlines the wide variety of options that are available for energy efficiency improvement. The ultimate decisions regarding implementation or alternative options will depend upon the criteria set by the plant management, including acceptable payback periods, and upon the overall corporate strategy.

5.1 No Or Low Cost Options

For the purposes of this paper, "no cost" items refer to projects which will be initiated at the expense of the plant, in cases where expenditures are involved. Although few of these recommendations are literal "no-cost" propositions, they should all be possible to implement within the existing framework of plant expenditures (i.e. leva purchases, improved maintenance and housekeeping). Local investment and installation labor for low cost initiatives will be provided by the plant. Hard currency for some of the low cost items will be available under the A.I.D. Emergency Energy Program; a summary of purchases made under this is included in **Section 6**. Justifications and specifications for these items are included in **Appendix IV**.

1. **Adoption of an Energy Management Program.** This "no cost" project has potential savings of over 1,000,000 lv/year with ROI's in excess of 100%, and a payback period of less than three months.

2. **Repair and restore condensate systems.** This project would cost approximately 50,000 lv, and result in savings of 200,000 lv/year, with a ROI of 100% and a payback period of 0.4 years. The U.S. Agency for International Development will help finance part of this project.

3. **Install oxygen and temperature instrumentation for Stack Gas.** This project would cost 90,000 lv, resulting in savings of 100,000 lv/year, with a payback period of 0 9 year. The U.S. Agency for International Development will also help finance part of this project.

4. **Install watt meter and remote demand monitor in the hatchery building.** This is an experimental project, and as such no investment costs or project benefits have yet been calculated.

5. **Lighting Improvements**

   - **Replacement of incandescent vacuum lamps by incandescent krypton lamps.** This project would cost approximately 36,000 lv, and would achieve energy savings of 15%, valued at 72,000 lv/year, with a payback period of .5 years.

- **Replacement of incandescent lamps by fluorescent lamps.** The project, which could be approached incrementally, would cost approximately 240,000 lv to implement completely. The expected economic effect is about 60% savings, or total of 290,000 lv/year, with a payback period of .82 years. Moreover, since the average time of operation of an incandescent lamp is 1,000 hours versus 6,000 hours for a fluorescent, additional savings should be taken into consideration. The U.S. Agency for International Development will assist with the financing for part of this project.

- **Replacement of Burned Out Lamps.** A program to replace burned out lamps and disconnect empty fixtures would cost approximately 20,000 lv. For this plant the savings resulting from this activity are unknown. Thus more data would be required to evaluate this investment.

6. **Repair timers in the hatchery.** This project would cost 5,000 lv and result in savings of 20,000 lv/yr, at a ROI of 100% and a payback period of 0.4 year.

7. **Implement and use chemical treated closed water circulation cycle for condenser cooling.** This project would cost 14,000 lv and result in savings of 69,000 lv/years, at a ROI of more than 100% and a payback period of 4 months.

8. **Repair insulation.** This project will cost an estimated 2,400 lv and yield savings of 7,400 lv/year. This represents a ROI of more than 100% and a payback period of 5 months.

9. **Change and use appropriate outside insulation of cold storage chambers, with water proof protection layer against cold water condensation.** This project would require an estimated 12,000 lv to implement, and would result in savings of 7,100 lv/year, with a payback in 1.7 yrs.

10. **Refrigeration Improvements.**

- **Provide for regular defrosting cycle in cold storage chambers.** The cost of this project will be 7,600 lv, and it will yield savings of 194,000 lv/yr, with a ROI of 100% and a one month payback. This new arrangement of ready production in cold storage chambers is recommended for periodic defrosting of evaporators. New arrangements should provide access (with a path 1.5 m wide) to all evaporators.

- **Repair or change all doors of cold storage chambers and freezing tunnel type "Rodopa" to avoid infiltration and additional cooling load.** This change will require 8,000 lv and result in savings of 35,000 lv/year. This represents a ROI of greater than 100% in 3 months.

- **Purge Non-Condensables periodically to maintain low pressure of condensate.** To repair existing purge points and install an additional one to improve removal of non-condensables from refrigeration system would

cost 8,800 lv, and result in savings of 167,000 lv/yr. This has a ROI of 100%, with payback in one month.

- **"No Cost" Refrigeration Process Improvements.** In addition to the projects outlined above, the Audit Team recommended a number of maintenance and operation changes pertinent to refrigeration energy conservation opportunities.

  - **Optimize Defrost Cycle.** Set the defrost cycle based on seasonal, humidity, and load requirements.

  - **Properly Sequence Compressors.** Manage compressors so that each operates at or near full capacity.

  - **Reduce Condensing Pressure.** Operate the refrigeration system at the lowest condensing pressure possible with existing condenser capacity.

  - **Maintain Cooling Tower and related equipment, and treat cooling tower water.**

  - **Load Management.** Manage both supplementary and product loads.

5.2 Capital Intensive Options

The following four capital intensive energy efficiency options were discussed with plant management, and initial comments were made concerning each. However, since requisite data including plant payback period requirements, were not available for the last three options and feasibility studies had not been conducted for these projects, the Audit Team was not in a able to recommend any option other than the first one. The IRG Energy Conservation Audit Team recommends a comprehensive evaluation be made of both the technical and economic aspects of the other three investments prior to the commitment of any funds.

1. **Install water sprays, clean ammonia coils, and close side watering space, as a first step of improving poorly functioning condensers.** This project will cost 12,000 lv and save 110,000 lv/year, a payback period of .1 years.

2. **Replace poorly functioning condensers, with shell-tube type condensers.** The cost of this capital intensive project would be at least 180,000 lv, and is estimated to result in savings of 167,000 lv/yr. This project has a payback period of at least 1.2 years. Thus, without information about plant management economic payback criteria, the Audit Team cannot recommend this project.

3. **Develop a chicken manure utilization process and system.** No data is available on this project.

4. **Replace incandescent lamps with compact fluorescent lamps**. The cost of this project would be 1.6 million lv. with an expected economic effect of 60% energy savings, or total of 384,000 lv/yr. Since the payback period for this investment is over four years, the Audit Team does not recommend that this investment be undertaken now.

6. RECOMMENDATIONS AND CONCLUSIONS

The following recommendations and conclusions represent those areas which the Audit Team believes should be a priority for the Poultry Complex.

6.1 Improved Energy Management

The priority areas for corporate energy management at the Poultry Complex should be the establishment of training initiatives designed to improve energy efficiency awareness, data collection techniques, energy cost accounting, and energy investment planning capabilities and the establishment of a comprehensive energy management program, including an energy management committee.

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 attempt to conduct a comprehensive evaluation of all investment options, both low cost and capital intensive to determine the cost of the required investment and the payback on the investment (in terms of energy saved, losses avoided or production increases), to prioritize investment opportunities.

6.2 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 energy management, condensate and steam systems, lighting, instrumentation and dryers, in addition to changes in the operation of the boilers.

1.	**Energy Management**	The Audit Team recommends the Plant establish an Energy Management Program to ensure awareness of energy issues is established at the Textile Plant, and appropriate mechanisms exist for monitoring energy use and encouraging energy savings. Suggested organizational plans were discussed and reviewed with the Director and staff. Some commitments were made by plant personnel to upgrade the skill levels of engineers and technicians, particularly in steam and refrigeration physics/operation.
2.	**Condensate**	Repair and restore the condensate systems at the Poultry Plant Hatchery, Broiler Farm and Slaughter House. Provide a limited amount of equipment (pumps, fittings and traps) to demonstrate a workable system. Repair and replace insulation.

3.	**Instrumentation**	Prioritize the purchase, installation, and use of energy meters and portable instruments to identify energy waste areas, monitor improvements, and provide data for evaluation of energy efficiency investments. Priority items should include oxygen analyzers, recording meters, temperature monitors for stack gas, electric power monitor, and condensate pump.
4.	**Steam Systems**	Repair steam leaks, replace insulation on steam lines, and replace steam traps.
5.	**Lighting**	Replace incandescent vacuum lamps with incandescent krypton lamps and fluorescent lamps. Replace burned out lamps, and disconnect ballasts.
6.	**Timers**	Repair timers in the hatchery.
7.	**Condensers**	Implement and use chemically treated closed water circulation cycle for condensers cooling.
8.	**Refrigeration**	Provide for regular defrosting cycle in cold storage chambers. Repair or change all doors of cold storage chambers and freezing tunnel type "Rodopa" to avoid infiltration and additional cooling load. Purge non-condensables periodically to maintain low pressure of condensate. Optimize defrost cycle. Properly sequence compressors. Reduce condensing pressure. Maintain cooling tower and related equipment, and treat cooling tower water. Institute load management programs.
9.	**Information/ Feasibility Study**	Gather recent data and proposal(s) for gasification of manure systems and installations. Also conduct cursory literature search on state-of-the art production costs of fryers and eggs in the U.S. Compile limited amount of fryer and egg production technological publications to evaluate these technologies. From the foregoing information, conduct a cursory viability analysis of the Dobritch facility as significant exporter.

6.3 Recommended Capital Investments

Equipment Purchased Under the Emergency Energy Program.

1.	**Infrared Thermometer**	The portable infrared thermometer will be used to identify damaged insulation or heat losses from other sources throughout the plant. The cost of the item was $437 and the estimated savings from this instrument are expected to be $1,200 per year.

2. **Oxygen Analyzers** These items will be used to monitor excess air in the combustion process. The cost of these items was $1,428 and the savings from the items are estimated at over $2,600 per year.

3. **Fluorescent Lights** More efficient fluorescent lights will replace some of the burned out fixtures within the plant, achieving a higher level of light at a lower energy consumption rate. The cost for these fixtures was $14,250 and the savings are estimated to be approximately $19,000. However, additional economic savings will be achieved through productivity increases, that will bring the payback period for this item to well under a year.

4. **Industrial Stethoscope** The industrial stethoscope will be used to check for steam trap leakages. The cost of this item was $451, and the resulting energy savings are valued at $4,200 per year.

5. **Steam Traps** The high quality US-made steam traps will improve steam utilization within the plant and avoid large energy losses associated with steam leaks and faulty steam traps. This investment cost $8,434, and its resulting energy savings are valued at nearly $8,500.

6. **Pipe Fittings** The pipe fittings will be used along with the steam traps to improve the steam utilization within the plant. This investment costs $5,149 and will save an estimated $5,500 worth of energy per year.

7. **Power Monitor** The electric power monitor, which cost $5,870, will be used to monitor electric energy use throughout the plant, where in-situ meters are not available. The monitor will help energy managers to identify energy waste areas, monitor improvements, and provide data for evaluation of energy efficiency investments.

8. **Temp/Humidity Meter** The temperature and humidity meter and recorder, which cost $557 and will yield savings of $24,00 will be used to assist in the periodic purge of non-condensables to maintain the low pressure of condensate. This would allow for significant energy savings in refrigeration.

9. **Pressure Recorder** The pressure recorder will be used as part of the plant Energy Management Program, and will allow energy managers to monitor pressure in the plant.

Other Recommended Capital Projects

Although the Agency for International Development is not in a position to finance all of the opportunities available for energy efficiency improvements, the IRG Audit Team recommends a number of other investment projects for the plant to implement on its own. These recommendations include:

1. **Insulation** — The plant management should purchase insulation for condensate and steam lines as part of a comprehensive condensate and steam system improvement initiative.

2. **Instruments** — To the extent that the U.S. Agency for International Development is unable to fund all necessary instrument purchases, the plant should make it a priority to purchase measuring and metering devices for temperature, pressure, oxygen, and electricity.

3. **Water Sprays** — To begin the process of cleaning and improving the condensers, the plant should purchase the required water sprays.

APPENDIX I

PRODUCTION AND ENERGY CONSUMPTION STATISTICS -

EGG LAYING & HATCHERY (Dontchevo)

	Electric Power per kWhr				Cost
Month	Off Peak	Mid	Peak	Total	
4-90	194,000	120,000	144,000	458,000	-
5-90	184,000	532,000	120,000	836,000	-
6-90	240,000	448,000	120,000	808,000	0.991
7-90	224,000	440,000	112,000	776,000	0.989
8-90	248,000	504,000	128,000	880,000	0.975
9-90	176,000	448,000	88,000	712,000	0.973
10-90	168,000	328,000	128,000	624,000	0.993
11-90	168,000	328,000	136,000	632,000	0.993
12-90	136,000	280,000	120,000	536,000	0.996
1-91	104,000	248,000	96,000	448,000	0.997
2-91	124,000	200,000	80,000	404,000	0.998
3-91	88,000	200,000	64,000	352,000	0.995
Total	2,054,000	4,076,000	1,336,000	7,446,000	

APPENDIX II

PRODUCTION AND ENERGY CONSUMPTION STATISTICS - FRYERS & HENS (Tzarevetz)

Month	Electric Power per kWhr				React. (kVA)	Mazut (tons)
	Off Peak	Mid	Peak	Total		
3-90	120,000	160,000	68,000	348,000	72,000	720
4-90	104,000	180,000	72,000	356,000	60,000	120
5-90	92,000	160,000	76,000	328,000	64,000	120
6-90	108,000	176,000	60,000	344,000	64,000	190
7-90	96,000	156,000	60,000	312,000	44,000	100
8-90	100,000	164,000	56,000	320,000	48,000	120
9-90	92,000	176,000	80,000	348,000	44,000	300
10-90	92,000	184,000	84,000	360,000	48,000	250
11-90	80,000	200,000	60,000	340,000	52,000	500
12-91	100,000	220,000	64,000	384,000	56,000	750
1-91	140,000	164,000	60,000	364,000	48,000	560
2-91	112,000	160,000	60,000	332,000	48,000	992
Total	1,236,000	2,100,000	800,000	4,136,000	648,000	4,722

Month	Fryers = 1.3 kg	Hens	Total
3-90	277,460	27,741	305,201
4-90	221,200	47,871	269,071
5-90	153,290	16,278	169,568
6-90	204,030	24,252	228,282
7-90	222,850	46,369	269,219
8-90	163,820	23,909	187,729
9-90	185,010	24,446	209,456
10-90	99,370	42,393	141,763
11-90	163,700	17,681	181,381
12-90	145,460	19,024	164,484
1-91	82,400	6,956	89,356
2-91	-	21,773	21,773
3-91	32,000	-	32,000
Total	1,950,590	318,693	2,269,283

APPENDIX III

PRODUCTION AND ENERGY CONSUMPTION STATISTICS - SLAUGHTERHOUSE

Month	Electric Power per kWhr				Mazut (Tons)	Diesel (kg)
	Off Peak	Mid	Peak	Total		
4-90	106,400	241,600	88,800	436,800	60	4,000
5-90	155,200	388,700	119,000	622,900	60	3,000
6-90	132,800	377,200	123,500	633,500	60	800
7-90	144,000	409,500	96,400	649,900	60	2,000
8-90	152,800	367,200	94,000	614,000	60	3,000
9-90	121,200	357,700	54,600	533,500	70	1,800
10-90	140,000	351,400	116,300	607,700	80	1,000
11-90	120,000	319,800	104,500	544,300	100	1,200
12-90	96,000	293,900	96,400	486,300	130	1,200
1-91	46,000	296,000	78,800	420,800	110	1,300
2-91	15,200	29,600	17,200	62,000	80	1,200
3-91	116,000	283,600	77,400	477,000	60	1,300
Total	1,305,600	3,716,200	1,066,900	6,088,700	930	21,800

Month	Poultry Meat (Tons)	Sausages (Tons)	Smoked Chicken (Tons)
4-90	1,114	87	18
5-90	1,282	67	18
6-90	1,317	79	21
7-90	1,448	82	18
8-90	1,448	76	23
9-90	1,233	67	26
10-90	1,420	55	24
11-90	1,105	102	23
12-90	1,078	87	18
1-90	781	61	15
2-91	351	10	-
3-91	454	134	-
Total	13,031	907	204

APPENDIX IV

STACK GAS ANALYSIS

BROILER FARM (Tzarevetz)

BOILER # 3: KM-12

Position		1	3	2	1	3
Date:	4-22-91					
Time		11:21	11:42	12.07	12:20	12:14
Oil Pressure	kg/cm²	19	14	14	17.5	13.8
Combustion Eff.	%	77.7	79.0	78.2	76.7	78.5
Ambient Temp	°C	23	24	25	26	28
Stack Temp	°C	192	183	186	192	184
Oxygen	%	5.1	2.1	3.5	4.3	2.3
Carbon Monoxide	PPM	61	285	39	92	101
Carbon Dioxide	%	7.3	8.8	8.1	7.7	8.6
Combustible Gases	%	0.00	0.03	0.07	0.16	0.09
Excess Air	%	29	10	18	23	11
Oxides of N	PPM	127	143	95	55	10
Sulfur Dioxide	PPM	0	874	590	506	468

Conditions:

1. Closed damper to pos.1 from 5 positions (1 = fully opened; f = fully closed).
2. Closed damper to pos.2 from 5 positions.
3. Closed damper to pos.3 from 5 positions.
4. Fuel in computer was 16,230 Btu/lb versus 16,500 as estimated for Mazut.
5. Condensate was at 110°C and the feed water temperature was 82°C.

APPENDIX V

STACK GAS ANALYSIS

SLAUGHTERHOUSE

BOILER # 1: PKM-4

Position		1	3	2	1	3
Date:	4-22-91					
Time		15:19	16:03	16.15	16:20	16:25
Oil Pressure	kg/cm²	11	-	-	-	14
Combustion Eff.	%	73.4	77.4	76.4	77.6	78.6
Ambient Temp	°C	29	11	0	0	0
Stack Temp	°C	253	200	164	157	145
Oxygen	%	6.4	3.3	8.4	6.8	5.4
Carbon Monoxide	PPM	29	0	0	0	0
Carbon Dioxide	%	6.7	8.2	6.[illegible]	6.5	7.2
Combustible Gases	%	0.06	0.00	0.00	0.00	0.03
Excess Air	%	39	16	55	42	30
Oxides of N	PPM	0	0	0	0	0
Sulfur Dioxide	PPM	154	249	108	105	137

Conditions:

1. Fuel in computer was 16,230 Btu/lb versus 16,500 as estimated for Mazut.
2. Condensate was 90°C and the feed water temperature was 25°C. The make up water temperature was 15°C.

APPENDIX VI

STACK GAS ANALYSIS

EGG LAYING & HATCHERY (BOILER #1: PKM-4)

BOILER # 1: PKM-4

Position		1	2
Date:	4-23-91		
Time		10:35	11:04
Oil Pressure	kg/cm^2	-	-
Combustion Eff.	%	61.0	72.5
Ambient Temp	°C	24	25
Stack Temp	°C	208	208
Oxygen	%	11.4	10.7
Carbon Monoxide	PPM	853	222
Carbon Dioxide	%	4.2	4.8
Combustible Gases	%	0.65	0.06
Excess Air	%	108	89
Oxides of N	PPM	0	0
Sulfur Dioxide	PPM	98	40

Conditions:

1. Fuel in computer data base was listed as 16,230 Btu/lb versus 16,500 as estimated for Mazut.
2. Some condensate was being returned. The feed water temperature was about 50°C. The make-up water temperature was 15°C.

APPENDIX VII

STACK GAS ANALYSIS (BROILER #2: PKM-4)

EGG LAYING & HATCHERY

BOILER # 2: PKM-4

Position		1	2	3
Date:	4-23-91			
Time		9:55	10:02	10.22
Oil Pressure	kg/cm^2	8	10	-
Combustion Eff.	%	76.1	76.4	77.1
Ambient Temp	°C	21	21	23
Stack Temp	°C	207	202	204
Oxygen	%	6.4	5.5	3.3
Carbon Monoxide	PPM	15	22	75
Carbon Dioxide	%	6.8	7.2	8.2
Combustible Gases	%	0.00	0.05	0.08
Excess Air	%	38	31	17
Oxides of N	PPM	0	0	0
Sulfur Dioxide	PPM	21	152	188

Conditions:

1. Fuel in computer was 16,230 Btu/lb versus 16,500 as estimated for Mazut.
2. Some condensate was being returned. The feed water temperature was about 50°C. The make up water temperature was 15°C.

APPENDIX VIII

STACK GAS ANALYSIS

SLAUGHTERHOUSE

BOILER # 2: PKM-4

Position		1	2
Date:	4-23-91		
Time		15:28	15:36
Oil Pressure	kg/cm²	14.5	14.5
Combustion Eff.	%	75.3	75.5
Ambient Temp	°C	28	28
Stack Temp	°C	241	234
Oxygen	%	4.4	5.0
Carbon Monoxide	PPM	51	0
Carbon Dioxide	%	7.7	7.4
Combustible Gases	%	0.06	0.04
Excess Air	%	24	28
Oxides of N	PPM	0	0
Sulfur Dioxide	PPM	67	103

Conditions:

1. Fuel in computer was 16,230 Btu/lb versus 16,500 as estimated for Mazut.
2. Some condensate was being returned. The feed water temperature was about 50°C. The make up water temperature was 15°C.

APPENDIX IX

WATER ANALYSIS OF THE BROILER BOILER
April 23, 1991

	Hardness	CC1	Alkalinity	pH
MAKE UP WATER	0.01	50	-	-
CONDENSATE	0.03	60	4.84	-
FEED WATER	0.04	70	7.48	9.0

APPENDIX X

MEETING PARTICIPANTS
APRIL 1991

Meeting
April 19, 1991 Friday
Poultry Plant - Dobritch

NAME	POSITION	PLANT
Norbert Methven	Engineer	International Resources Group
Christian Spassov	President	Ecotechproduct
Ivan Nickolov	Computers & Heating	Ecotechproduct
Miglena Gaberova	Heating & Refrig. Eng.	Ecotechproduct
Svetla Razmova	Inspector of Energy	Energy Department
Emil Nikolov	consumption	Energy Department
Rumen Savov	Inspector of Energy	Energy Department
Emil Christov	consumption	Energy Department
Georgi Donev	Inspector of Energy	Poultry Complex
Ivan Ivanov	consumption	Egg Laying & Hatchery
Ivan Alexandrov	Inspector of Energy	Slaughter House
Peter Indjiev	consumption	Broiler Farm
Stamo Dukov	Deputy Director	Poultry Complex
Ivo Kolev	Director	Slaughter House
Ivan Yanakiev	Director	Egg Laying & Hatchery
Nedeltcho Nedeltchev	Director	Egg Laying & Hatchery
Christo Dimov	Chief Engineer	Broiler Farm
Paun Stantchev	Chief Energy Engineer	Egg Laying & Hatchery
Stoian Radev	Chief Engineer	Egg Laying & Hatchery
Stoiko Stoianov	Energy Engineer	Egg Laying & Hatchery
Georgi Stanev	Energy Engineer	Egg Laying & Hatchery
Nikola Nikolov	Chief Mech. Technician	Egg Laying & Hatchery
Georgi Iliev	Power St. Superintendent	Egg Laying & Hatchery
Stelijan Marinov	Power St. El. Techn.	Slaughter House
Slaveitcho Vasilev	Chief Mech. Technician	Slaughter House
Boijan Iliev	Chief Mech. Technician	Slaughter House
Plamen Ivanov	Chief Mech. Technician	Egg Laying & Hatchery
Georgi Dimov	Mech. & Autom. Engineer	Egg Laying & Hatchery
	Energy Engineer	
	Chief Mech. Room	
	El. Technician	
	El. Technician	

APPENDIX XI
EQUIPMENT SPECIFICATIONS AND JUSTIFICATION FOR PURCHASE OF EQUIPMENT

POULTRY COMPLEX, DOBRITCH

All consumable items and critical spare parts must be provided for two years usage. Two sets of operating and maintenance manuals are required. The equipment must be rugged and proven for the service desired. Metric units are to be used unless otherwise specified. 220 V, 50 hertz power is available. The units should be complete and ready for installation with all required equipment. Quotations should provide complete installation sketch and description of all equipment to be supplied.

1. **Industrial Stethoscopes.** Detailed Description and Justification: to be used with other appropriate equipment in support of the adoption of an Energy Management Program. The stethoscopes would also be useful in support of efforts to repair condensate systems in the plant. Davis Instruments is a representative vendor.

2. **Pressure Recorder.** Detailed Description: with Pigtail for steam Dickson Company Model 798-001100 or equivalent. Accessory kit Dickson Model 798-001400 or equivalent, Pens Dickson Model 700-022200 or equivalent, and AA batteries Dickson Model 19111 or equivalent. 7 day - kpa Model from Dickson Company or equivalent is recommended. To be used as part of the establishment of an Energy Managment Program for the plant. The Pressure Recorder would allow accurate pressure measurements, enhancing overall plant energy management capability.

<u>For items 1 - 2, (plus teaching tools, listed below)</u>

<u>For Energy Management Program</u>

Estimated annual energy savings:	3,448,276 KWh/year
Estimated cost savings:	1,000,000 levs/year ($66,667)
Estimated cost:	15,000 levs ($1,000)
Estimated payback:	3-5 months

3. **Portable Infrared Temperature Measuring Instrument.** Detailed Description: to be used to provide necessary measurements associated with repairing the condensate system. More accurate measurements of condensate losses are essential to the initiation of a condensate recovery program, that will ultimately result in energy savings. Dickson Company model IR-550 or equivalent is recommended. (Dickson Co. 1-800-323-2448).

4. **Thermostatic Steam Trap.** Detailed Description: 1" 152 NPT, 1" 152 Internal Kit and 1" 152H Internal Kit in Stainless Steel where available. To be used to replace faulty steam traps as part of an overall strategy to repair the condensate system. Condensate recovery, and hence, energy savings would result. Yarway Models (1-215-825-2100, George Hahn) or Armstrong or equivalent recommended.

5. **Unibody Disc Traps with Strainer.** Detailed Description: 3/4" 721 NPT, 3/4" 721 Internal Kit, 3/4" 721 Blowdown kit, 1" 721 NPT, 1" 721 Internal Kit, 1" 721 Blowdown Kit. To replace traps as part of an overall strategy to repair the condensate system and save energy by avoiding excess lost condensate. Yarway or Armstrong Models or equivalent recommended.

6. **Unibody Variable Orifice.** Detailed Description: 3/4" 741L NPT, 3/4" 741A Internal Kit, 3/4" 741B Internal Kit, 3/4" 741C Internal Kit, 3/4" 741D Internal Kit, 3/4" 741 Blowdown Kit, 1" 741L NPT, 1" 741A Internal Kit, 1" 741B Internal Kit, 1" 741C Internal Kit, 1" 741D Internal Kit, 1" 741 Blowdown Kit. To be used as part of an overall strategy to repair the condensate system and achieve energy savings through condensate recovery. Yarway or Armstrong Models or equivalent recommended.

7. **Pipe Fittings.** Detailed Description: 3/4" Unions, 1" Unions, 3/4" x 6" Nipples, 1" dia x 12" Nipples, 3/4" NPT Dies, 1" NPT Dies, Die Wrench/handle, 3/4" Strainer Y-type w/stainless steel woven strainer, 1" Strainer y-type w/ stainless steel woven strainer, 3/4" tees, 1" tees, 3/4" gate valves, 1" gate valves, 3/4" swing check valves, 1" swing check valves. To be used as part of a strategy to repair the condensate system and achieve energy savings through improved condensate recovery.

For items 1 - 7, (plus teaching tools, listed below)

To repair condensate systems

Estimated annual energy savings:	689,655 KWh/year
Estimated cost savings:	200,000 levs/year ($1,333)
Estimated cost:	30,000 levs ($2,000)
Estimated payback:	0.4 years

8. **Electric Power Energy Monitor with Sensor.** Detailed Description: 220 V. and 400 V., 50 hertz. The monitor and related equipment (listed below) would help to improve energy efficiency in the hatchery building by improved monitoring, since currently no electricity use monitor is present, leading to wasted electricity. Davis Instruments Models MC 293345 or EM-KWDR 51350 or equivalent are recommended.

9. **Digital Recorder.** Detailed Description: Davis Instruments DRO Model or equivalent for use with above monitor.

10. **Digital Printer.** -Detailed Description: Davis Instruments DP-100 or equivalent for use with above monitor.

11. **Power Supply.** -Detailed Description: Davis Instruments Model or equivalent with 220 V., 50 hertz.

12. **Recording Paper.** Detailed Description: Davis Instruments or equivalent for use with above monitor.

13. **Spare Inking Supply.** Detailed Description: Davis Instruments or equivalent for use with above monitor.

For items 8 - 13

Experimental project benefits not yet known

14. **Energy Efficient Fluorescent Lighting Luminaries.** Detailed Description: designed for the packaging room in the slaughterhouse. Improved lighting with more efficient fluorescent light should improve overall energy efficiency and possibly lead to greater productivity.

Estimated annual energy savings:	unknown
Estimated cost savings:	unknown
Estimated cost:	20,000 levs ($1,333)
Estimated payback:	unknown

15. **Oxygen Analyzer.** Detailed Description: to be installed in order to analyze gas emissions for efficiency. By installing oxygen and temperature instrumentation the boilers will be able to operate more efficiently and avoid current amount of energy losses. Davis Instruments Model BC 108101 (1-800-368-2516) or Universal Enterprises Model C5A or equivalent is recommended.

16. **Replacement Oxygen Sensors.** Detailed Description: to provide replacement sensors for the oxygen analyzer, to ensure the effective operation of this instrument in the future. This would facilitate the analysis of emissions. By installing oxygen and temperature instrumentation the boilers will be able to operate more efficiently. Davis Model BC 108927 or Universal Enterprises Model AO51 or equivalent are recommended.

For items 15 and 16

Estimated annual energy savings:	344,828 KWh/year
Estimated cost savings:	100,000 levs/year ($6,666)
Estimated cost:	90,000 levs ($6,000)
Estimated payback:	80 % return on investment in one year

17. **Portable Humidity and Temperature Meter - Vaisala.** Detailed Description: with 9V Duracell battery. The instrument will provide measurements that will enable the plant to establish a regular defrosting cycle in cold storage chambers and allow for periodic defrosting of evaporators, which would provide access to all evaporators. This would allow for energy savings in refrigeration. Davis Instruments Model HM 34 or equivalent recommended. The instrument would also enable plant personnel to take measurements that would assist in the periodic purge of non-condensables to maintain the low pressure of condensate.

To allow for regular defrosting

Estimated annual energy savings:	668,966 KWh/year
Estimated cost savings:	194,000 levs/year ($12,933)
Estimated cost:	7,600 levs ($506)
Estimated payback:	one month

To allow for periodic purge of non-condensables

Estimated annual energy savings:	575,862 KWh/year
Estimated cost savings:	167,000 levs/year ($11,133)
Estimated cost:	8,800 levs ($586)
Estimated payback:	one month

APPENDIX XII
SAMPLE WORKSHEETS USED IN CONDUCTING THE POULTRY COMPLEX ENERGY EFFICIENCY UNIT
STATE COMPANY – DOBRITCH

ELECTRICAL OPPORTUNITIES

Date apr 26
Area EGGS AND POULTRY

	Location (Be Specific)	Comments *	Tag No.	Type **	Watt / HP	No. (Брой)	Repair Costs $	Savings $/Yr***	RC %
A.	Птицекомплекс-Добрич						(Lv)	(Lv/год)	
	EGG-LAYING HENS- DONTCHEVO								
		Replacement of lamps with more efficiently							
1.	Птицекомплекс-Добрич	вътр.	Подмяна на осветителните лампи с крушки						
	EGG-LAYING	indoor	(икономия средно 15%) × 0,29 Lv/KWt						
	HENS- DONTCHEVO	indoor							
		indoor		INC	295000	7200	3600	72000	
2.	Птицекомплекс-Добрич	Подмяна на осветителните лампи с луминесцентни							
	EGG-LAYING HENS	(INC → FL) (средна икономия 60%)							
	Replacement of INC lamps by FL type of lamps								
	Expected efficiency of 60%								
		indoor		INC	295000	7200	240000	290000	
3.	Птицекомплекс-Добрич	Подмяна на INC лампи с компактни луминесцентни							
	EGG-LAYING HENS	(INC → compact FL)							
		(средна икономия 80%)							
	Replacement of INC lamps by compact FL type								
	Expected efficiency of 80%								
		indoor		INC	295000	7200	108000	384000 (Lv/год)	
B.	Птицеклаличка-Добрич	Почистване и подмяна на изгорялите лампи							
1.	Кех-Месодетайлно на Вътрешности	SLAUGHTERY, PACKAGING DEPARTMENT for hearts, liver, gizzards. Cleaning and replacement of burnt out lamps							
		indoor (E=20÷100 Lx)		FL	24000	63	4000		
2.	Кех-Колбаси (E=60÷250 Lx)								
	SAUSAGE DEPARTMENT	indoor		FL	3600	90	380		

* Indicate whether it is inside or outdoor lighting.
** For type show MV = mercury vapor, HPS = high pressure sodium, INC = incandescent, and MH = metal halide.
*** Unless actual HP is known, multiply nameplate HP rating by 1 HP costs.

Formuled by: Eng. E. Nikozov

cpw/0212/c25-1
2C 02/12/86

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WATER LEAKS Losses of water (hole[mm]/stream length [m]) mm/m

Date apr. 23. 1991
Area TPS H - Dobrich

Location (Be Specific)	Comments *	Tag No.	GPM	Repair Costs Lv	Savings Lv/Yr	ROI %
Мивка холи (отработната на машината вода, надлъжна бръзгалка)	heated 50°C	25,4/10	35000	150	345	
Скубачно (кипящата вода домъртвяла)	heated	200/0,3	8400	200	86	
Скубачно, мияне под (маркуча без накрайник)	cold water	25,4/5	35000	80	345	
Кормачно, мияне под (маркуч без накрайник)	heated	25,4/5	35000	80	345	
Кормачно, кран вода отопление (смяна солник)	heated	MDr.	2600	5	30	
Пакетиране вътрешности (маркуч без накр.)	cold water	25,4/10	35000	80	345	
Маш. зала (схл. алуминиеви – обратно)	cold ---	19 mm	100600	17250	14523	
Маш. зала (схл. кондензатори – помпи 12 бр.)	cold ---	19 mm	100600	25000	14523	
Маш. зала (помпа обратна вода – солник)	cold ---	MDr	2600	5	30	
Колбаси-охлаждане (кран – солник)	cold ---	SDr	1400	5	30	
Месобобик 2 (помпа за мляко – солник)	heated	BDr	5800	10	60	
Месобобик 2, мияне под (маркуч без накр.)	cold	25,4/10	35000	150	545	
			397400 GPM	43015 Lv	31007 Lv	
			~4%			

* Indicate whether it is demineralized, mill, chilled, or heated water.

For 12 months leaks, 1 GPM demineralized water = , 1 GPM mill water=

Small Drops – SDr.
Midl Drops – MDr. (tricks)
Quick Drops – QDr. (stream)

Formulated by:
eng. E. Nikolov

cpw/0212/c25-6
2C 02/12/86

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CONDENSATE LEAKS

Date 4.22.1991
Area

Location (Be Specific)	Comments	T/yr Tag No.	* GPM	Repair Costs $	Savings $/Yr	RC %
M-St meat producing shop						
heat exchanger I	Back of cond pipe - 5m	850		380	10080	
heat exchanger II	cond. pipe	600		6820	8400	
M st building in office use and storage - 2n	Back of autom level	310		1000	3720	
Ineffectively used in evaporation at ~100-110°C						
(from boiler heating and sausaging and smoking chicken shop)	(only heat not quality)	4000		20000	22000	
	Total			28200	54200	

* all condensate returned at 55 psig values.

For 12 months leaks, 1 GPM = .

Razmovski

cpw/0212/c25-5
2C 02/12/86

SLAUGHTER HOUSE

INSULATION OPPORTUNITIES

Date 4.22.1991
Area Poultry slaughtering

Location (Be Specific)	Comments *	Tag No.	Length ** (m)	Wid. **	Dia. **	Repair Costs $	Savings $/Yr	RC %
			F[m²]					
In the open								
1. Steam pipe line for the meat producing shop - 1								
- near the boiler st	cond. t=70°	0,66	3		76	42,9	523,55	
- near the m. sh. - 1	cond. t=70°	0,82	4		76	57,2	43,14	
— " —	steam t=140°	1,48	3,5		133	94,9	1518,8	
2. St pipe line for the m. pr sh - 2								
- near the boiler st.	cond. t=70°	3,3	4,5		76	214,5	1617,8	
3. Pipe line for cage move-up shop	steam t=140°	0,8	10		2,5	52	6943	
— " —	hot water t=80°C	1,57	20		2,5	102	11407	
4. Pipe line for the guard's room	st. t=140°	0,23	4		20	14,9	348	
— " —	cond. t=70°	0,23	4		20	14,9	168	
Indoor								
H. st m sh - 1	st. t=140°	3,3	3,5		300	145	1345	
pipeline for refrigeration	st. t=140°	3,82	32		38	248,3	2381	
pipeline for storage	st. t=140°	3,4	24		45	221	2083,2	
— " —	cond. t=70°	3,9	31		40	253,5	1340	
H st m sh - 1	cond. t=70°	1,1	5		76	71,5	324	
H st m sh - 2	st. t=135°C	1,7	5		108	110,5	1116	
— " —	st. t=135°C	0,57	0,6		300	370	230,6	
Pipe line for feathers sh	cond. t=70°	0,41	10		13	26,6	285	
Boilers station	st. t=150°C	0,34	6		20	22,1	342,5	
— " —	cond. t=70°	0,34	6		20	22,1	178,5	
cond. tank office use building		7,8	1,3	1	1000	507	793	
cond tank storage st		7,8	1,3	1	1000	507	793	
			Total			2834,1	17,452,8	

* Indicate what it is: tank, pipe, duct, etc.
** Show all dimensions in feet, except show pipe diameter in inches.

For pipe, annual cost (multiply by 2 for outside items).
For flat surfaces, annual cost (multiply by 2 for outside items).

Razmeva

cpw/0212/c25-2
2C 02/12/86

STEAM LEAKS

Date 4.22 1991
Area Poultry Slaughter

Location (Be Specific)	Comments	Tag No.	* Size	Repair Costs $	Savings $/Yr
H.St meat producing shop-1	flange of valve	1n	W	30	9900
—"—	flange of valve	1n	M	30	45000
Meat producing shop-scalding trough	flange of valve	2n	W	60	19800
—"—	flange of valve	1n	M	30	45000
H.St meat producing shop-2	flange of valve	3n	W	90	29700
—"—	flange of valve	2n	M	60	90000
pipe line for a guard's room	Broken down pipe 3/4"	4n	M	48	60000
Total				348	299,400

* Can use the following code for leak size: W = wisp, M = moderate, S = severe.

For 12 months leaks, wisp = , moderate = , severe =

Razmir

cpw/0212/c25-4
2C 02/12/86

APPENDIX XIII

"ENERGY MANAGEMENT PRACTICES"
EXCERPT OF A PRESENTATION

BY MR. BARRY TUNNAH
AT THE
ENERGY MANAGEMENT WORKSHOP

SOFIA, BULGARIA

JANUARY 1992

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.