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BURNS AND ROE ENTERPRISES, INC.

DELIVERY ORDER No. 17

COMMODITIES IMPORT PROGRAM
Final Assessment Report -- Allocation MRMD-333
Murmansk District Heating System Controls

RUSSIA

September 1998

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KELLER MURMAN X COVE FN PD

ASSESSMENT REPORT
STATE REGIONAL UNITED HEATING POWER ENTERPRISE
MURMANSK, RUSSIA

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ASSESSMENT REPORT

1 0 INTRODUCTION

The work described in this report has been carried out by Burns and Roe Enterprises, Inc (BREI) within the framework of the U S Agency for International Development (USAID) NIS Energy Efficiency and Market Reform Project, Delivery Order No 17 - Commodity Import Program (CIP)-assessment reports

This work is a follow up to the End Use Checks made in July 1997 End Use Checks are performed for each CIP allocation under DO No 1, Task 4, of the CIP The End Use Checks verified that the equipment had been installed, was being used as intended, and that any open items between the importer and supplier were identified and are being resolved The purpose of these Assessment Reports is to go back to selected CIP allocations after they have been operating and assess their actual performance These Assessments compare the expected results from the project specifications with the actual operation and maintenance results

For this reason the Assessment for the Murmansk District Heating Boiler Controls upgrades was not made until the system operated through one heating season Specifically, in February, 1998 BREI representatives George Keller and Aram Akopov made an end-use assessment visit to the State Regional United Heating Power Enterprise (TEKOS) in Murmansk, Russia TEKOS is the importer for Allocation No MRMD-333 Honeywell's Industrial Automation Division supplied the distributed control system and other control equipment for this allocation

The purpose of this visit was to assess the status of the boiler house control upgrade and the resultant energy efficiency improvements and reductions in greenhouse gas emissions, to assess financial, economic and public relations benefits, and to assist the importer in resolving any remaining technical issues

2 0 FINDINGS

1 The distributed control system and other control equipment supplied under this delivery order has been in operation in the main boiler house of the Importer for about two years It controls four out of fifteen boilers in the boiler house

While other system upgrades have open issues of varying degrees of severity, TEKOS reports no open issues for this project Without a doubt, this is the most technically successful of the four control upgrade projects because everything works and the Supplier completely fulfilled his obligations

2 Due to this project there are reductions in greenhouse gas emissions for the four boilers 4 44% reduction at the boilerhouse (associated with the fuel savings for the four boilers) and 38 36% reduction at the local power company (associated with the electrical power savings for the four boilers)

Specifically, an environmental benefit includes 118 t reduction in SO_2 emissions, 9 78 t reduction in NO_x emissions, and 5,290 t reduction in CO_2 emissions The value of the environmental benefit exceeds the value of the fuel savings The simple payback on $1,276,000 investment is 5 3 years when only fuel savings are considered It is 2 years if both fuel savings and an environmental benefit are considered

3 In February, 1998 TEKOS and Honeywell's Industrial Automation Division signed a contract to automate an additional five boilers in the boiler house Honeywell is providing the credits TEKOS payments are guaranteed by the local government

TEKOS management is one of the most competent group of people that we have seen in the former S U As result of their success with the first project, they achieved high standing with the local government Therefore, when the boiler house of Koly (suburb of Murmansk) failed financially, TEKOS was asked to take over Presently there is talk of TEKOS taking over the power plant (TES) in Murmansk

4 The reputation of the American control industry in general and Honeywell's reputation in particular were enhanced by this project

5 TEKOS never reported any problems, not even ones that were solved and closed We believe that they were anxious to continue with Honeywell on the next project and suppressed any problem reporting

For example, we have learned by accident that there was an incident of a sheared shaft on an ID fan controlled by Honeywell's variable frequency drive (VFD) Apparently the VFD was braking too hard for a shaft coupled with a heavy Russian-made cast iron fan The problem was resolved by using more conservative ramp rates for braking

We also have learned that the importer configured the new boiler control system using an "advanced" Russian control strategy relying on FD discharge pressure measurement as a substitute for air flow measurement Since the changes in the firing rate, ambient pressure, and wind velocity affect the furnace pressure and the FD discharge pressure, just about anything can upset the air flow measurement and therefore excess air control As a result, this excess air control is usually run in manual ("it fires better in manual" explained the I&C manager during our visit)

It is worth noting that automatic excess air control is a major source of energy savings for industrial boilers as compared with manual excess air control Russian specialists usually quote 5 % savings over manual excess air control Of course the savings depend on how poorly the boiler operator performs his functions now With an extremely dedicated operator and steady-state boiler load the savings could be close to zero

Our estimation is that the operators in Murmansk are better than the Russian average so we will assume that the overall energy savings were 2 5 to 3% short of their full potential The calculations in this report are based on results achieved with manual excess air control of the boilers

We told the importer how to re-program the system, so no permanent harm was done Hopefully the excess air control will be in automatic after all, thus further improving the economics of the project

6 All equipment originally had the required USAID label At this time only about 30% of the labels remain Since these are popular souvenir items, it is not possible to keep them on all equipment This is a common problem for all sites

7 The Supplier provided the necessary start-up assistance and training to the satisfaction of the importer

8 The importer has consumables to support two years of operation He has funds to replenish them thereafter

9 The importer believes that he saved 8% in fuel cost from beneficial use of CIP provided equipment Our analysis of fuel savings based on the data supplied by the importer (October 1997 through January 1998) indicates more modest 4 44% savings

Comparison of Fuel Consumption (Kg/GCal) Boilers K-11,12,13 &14 vs Boilers K-9 &10

Boiler Upgrades	Boiler No	Oct 1997	Nov 1997	Dec 1997	Jan 1998	Four Month Avg
Heat & Fuel Meters Only	K-9	120 50	119 99	120 29	119 69	
Ditto	K-10	121 01	120 07	120 26	119 75	
Avg Fuel Consumptn		120 76	120 03	120 28	119 72	120 2
New Control System	K-11	115 46	115 22	115 23	114 60	
	K-12	114 58	114 65	115 54	114 39	
	K-13	115 01	115 22	114 74	114 43	
	K 14	114 92	114 82	114 70	114 27	
Avg Fuel Consmptn		114 99	114 98	115 05	114 42	114 86
Fuel Savings %		4 77%	4 21%	94 26%	4 42%	**4 44%**
Fuel Savings T/yr						**2077**

Two comments are appropriate here

- These are fuel savings with excess air control in manual If the importer manages to resolve the excess air control problem, additional 2-3% savings are quite possible

  Our methodology is to compare an average fuel consumption per Gcal of heat generated for boilers K-11,12,13 &14 (which have undergone full scale control retrofit) vs two "control" boilers K-9 &K-10 (they are of the same size) Boilers K-9 &K-10 had heat and fuel meters installed for measurement and recording purposes, but no new boiler control

  We cannot compare fuel consumption of boilers K-11,12,13 &14 before and after boiler control upgrade for the simple reason that heat and fuel metering did not exist before the upgrade So the next best thing is to compare them to boilers K-9 &K-10

- One can argue that by virtue of installing heat and fuel meters on boilers K-9 &K-10 we forced operators to be more careful about fuel consumption and thus reduced consumption for "control" (or reference) boilers It is quite possible that actual savings for boilers K-

11,12,13 &14 are about 8% based on total fuel purchased and total heat generated for the boiler house as a whole

10 The importer believes that he saved 40 -50%in electrical cost from beneficial use of CIP provided variable frequency drives Our analysis of power consumption savings based on the data supplied by the importer (October 1995 through January 1998) indicates 38 36% savings on average

Comparison of Power Consumption (in KWHR/GCAL) for Boilers K-13 and K-14 Before and after the Installation of Variable Frequency Drives

Reference Month	Avg Power Consumption **before**	Avg Power Consumption **after**	Savings (in KWHR/GCal)	Savings in %	Savings in KWHR per year for 4 Blrs
Oct 1995 vs Oct 1997	6 255	3 675	2 58	41 25	
Nov 1995 vs Nov 1997	5 5	3 513	1 99	36 1	
Dec 1995 vs Dec 1997	5 45	3 62	1 83	33 5	
Jan 1996 vs Jan 1998	5 975	3 428	2 547	42 6	
					931,840

3 0 ANALYSIS OF ENERGY AND POWER SAVINGS

3 1 Energy Savings

To calculate the energy savings that resulted from a full scale control retrofit of boilers K-11,12,13 &14 with a modern distributed control system (TDC-3000) we will compare an average fuel consumption (in Kg of standard fuel per Gcal of heat generated) of these boilers vs two "control" boilers K-9 &K-10 of the same size Boilers K-9 &K-10 had heat and fuel meters installed for measurement and recording purposes, but no new boiler control

We cannot compare fuel consumption of boilers K-11,12,13 &14 before and after boiler control upgrade since the heat and fuel metering did not exist before the upgrade

- For the month of **October 1997**, the TEKOS printout gives average fuel consumptions for boilers K-11,12,13 &14 as 115 46, 114 58, 115 01 and 114 92 for a four boiler average of 114 99 (KgSF/Gcal)

  For the same period the TEKOS printout gives average fuel consumptions for boilers K-9&10 as 120 5 and 121 01 for a two boiler average of 120 755 (KgSF/Gcal) The difference of 5 765 Kg of standard fuel is the fuel economy per Gcal of heat generated or 5 765/120 755 = **4 77%** fuel savings

- For the month of **November 1997**, The TEKOS printout gives average fuel consumptions of boilers K-11,12,13 &14 as 115 22, 114 65, 115 22 d 114 82 for a four boiler average of 114 98 (KgSF/Gcal)

  For the same period "the TEKOS" printout gives average fuel consumptions for boilers K-9&10 as 119 99 and 120 07 for a two boiler average of 120 03 (KgSF/Gcal) The difference of 5 05 Kg of standard fuel is the fuel economy per Gcal of heat generated or 5 05/120 03 = **4 2%** fuel savings

- For the month of **December 1997**, The TEKOS printout gives average fuel consumptions for boilers K-11,12,13 &14 as 115 23, 115 54, 114 74 and 114 70 for a four boiler average of 115 05 (KgSF/Gcal)

  For the same period The TEKOS printout gives average fuel consumptions for boilers K-9&10 as 120 29 and 120 26 for a two boiler average of 120 28 (KgSF/Gcal) The difference of 5 23 Kg of standard fuel is the fuel economy per Gcal of heat generated or 5 23/120 28 = **4 35%** fuel savings

- For the month of **January 1998**, The TEKOS printout gives average fuel consumptions for boilers K-11,12,13 &14 as 114 60, 114 39, 114 43 and 114 27 for a four boiler average of 114 425 (KgSF/Gcal)

  For the same period The TEKOS printout gives average fuel consumptions for boilers K-9&10 as 119 69 and 119 75 for a two boiler average of 119 72 (KgSF/Gcal) The difference of 5 295 Kg of standard fuel is the fuel economy per Gcal of heat generated or 5 295/119 72 = **4 42%** fuel savings

- The average fuel savings for four months will be the sum of **4 77% + 4 2% +4 35% +4 42%** divided by 4 or **4 435%** **It is worth noting that due to this project there is an associated 4 44% reduction in greenhouse gas emissions for the four boilers**

- Assuming 6 5 month heating season and average fuel consumptions of 1,800 T per boiler per month (December 1997 average fuel consumption is 1,922 T per boiler), total fuel savings will be

  1800 x 4 x 6 5 x 0 0435 = 2,036 T per year

3 2 Power Savings

In the case of power savings we can make a direct comparison of power consumption (in KWHR/Gcal) for boilers K-13 and K-14 before and after the installation of variable frequency drives

- For the month of **October 1995**, The TEKOS printout gives average power consumptions for boilers K-13 &14 as 4 12 and 8 39 for a two boiler average of 6 255 (KWHR/Gcal)

  For the month of October 1997,average power consumptions for boilers K-13 &14 can be calculated using The TEKOS printout as 3 35 and 4 for a two boiler average of 3 675 (KWHR/Gcal)
  The difference of 6 255 - 3 675 = 2 58 KWHR/Gcal is the power consumption economy per Gcal of heat generated or 2 58/6 255 = **41 25%** of power savings

- For the month of **November 1995**, The TEKOS printout gives average power consumptions for boilers K-13 &14 as 4 0 and 7 0 for a two boiler average of 5 5 (KWHR/Gcal)

  For the month of **November 1997**,average power consumptions for boilers K-13 &14 can be calculated using The TEKOS printout as 3 037 and 3 99 for a two boiler average of 3 513 (KWHR/Gcal)

The difference of 5 5 - 3 513 = 1 99 KWHR/Gcal is the power consumption economy per Gcal of heat generated or 1 99/5 5 = **36 1%** of power savings

- For the month of **December 1995**, The TEKOS printout gives average power consumptions for boilers K-13 &14 as 3 9 and 7 0 for a two boiler average of 5 45 (KWHR/Gcal)

  For the month of **December 1997**, average power consumptions for boilers K-13 &14 can be calculated using The TEKOS printout as 3 266 and 3 98 for a two boiler average of 3 62 (KWHR/Gcal)

  The difference of 5 45 - 3 62 = 1 83 KWHR/Gcal is the power consumption economy per Gcal of heat generated or 1 83/5 45 = **33 5%** of power savings

- For the month of **January 1996**, the TEKOS printout gives average power consumptions for boilers K-13 &14 as 3 95 and 8 0 for a two boiler average of 5 975 (KWHR/Gcal)

  For the month of **January 1998**, average power consumptions for boilers K-13 &14 can be calculated using the TEKOS printout as 3 27 and 3 585 for a two boiler average of 3 428 (KWHR/Gcal)

  The difference of 5 975 - 3 428 = 2 547 KWHR/Gcal is the power consumption economy per Gcal of heat generated or 2 547/5 975 = **42 6%** of power savings

- The average power savings for four months will be the sum of **41 25%** + **36 1%** +**33 5%** +**42 6%** divided by 4 or **38 36%** **It is worth noting that due to this project there is an associated 38 36% reduction in greenhouse gas emissions at the local power company (consumption of the four boilers)**

  The average power savings in KWHR/Gcal for four month will be the sum of 2 58+ 1 99 + 1 83 + 2 547 divided by 4 or **2 24 KWHR/Gcal**

- We arrived at the average power savings per boiler for boilers K-13 &14 Since the boilers K-11 &12 are of the same size and have identical variable frequency drives, we will assume identical saving

Therefore assuming 6 5 month heating season and average heat generation of 16,000 Gcal per boiler per month (December 1997 average fuel consumption is 16,711 Gcal per boiler), total power savings for 4 boilers will be

16,000 x 4 x 6 5 x 2 24 = 931,840 KWHR per year

3 3 Financial Benefit and Simple Payback

Fuel Savings in $

Assuming $100 per ton of standard fuel, the financial benefit due to fuel savings will be

2,036 x 100 = $203,600 per year

Power Savings in $

Assuming $0 04 per KWHR and given 931,840 KWHR per year savings, the financial benefit due to power savings will be

931,840 x $0 04 = $37,274 per year

Total Financial Benefit

Total financial benefit due to the retrofit

$203,600 + $37,274 = $240,870 per heating season

Simple Payback

Given the total cost of the project, the simple payback is

$1,276,000 / 240,870 = 5 3 years

3 4 Environmental Benefits and Total Payback

Assuming $100 per ton of standard fuel and $240,870 in fuel savings, we will calculate the heat quantity of the displaced fuel

$240,870 / $100 *7,000,000 Kcal = 16,861 *10^6 Kcal

(This is a simplified calculation which is sufficiently accurate, since the electric power in Russia is presently sold very close to the cost of fuel necessary for its generation)

Assuming that the boilerhouses would burn mazut with a Lower Calorific Value of 9,880 Kcal/kg, we can estimate the quantity of displaced fuel in t/yr

$16,861 * 10^6 / 9,880 = 1\ 707\ 10^6$ kg or 1,707 (t)

According to our calculations (see Appendix F), every 1 0 kg of mazut combusted will produce 3 10 kg of CO2 and 0 069 kg of SO_2

Therefore 1,707 t of savings in mazut consumption will reduce greenhouse emissions by

1,707 * 3 1 = 5,290 t of CO_2

At the same time there will be

1,707 * 0 069 = 118 t reduction in SO_2 emissions

Considering that the total cost of this project was $1,276,000, every ton of reduction in CO_2 emissions costed

$1,276,000 / 5,290 = $241

while every ton of reduction in SO_2 emissions costed

$1,276,000 / 118 = $10,800

To estimate reduction in NO_x emissions, we will use Russian allowable NO_x emission per Gcal, which is 0 58 kg Since annual savings in energy are 16,861 Gcal, reduction in NO_x emissions will be

16,861 * 0 58 = 9,783 kg or 9 78 t

To calculate the total environmental benefit we will use the data from Appendix G Assuming costs of major air pollutants to be $1 65 per kg of SO_2, $7 15 per kg of NO_x, and $0 024 per kg of CO_2, the total environmental benefit will be

1 65 * 118,000 + 7 15 * 9,783 + 0 024 * 5,290,000 = $391,608

We can see that the environmental benefit exceeds the benefit from fuel savings

We will now calculate the total payback, taking into consideration both fuel savings and environmental benefit

$1,276,000 / ($240,870 + $391,608) = 2 017 years

4 0 CONCLUSIONS AND RECOMMENDATIONS

1 The project resulted in fuel savings of 1,707 t of mazut and a reduction in discharge of major air pollutants An environmental benefit includes a 118 t reduction in SO_2 emissions, 9 78 t reduction in NO_x emissions, and 5,290 t reduction in CO_2 emissions The value of the environmental benefit exceeds the value of the fuel savings The simple payback on $1,276,000 investment is 5 3 years when only fuel savings are considered It is 2 years if both fuel savings and an environmental benefit are considered

2 It is interesting to notice that as boiler load increases in winter months, savings in power consumption due to installation of the variable frequency drives decreases That make sense since the savings are due to overcoming oversizing of motors which are less oversized at higher loads

3 The following steps would make a boiler control retrofit more viable economically

- Concentrate on larger boilers Expenses are almost the same while economic benefits are more or less proportional to the boiler size

- Attempt to re-use Russian made electrical control drives They are rugged and reliable

- Supply a complete Distributed Control System but install, connect and configure only the excess air control and the most troublesome loops Most of the economic benefits will be captured at half the cost The Importer can gradually expand the system as existing loops become dysfunctional

4 About $40,000 in parts, labor and expenses would insure that the excess air control is in automatic thus further improving the economics of the project by some 50% (from 4 44% fuel savings to 6 5-7%)

Specifically the upgrade will include supervision of a piezometer ring fabrication and its installation on the FD fan suction The piezometer ring should be made out of 12 mm stainless steel tubing with inside holes drilled to 1 5 mm diameter every 100 mm The piezometer ring should be connected to the negative side of the differential pressure transmitter via 10 mm stainless steel tubing The positive side of the differential pressure transmitter shall be connected to the atmosphere

The existing pressure transmitter can perhaps be converted for this service, if not, 4 new differential pressure transmitters will have to be bought (one for each of 4 boilers) at a cost of about $1,200 each

The existing control system would require minor reprogramming and tuning of the excess air control for all 4 boilers The whole effort should be no more than 20 days of labor plus parts plus expenses

Appendix A

Fuel Consumption in Kg of Standard Fuel per Gcal of Heat Generated for Boilers K-11,12,13 &14 (Oct 1997 to Jan 1998)

Характеристика работы котлов ГМ-50-14/250 ст N 11,12,13,14
оборудованных системой автоматизации фирмы " HONEYWELL "
(октябрь 1997г)
October

Дата	К - 11			К - 12			К - 13			К - 14		
	Выработка Гкал	Расход топл тнт	Удельн норма Кгнт/Гкал	Выработка Гкал	Расход топл тнт	Удельн норма Кгнт/Гкал	Выработка Гкал	Расход топл Гкал	Удельн норма Кгнт/Гкал	Выработка Гкал	Расход топл тнт	Удельн норма Кгнт/Гкал
1	2	3	4	5	6	7	8	9	10	11	12	13
01 10 97г	555,03	63,04	113,58	596,48	67,87	113,78	-	-	-	-	-	-
02 10 97г	546,44	62,41	114,21	599,74	68,20	113,72	-	-	-	-	-	-
03 10 97г	548,87	62,74	114,31	606,65	69,48	114,53	-	-	-	-	-	-
04 10 97г	545,35	62,54	114,58	403,24	46,46	115,22	-	-	-	-	-	-
05 10 97г	532,03	61,69	115,95	-	-	-	558,26	64,20	115,00	-	-	-
06 10 97г	530,58	60,70	114,40	-	-	-	574,56	66,29	115,38	-	-	-
07 10 97г	548,33	62,63	114,22	-	-	-	573,60	65,53	114,24	-	-	-
08 10 97г	557,79	64,50	115,63	573,36	66,16	115,39	585,27	67,60	115,50	-	-	-
09 10 97г	549,93	63,74	115,91	575,88	66,30	115,13	574,19	66,30	115,47	-	-	-
10 10 97г	561,85	65,29	116,21	559,54	64,21	114,75	583,77	67,55	115,71	-	-	-
11 10 97г	562,26	65,10	115,78	539,09	61,94	114,90	578,28	66,62	115,20	-	-	-
12 10 97г	559,89	64,52	115,24	551,71	63,21	114,57	579,05	66,18	114,29	-	-	-
13 10 97г	567,85	65,72	115,73	541,15	61,80	114,20	579,81	67,10	115,73	193,48	22,17	114,59
14 10 97г	316,10	36,90	116,74	571,71	65,24	114,11	584,06	67,70	115,91	597,03	68,34	114,47
15 10 97г	201,51	23,60	117,12	579,98	67,20	115,87	610,25	70,55	115,61	603,64	69,99	115,95
16 10 97г	593,96	68,71	115,68	583,64	67,63	115,88	558,77	63,94	114,43	601,68	69,24	115,08
17 10 97г	590,28	67,50	114,35	588,92	67,24	114,18	595,60	68,08	114,30	297,02	30,76	115,20
18 10 97г	580,89	66,29	114,12	555,81	62,93	113,22	593,50	68,15	114,83	589,32	67,47	114,49
19 10 97г	587,91	68,10	115,83	559,16	63,44	113,46	580,47	66,82	115,11	598,46	68,66	114,73
20 10 97г	580,42	67,64	116,53	576,61	66,67	115,62	576,21	66,88	116,07	607,75	70,53	116,05
21 10 97г	570,37	66,34	116,31	562,69	64,83	115,21	595,59	68,77	115,47	616,26	71,26	115,63
22 10 97г	579,80	67,05	115,64	561,23	64,75	115,37	565,46	65,35	115,57	619,58	71,58	115,53
23 10 97г	590,22	68,36	115,82	551,18	63,36	114,95	-	-	-	604,78	69,78	115,38
24 10 97г	581,45	67,65	116,35	559,80	64,29	114,84	-	-	-	600,29	69,08	115,08
25 10 97г	579,07	66,97	115,65	564,95	64,52	114,20	-	-	-	586,79	67,32	114,73
26 10 97г	565,18	65,23	115,41	559,95	63,73	113,81	-	-	-	585,71	66,88	114,19
27 10 97г	588,53	68,67	116,68	592,37	67,60	114,12	-	-	-	621,65	71,16	114,47
28 10 97г	585,77	68,13	116,31	-	-	-	596,84	68,11	114,12	602,05	68,76	114,21
29 10 97г	599,25	69,03	115,19	-	-	-	587,45	67,00	114,05	596,73	68,02	113,99
30 10 97г	-	-	-	-	-	-	444,06	50,61	113,97	579,05	66,34	114,57
31 10 97г	-	-	-	483,81	54,92	113,52	578,88	65,68	114,05	-	-	-
	15856,91	1830,79	115,46	13998,65	1603,98	114,58	12650,01	1455,01	115,01	10071,27	1157,34	114,92

Fuel consumption
in Kg of standard Fuel
per Gcal

A-1

14

Характеристика работы котлов ГМ-50-14/250 ст N 11,12,13,14
оборудованных системой автоматизации фирмы " HONEYWELL "
(ноябрь 1997г)

Дата	К - 11			К - 12			К - 13			К - 14		
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1	2	3	4	5	6	7	8	9	10	11	12	13
01 11 97г	-	-	-	575,03	65,31	113,58	574,04	65,61	114,30	149,59	17,18	114,84
02 11 97г	-	-	-	571,35	64,83	113,47	550,98	63,13	114,58	576,44	65,90	114,32
03 11 97г	-	-	-	563,50	64,36	114,21	560,05	64,47	115,11	564,98	65,09	115,39
04 11 97г	-	-	-	563,31	64,52	114,54	581,51	67,00	115,22	570,20	65,79	115,38
05 11 97г	-	-	-	575,29	66,34	115,32	598,54	68,44	114,34	597,61	68,11	113,97
06 11 97г	-	-	-	567,09	65,61	115,70	562,55	64,46	114,59	527,96	60,74	115,05
07 11 97г	-	-	-	563,39	64,35	114,22	562,64	64,33	114,34	567,35	64,85	114,30
08 11 97г	-	-	-	558,24	64,48	115,51	556,37	63,17	113,54	585,65	67,06	114,51
09 11 97г	-	-	-	549,22	62,34	113,51	551,24	62,74	113,82	553,92	63,66	114,93
10 11 97г	-	-	-	546,52	62,65	114,63	550,57	62,96	114,35	568,33	65,68	115,57
11 11 97г	-	-	-	556,38	63,40	113,95	551,16	62,97	114,25	563,41	65,34	115,97
12 11 97г	-	-	-	552,14	63,34	114,72	561,90	64,85	115,41	572,42	66,54	116,24
13 11 97г	-	-	-	544,93	63,24	116,05	549,67	68,27	124,20	550,45	65,12	118,30
14 11 97г	-	-	-	564,05	65,00	115,24	562,54	66,22	117,72	571,73	65,97	115,39
15 11 97г	-	-	-	556,82	64,91	116,57	553,54	66,89	120,84	564,24	64,90	115,02
16 11 97г	298,72	34,20	114,49	563,62	64,63	114,67	558,97	63,33	113,30	571,80	65,16	113,96
17 11 97г	563,97	64,25	113,92	572,43	65,22	113,94	565,40	64,44	113,97	581,41	66,14	113,76
18 11 97г	435,94	49,83	114,30	546,01	62,91	115,22	558,68	66,06	118,24	572,59	65,30	114,04
19 11 97г	-	-	-	550,65	62,95	114,32	559,91	64,25	114,75	590,11	67,98	115,20
20 11 97г	-	-	-	552,90	63,25	114,40	557,19	64,02	114,90	583,95	67,23	115,13
21 11 97г	604,46	69,64	115,21	595,81	67,67	113,58	596,51	68,31	114,52	607,27	69,20	113,95
22 11 97г	594,82	68,80	115,67	563,48	64,32	114,15	568,53	65,34	114,93	575,15	65,72	114,27
23 11 97г	563,38	64,75	114,93	537,78	61,54	114,43	554,26	63,20	114,21	588,00	67,24	114,35
24 11 97г	580,38	66,96	115,37	475,83	54,96	115,50	574,12	66,22	115,34	582,81	66,78	114,58
25 11 97г	559,69	64,64	115,49	560,69	63,97	114,09	561,30	64,05	114,11	581,03	66,22	113,97
26 11 97г	577,04	66,86	115,69	557,64	63,73	114,29	565,01	64,39	113,96	584,70	66,99	114,57
27 11 97г	594,82	68,96	116,00	574,96	66,24	115,21	574,34	65,81	114,58	588,76	67,49	114,63
28 11 97г	561,83	65,35	116,32	561,60	64,75	115,30	570,85	64,96	113,80	576,05	65,76	114,16
29 11 97г	595,63	68,62	115,21	586,97	67,44	114,90	576,64	66,46	115,25	606,82	69,61	114,71
30 11 97г	608,00	69,76	114,74	603,27	69,15	114,63	409,97	46,86	114,30	578,42	66,26	114,55
31 11 97г	-	-	-	-	-	-	-	-	-	-	-	-
	7139,58	822,62	115,22	16810,90	1927,41	114,65	16778,98	1933,31	115,22	16853,15	1935,01	114,82

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ХАРАКТЕРИСТИКА РАБОТЫ КОТЛОВ ГМ-50-14/250 ст N 11,12,13,14

ОБОРУДОВАННЫХ СИСТЕМОЙ АВТОМАТИЗАЦИИ ФИРМЫ " HONEYWELL "

(ДЕКАБРЬ 1997 г)

Дата	К - 11			К - 12			К - 13			К - 14		
	Выработка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал	Выработка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал	Выработка Гкал	Расход топл Гкал	Удельн норма Кгнт/ Гкал	Выработка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал
1	2	3	4	5	6	7	8	9	10	11	12	13
01 12 97г	595 74	68 64	115 22	607 23	69 90	115 11	159 03	18 20	114 44	594 45	67 99	114 37
02 12 97г	594 17	68 66	115 56	568 13	65 61	115 48	609 46	69 86	114 63	589 94	67 38	114 22
03 12 97г	595 86	69 52	116 67	585 65	68 11	116 30	600 54	69 21	115 25	583 37	67 48	115 67
04 12 97г	607 22	70 59	116 25	596 84	69 30	116 11	609 37	69 65	114 30	603 69	69 37	114 91
05 12 97г	586 79	68 66	117 01	586 49	68 61	116 98	594 70	68 90	115 86	586 0	67 57	115 31
06 12 97г	535 34	62 56	116 86	536 40	62 52	116 55	545 04	62 35	114 40	592 38	67 79	114 44
07 12 97г	552 89	63 90	115 57	545 46	63 22	115 90	566 43	64 90	114 58	583 55	66 71	114 32
08 12 97г	572 70	67 47	117 81	481 77	56 17	116 59	575 96	66 37	115 23	583 59	66 92	114 67
09 12 97г	570 65	65 99	115 64	-	-	-	560 51	64 12	114 40	569 93	65 46	114 86
10 12 97г	548 47	63 98	116 65	-	-	-	554 07	63 47	114 55	568 16	64 95	114 32
11 12 97г	567 34	65 93	116 21	-	-	-	586 61	67 36	114 83	574 47	66 28	115 38
12 12 97г	588 24	68 21	115 96	-	-	-	592 74	67 74	114 28	586 44	67 77	115 56
13 12 97г	600 9	69 60	115 83	-	-	-	615 17	70 82	115 12	589 33	67 55	116 62
14 12 97г	603 48	69 14	114 57	-	-	-	618 47	71 09	114 94	600 47	68 66	114 34
15 12 97г	596 98	68 22	114 28	184 47	21 05	114 11	410 08	46 90	114,37	589 16	67 15	113 98
16 12 97г	590 80	67 68	114 56	575 52	65 59	113 97	-	-	-	605 17	69 35	114 60
17 12 97г	604 45	68 77	114 10	603 43	68 92	114 21	-	-	-	614 64	69 92	113 76
18 12 97г	582 93	67 83	116 36	596 82	68 80	115 28	488 77	55 93	114 43	611 29	69 91	114 36
19 12 97г	586 83	67 41	114 87	592 91	68 56	115 63	615 75	70 56	114 59	620 08	70 99	114 49
20 12 97г	584 81	68 02	116 31	583 32	67 74	116 13	593 75	68 47	115 32	609 88	70 26	115 20
21 12 97г	595 81	69 22	116 18	599 32	69 48	115 93	614 31	70 39	114 58	616 53	70 49	114 33
22 12 97г	572 84	67 23	117 36	586 83	68 34	116 46	588 09	67 27	114 39	608 80	70 08	115 11
23 12 97г	584 7	66 73	114 13	596 35	68 65	115 12	603 11	69 21	114 76	611 8	69 98	114 38
24 12 97г	596 42	67 75	113 59	600 51	68 61	114 25	603 72	68 91	114 14	609 41	70 53	115 73
25 12 97г	417 11	49 49	118 65	574 15	67 07	116 82	585 54	67 48	115 24	610 21	69 79	114 37
26 12 97г	279 43	33 35	119 35	587 88	68 54	116 59	597 76	68 98	115 40	604 72	69 62	115 13
27 12 97г	590 95	69 04	116 83	585 84	67 70	115 56	600 22	68 67	114 41	595 92	68 87	115 57
28 12 97г	588 93	67 29	114 26	577 77	66 04	114 39	580 74	66 27	114 11	590 5	68 01	115 17
29 12 97г	597 21	69 27	115 99	591 81	68 37	115 53	601 10	69 34	115 36	589 16	67 39	114 38
30 12 97г	619 57	70 72	114 14	609 86	69 76	114 39	608 67	69 62	114 38	600 11	68 50	114 15
31 12 97г	604 45	69 14	114 38	607 24	69 50	114 45	601 14	68 90	114 62	598 54	68 22	113 98
	17714 01	2041 21	115 23	14161 99	1636 21	115 54	16480 85	1890 94	114 74	18491 69	2120 94	114 70

ХАРАКТЕРИСТИКА РАБОТЫ КОТЛОВ ГМ-50-14/250 ст N 11,12,13,14

ОБОРУДОВАННЫХ СИСТЕМОЙ АВТОМАТИЗАЦИИ ФИРМЫ " HONEYWELL "

(ЯНВАРЬ 1998 г)

Дата	К - 11			К - 12			К - 13			К - 14		
	Выработка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал	Выработка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал	Выработка Гкал	Расход топл Гкал	Удельн норма Кгнт/ Гкал	Выработка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал
1	2	3	4	5	6	7	8	9	10	11	12	13
01 01 98г	597 21	68 77	115 15	591 81	67 77	114 51	601 10	68 49	113 94	589 16	67 01	113 74
02 01 98г	619 57	70 99	114 58	609 86	69 86	114 55	608 67	69 62	114 38	600 11	68 23	113 70
03 01 98г	604 45	69 29	114 63	607 24	69 68	114 75	601 14	68 69	114 27	598 54	67 96	113 54
04 01 98г	589 15	67 87	115 20	582 61	67 16	115 47	584 9	66 73	114 09	-	-	-
05 01 98г	595 27	69 23	116 30	581 23	67 31	115 81	601 68	69 48	115 48	-	-	-
06 01 98г	600 44	68 35	113 83	597 49	67 85	113 56	597 62	68 57	114 74	-	-	-
07 01 98г	602 3	68 95	114 48	602 42	68 77	114 16	602 35	68 76	114 15	-	-	-
08 01 98г	606 33	68 85	113 55	600 77	68 43	113 90	598 04	67 85	113 45	-	-	-
09 01 98г	592 07	67 36	113 77	588 58	67 19	114 16	592 39	67 10	113 27	-	-	-
10 01 98г	592 37	67 44	113 85	586 4	66 57	113 52	594 03	68 14	114 71	586 44	67 27	114 71
11 01 98г	595 74	67 91	113 99	589 3	67 42	114 41	596 26	68 53	114 93	588 84	67 34	114 36
12 01 98г	592 3	67 57	114 08	591 91	67 23	113 58	586 18	67 02	114 33	346 5	39 81	114 89
13 01 98г	598 39	68 53	114 52	590 14	67 48	114 35	596 38	68 16	114 29	-	-	-
14 01 98г	590 5	67 47	114 26	584 65	67 27	115 06	593 4	68 15	114 85	-	-	-
15 01 98г	594 72	68 25	114 75	601 33	69 08	114 88	598 37	68 26	114 08	-	-	-
16 01 98г	587 77	67 21	114 35	594 63	67 54	113 58	595 1	67 43	113 31	-	-	-
17 01 98г	600 03	68 82	114 69	578 11	66 08	114 30	602 67	68 76	114 09	-	-	-
18 01 98г	562 01	64 11	114 07	564 94	64 46	114 10	598 65	68 57	114 54	-	-	-
19 01 98г	590 97	67 32	113 91	559 92	63 58	113 55	598 66	67 90	113 42	-	-	-
20 01 98г	597 11	68 57	114 84	570 31	65 29	114 48	594 15	67 63	113 83	572 64	65 01	113 53
21 01 98г	581 55	66 49	114 33	563 12	64 16	113 94	591 33	67 52	114 18	594 0	67 99	114 46
22 01 98г	570 38	65 54	114 91	561 53	64 81	115 42	586 3	67 59	115 28	576 19	66 17	114 84
23 01 98г	578 63	67 15	116 05	563 88	64 39	114 19	588 32	68 08	115 72	592 43	68 21	115 14
24 01 98г	577 02	67 59	117 14	550 1	63 62	115 65	588 37	67 98	115 54	592 17	68 15	115 09
25 01 98г	566 63	65 30	115 24	572 21	65 84	115 06	582 38	66 65	114 44	587 51	67 34	114 62
26 01 98г	572 95	65 59	114 48	577 76	66 19	114 56	578 83	66 36	114 65	589 46	67 02	113 70
27 01 98г	605 75	69 21	114 26	585 16	66 90	114 33	610 34	70 09	114 84	605 04	68 99	114 03
28 01 98г	592 68	68 06	114 83	583 46	66 98	114 80	601 18	69 22	115 14	599 57	68 48	114 22
29 01 98г	591 79	67 91	114 75	570 94	65 37	114 50	594 64	68 14	114 59	595 84	68 10	114 29
30 01 98г	579 24	65 90	113 77	563 64	64 14	113 80	597 99	68 45	114 47	592 58	67 60	114 08
31 01 98г	568 35	64 91	114 21	557 5	63 12	113 22	592 71	67 75	114 31	591 05	67 47	114 15
	18293 67	2096 51	114 60	18021 93	2061 54	114 39	18454 13	2111 67	114 43	10398 07	1188 15	114 27

Appendix B

Fuel Consumption in Kg of Standard Fuel per Gcal of Heat Generated for Boilers K-9 and 10 (Oct 1997 to Jan 1998)

ХАРАКТЕРИСТИКА РАБОТЫ КОТЛОВ

ГМ-50-14/250 ст N 9, 10

October

(ОКТЯБРЬ 1997 г)

Дата	К - 9			К - 10		
	Выра-ботка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал	Выра-ботка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал
01 10 97г	328 89	41 23	125 36	-	-	-
02 10 97г	633 98	76 40	120 51	-	-	-
03 10 97г	622 46	74 93	120 38	-	-	-
04 10 97г	627 63	75 32	120 00	-	-	-
05 10 97г	619 9	75 20	121 31	-	-	-
06 10 97г	616 44	73 60	119 40	-	-	-
07 10 97г	-	-	-	-	-	-
08 10 97г	-	-	-	-	-	-
09 10 97г	-	-	-	-	-	-
10 10 97г	-	-	-	-	-	-
11 10 97г	-	-	-	-	-	-
12 10 97г	-	-	-	-	-	-
13 10 97г	-	-	-	-	-	-
14 10 97г	-	-	-	-	-	-
15 10 97г	-	-	-	-	-	-
16 10 97г	-	-	-	-	-	-
17 10 97г	-	-	-	-	-	-
18 10 97г	-	-	-	-	-	-
19 10 97г	-	-	-	-	-	-
20 10 97г	-	-	-	-	-	-
21 10 97г	-	-	-	-	-	-
22 10 97г	-	-	-	-	-	-
23 10 97г	506 29	61 32	121 12	-	-	-
24 10 97г	578 68	69 00	119 24	-	-	-
25 10 97г	589 61	70 54	119 64	-	-	-
26 10 97г	587 61	70 83	120 54	-	-	-
27 10 97г	562 77	68 01	120 85	-	-	-
28 10 97г	600 18	71 50	119 13	-	-	-
29 10 97г	609 36	72 82	119 50	237 97	30 08	126 40
30 10 97г	617 04	75 38	122 16	563 74	67 46	119 67
31 10 97г	604 97	72 97	120 62	596 6	71 67	120 13
	8705 81	1049 05	120 50	1398 31	169 21	121 01

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ХАРАКТЕРИСТИКА РАБОТЫ КОТЛОВ

ГМ-50-14/250 ст N 9, 10

(НОЯБРЬ 1997 г)

Дата	К - 9			К - 10		
	Выра-ботка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал	Выра-ботка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал
01 11 97г	588 14	70 70	120 21	594 61	71 91	120 94
02 11 97г	568 65	67 99	119 56	578 23	69 68	120 51
03 11 97г	573 45	68 42	119 31	572 05	69 07	120 74
04 11 97г	577 02	69 77	120 91	578 87	69 37	119 84
05 11 97г	583 42	69 82	119 67	580 35	69 50	119 76
06 11 97г	565 72	67 29	118 95	571 02	68 04	119 16
07 11 97г	577 91	68 93	119 27	572 52	68 27	119 24
08 11 97г	563 77	67 83	120 30	556 42	66 75	119 96
09 11 97г	575 43	69 69	121 05	577 5	69 70	120 69
10 11 97г	578 09	69 76	120 67	570 25	68 68	120 44
11 11 97г	579 85	69 06	119 10	592 34	70 55	119 10
12 11 97г	567 09	67 61	119 22	570 38	67 82	118 90
13 11 97г	567 07	67 41	118 87	572 19	67 84	118 56
14 11 97г	558 96	67 11	120 06	499 44	59 86	119 85
15 11 97г	571 37	68 91	120 60	-	-	-
16 11 97г	563 34	68 09	120 87	-	-	-
17 11 97г	566 88	67 87	119 73	-	-	-
18 11 97г	558 03	66 89	119 87	-	-	-
19 11 97г	572 19	68 78	120 20	-	-	-
20 11 97г	484 22	58 38	120 57	-	-	-
21 11 97г	165 34	19 56	118 30	-	-	-
22 11 97г	-	-	-	574 85	68 76	119 61
23 11 97г	-	-	-	562 66	67 82	120 53
24 11 97г	-	-	-	578 76	70 07	121 07
25 11 97г	-	-	-	400 78	48 44	120 86
26 11 97г	-	-	-	300 86	35 72	118 73
27 11 97г	-	-	-	-	-	-
28 11 97г	-	-	-	299 55	37 23	124 29
29 11 97г	-	-	-	486 25	58 53	120 37
30 11 97г	573 1	69 53	121 32	-	-	-
	12079 34	1449 4	119 99	11189 88	1343 61	120 07

ХАРАКТЕРИСТИКА РАБОТЫ КОТЛОВ

ГМ-50-14/250 ст N 9, 10

(ДЕКАБРЬ 1997 г)

Дата	К - 9			К - 10		
	Выработка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал	Выработка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал
01 12 97г	587 59	70 69	120 30	-	-	-
02 12 97г	574 1	69 23	120 59	-	-	-
03 12 97г	585 67	69 91	119 37	-	-	-
04 12 97г	-	-	-	-	-	-
05 12 97г	129 69	16 17	124 68	239 7	29 47	122 95
06 12 97г	543 28	65 38	120 34	545 05	65 35	119 90
07 12 97г	213 78	25 46	119 09	591 4	71 25	120 48
08 12 97г	-	-	-	578 52	68 80	118 92
09 12 97г	549 77	67 89	123 49	566 13	67 75	119 67
10 12 97г	547 63	65 70	119 97	543 31	65 24	120 08
11 12 97г	589 36	70 93	120 35	586 88	70 85	120 72
12 12 97г	592 84	71 78	121 07	599 05	72 40	120 86
13 12 97г	605 34	72 72	120 13	608 96	73 43	120 58
14 12 97г	625 43	75 26	120 33	620 39	75 01	120 91
15 12 97г	618 72	74 64	120 64	614 34	74 13	120 67
16 12 97г	597 27	71 42	119 58	596 35	71 39	119 71
17 12 97г	569 83	68 47	120 16	222 77	26 59	119 36
18 12 97г	575 99	68 95	119 71	-	-	-
19 12 97г	559 66	66 98	119 68	-	-	-
20 12 97г	575 73	69 12	120 06	-	-	-
21 12 97г	409 76	49 41	120 58	-	-	-
22 12 97г	445 13	53 11	119 31	-	-	-
23 12 97г	-	-	-	579 27	69 69	120 31
24 12 97г	-	-	-	594 9	71 37	119 97
25 12 97г	393 84	48 38	122 84	563 61	67 75	120 21
26 12 97г	583 28	70 08	120 15	310 06	37 11	119 69
27 12 97г	562 35	66 90	118 97	-	-	-
28 12 97г	577 07	69 09	119 73	-	-	-
29 12 97г	578 11	69 40	120 05	-	-	-
30 12 97г	595 73	71 17	119 47	-	-	-
31 12 97г	581 45	70 18	120 70	-	-	-
	14368 40	1728 42	120 29	8960 69	1077 58	120 26

В-3

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ХАРАКТЕРИСТИКА РАБОТЫ КОТЛОВ

ГМ-50-14/250 ст N 9, 10

(ЯНВАРЬ 1998 г)

Дата	К - 9			К - 10		
	Выра-ботка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал	Выра-ботка Гкал	Расход топл тнт	Удельн норма Кгнт/ Гкал
01 01 98г	387 36	46 82	120 87	-	-	-
02 01 98г	570 21	68 03	119 31	-	-	-
03 01 98г	586 59	70 30	119 85	-	-	-
04 01 98г	559 25	67 15	120 07	469 86	56 92	121 14
05 01 98г	587 53	70 22	119 52	599 19	71 59	119 48
06 01 98г	585 76	69 93	119 38	611 28	72 90	119 26
07 01 98г	569 06	68 35	120 11	612 80	73 40	119 78
08 01 98г	590 01	70 39	119 30	602 08	71 98	119 55
09 01 98г	386 77	46 01	118 96	601 10	71 73	119 33
10 01 98г	-	-	-	609 71	73 27	120 17
11 01 98г	-	-	-	597 08	71 92	120 45
12 01 98г	-	-	-	598 07	71 27	119 17
13 01 98г	-	-	-	597 23	71 42	119 59
14 01 98г	-	-	-	596 04	71 39	119 77
15 01 98г	-	-	-	583 10	69 66	119 46
16 01 98г	-	-	-	598 29	71 82	120 04
17 01 98г	-	-	-	613 01	73 79	120 37
18 01 98г	-	-	-	594 74	71 35	119 97
19 01 98г	-	-	-	591 26	70 76	119 68
20 01 98г	-	-	-	612 05	73 54	120 15
21 01 98г	-	-	-	607 86	73 01	120 11
22 01 98г	-	-	-	599 96	71 97	119 96
23 01 98г	-	-	-	590 70	70 65	119 60
24 01 98г	-	-	-	576 5	68 93	119 57
25 01 98г	-	-	-	583 56	69 87	119 73
26 01 98г	-	-	-	573 06	67 80	118 31
27 01 98г	-	-	-	570 99	68 59	120 12
28 01 98г	-	-	-	534 53	64 19	120 09
29 01 98г	-	-	-	595 04	71 04	119 39
30 01 98г	-	-	-	596 9	71 32	119 48
31 01 98г	-	-	-	610 2	72 97	119 58
	4822 54	577 2	119 69	16526	1979 05	119 75

Appendix C

Power Consumption in KWHR per Gcal of Heat Generated for Boilers K-13 and 14 (Oct 1995 to Jan 1996)

Характеристика расходов электроэнергии на котлах ГМ-50-14/250 ст.N 13, 14 до установки на Д, В частотных преобразователей.

ОКТЯБРЬ 1995 год

КОТЕЛ N 13				КОТЕЛ N 14			
ДАТА	кВт час	Гкал	кВт ч/Гкал	ДАТА	кВт час	Гкал	кВт ч/Гкал
01 10 95	-	-	-	01 10 95	4760	566 5	8 4
02 10 95	-	-	-	02 10 95	4760	553 31	8 6
03 10 95	-	-	-	03 10 95	4696	562 38	8 4
04 10 95	-	-	-	04 10 95	2808	306 04	9 2
05 10 95	-	-	-	05 10 95	1480	124 02	11 9
06 10 95	-	-	-	06 10 95	2344	141 2	16 6
07 10 95	-	-	-	07 10 95	4672	573 03	8 2
08 10 95	-	-	-	08 10 95	4768	527 56	9 0
09 10 95	-	-	-	09 10 95	1856	211 44	8 8
10 10 95	-	-	-	10 10 95	-	-	-
11 10 95	-	-	-	11 10 95	-	-	-
12 10 95	-	-	-	12 10 95	-	-	-
13 10 95	1672	337 25	4 96	13 10 95	-	-	-
14 10 95	2512	640 98	3 92	14 10 95	-	-	-
15 10 95	2488	641 91	3 88	15 10 95	1608	105 7	15 2
16 10 95	824	212 36	3 88	16 10 95	4888	571 09	8 6
17 10 95	-	-	-	17 10 95	4816	576 49	8 4
18 10 95	-	-	-	18 10 95	4888	568 06	8 6
19 10 95	-	-	-	19 10 95	5424	612 78	8 9
20 10 95	1472	335 38	4 39	20 10 95	5448	619 94	8 8
21 10 95	2392	649 48	3 68	21 10 95	3952	441 74	8 9
22 10 95	2664	670 14	3 98	22 10 95	2744	423 18	6 5
23 10 95	2624	686 65	3 82	23 10 95	1792	235 63	7 6
24 10 95	2520	663 02	3 8	24 10 95	1488	136 36	10 9
25 10 95	2456	644 85	3 81	25 10 95	4472	583 8	7 7
26 10 95	2544	630 6	4 03	26 10 95	4456	588 68	7 6
27 10 95	2912	656 58	4 44	27 10 95	4568	612 40	7 5
28 10 95	2896	660 89	4 38	28 10 95	4272	581 20	7 4
29 10 95	2712	643 43	4 21	29 10 95	4544	602 77	7 5
30 10 95	2880	619 94	4 65	30 10 95	4744	602 24	7 9
31 10 95	2752	618 23	4 45	31 10 95	4648	595 20	7 8
	38320	9311 69	4 12		100896	12023 04	8 39

Характеристика расходов электроэнергии на котлах ГМ-50-14/250 ст.N 13, 14 до установки на Д, В частотных преобразователей.

НОЯБРЬ 1995 год

КОТЕЛ N 13				КОТЕЛ N 14			
ДАТА	кВт час	Гкал	кВт ч/Гкал	ДАТА	кВт час	Гкал	кВт ч/Гкал
01 11 95	2464	636 33	3 8	01 11 95	4456	581 83	7 7
02 11 95	2368	627 74	3 8	02 11 95	1752	218 88	8 0
03 11 95	2472	633 07	3 9	03 11 95	1536	150 46	10 2
04 11 95	2456	619 39	4 0	04 11 95	4528	639 61	7 1
05 11 95	2336	618 04	3 8	05 11 95	4352	610 32	7 1
06 11 95	2360	627 81	3 8	06 11 95	864	124 0	7 0
07 11 95	2688	621 07	4 3	07 11 95	-	-	-
08 11 95	-	-	-	08 11 95	-	-	-
09 11 95	-	-	-	09 11 95	-	-	-
10 11 95	2472	631 3	3 9	10 11 95	4232	624 5	6 8
11 11 95	2384	608 77	3 9	11 11 95	3944	595 2	6 6
12 11 95	2424	620 51	3 9	12 11 95	4184	617 62	6 8
13 11 95	2480	625 21	4 0	13 11 95	4064	604 64	6 7
14 11 95	2480	618 86	4 0	14 11 95	3616	518 69	7 0
15 11 95	2504	608 36	4 1	15 11 95	4208	616 44	6 8
16 11 95	2624	630 6	4 2	16 11 95	4264	623 52	6 8
17 11 95	2480	613 49	4 0	17 11 95	4184	604 64	6 9
18 11 95	2560	611 72	4 2	18 11 95	4424	616 55	7 2
19 11 95	2640	624 66	4 2	19 11 95	4088	578 03	7 1
20 11 95	2400	633 55	3 8	20 11 95	4440	633 92	7 0
21 11 95	2504	626 47	4 0	21 11 95	4288	619 43	6 9
22 11 95	-	-	-	22 11 95	-	-	-
23 11 95	2376	635 32	3 7	23 11 95	-	-	-
24 11 95	2544	650 66	3 9	24 11 95	576	89 17	6 6
25 11 95	2416	654 92	3 7	25 11 95	4192	562 99	7 4
26 11 95	2760	673 91	4 1	26 11 95	4392	624 07	7 0
27 11 95	2672	659 14	4 1	27 11 95	4120	581 04	7 1
28 11 95	2520	625 94	4 0	28 11 95	4200	591 86	7 1
29 11 95	2480	409 98	6 0	29 11 95	4128	593 92	7 0
30 11 95	2608	647 05	4 0	30 11 95	3912	600 86	6 5
	67472	16803 9	4 0		92944	13222 19	7 0

Характеристика расходов электроэнергии на котлах ГМ-50-14/250 ст.N 13, 14 до установки на Д, В частотных преобразователей.

ДЕКАБРЬ 1995 год

КОТЕЛ N 13				КОТЕЛ N 14			
ДАТА	кВт час	Гкал	кВт ч/Гкал	ДАТА	кВт час	Гкал	кВт ч/Гкал
01 12 95	-	-	-	01 12 95	-	-	-
02 12 95	2736	651 68	4 2	02 12 95	4456	641 82	6 9
03 12 95	2600	654 03	4 0	03 12 95	4544	638 14	7 1
04 12 95	2664	642 35	4 1	04 12 95	4296	602 55	7 1
05 12 95	2568	645 27	4 0	05 12 95	4048	586 44	6 9
06 12 95	2632	657 66	4 0	06 12 95	4248	604 19	7 0
07 12 95	2648	651 17	4 1	07 12 95	4264	611 75	7 0
08 12 95	2592	646 45	4 0	08 12 95	4208	596 22	7 1
09 12 95	2440	649 98	3 8	09 12 95	3784	597 48	6 3
10 12 95	2616	664 4	3 9	10 12 95	2168	278 8	7 8
11 12 95	2504	643 49	3 9	11 12 95	-	-	-
12 12 95	2520	641 12	3 9	12 12 95	-	-	-
13 12 95	2552	658 55	3 9	13 12 95	-	-	-
14 12 95	2496	639 45	3 9	14 12 95	4312	593 8	7 3
15 12 95	2448	638 27	3 8	15 12 95	4144	579 04	7 2
16 12 95	2448	640 00	3 8	16 12 95	4032	582 8	6 9
17 12 95	2440	620 54	3 9	17 12 95	3880	569 4	6 8
18 12 95	2648	646 98	4 1	18 12 95	3888	586 4	6 6
19 12 95	2608	635 83	4 1	19 12 95	3976	566 88	7 0
20 12 95	2560	624 07	4 1	20 12 95	4144	577 2	7 2
21 12 95	2536	637 49	4 0	21 12 95	3976	553 71	7 2
22 12 95	2456	633 1	3 9	22.12 95	-	-	-
23 12 95	2624	656 56	4 0	23 12 95	-	-	-
24 12 95	2448	666 00	4 0	24 12 95	-	-	-
25 12 95	2512	664 82	3 8	25 12 95	-	-	-
26 12 95	2536	656 56	3 9	26 12 95	-	-	-
27 12 95	2600	653 87	4 0	27 12 95	-	-	-
28 12 95	2536	664 92	3 8	28 12 95	-	-	-
29 12 95	2512	655 38	3 8	29 12 95	-	-	-
30 12 95	2616	636 81	4 1	30 12 95	2248	307 12	7 3
31 12 95	2576	669 05	3 9	31 12 95	3984	566 88	7 0
	67472	19445 8	3 9		74600	10640 62	7 0

С-3

Характеристика расходов электроэнергии на котлах ГМ-50-14/250 ст.N 13, 14 до установки на Д, В частотных преобразователей.

ЯНВАРЬ 1996 год

КОТЕЛ N 13				КОТЕЛ N 14			
ДАТА	кВт час	Гкал	кВт ч/Гкал	ДАТА	кВт час	Гкал	кВт ч/Гкал
01 01 96	2464	632 31	3 9	01 01 96	4000	566 88	7 06
02 01 96	2536	648 48	3 91	02 01 96	552	57 74	9 56
03 01 96	1480	655 1	3 79	03 01 96	-	-	-
04 01 96	2344	626 47	3 74	04 01 96	-	-	-
05 01 96	2496	631 55	3 95	05 01 96	-	-	-
06 01 96	2480	641 18	3 87	06 01 96	-	-	-
07 01 96	2448	622 85	3 93	07 01 96	-	-	-
08 01 96	384	91 08	4 2	08 01 96	4072	472 4	8 62
09 01 96	-	-	-	09 01 96	3960	562 74	7 04
10 01 96	800	118 7	6 7	10 01 96	4032	566 88	7 11
11 01 96	2344	618 38	3 79	11 01 96	4016	583 54	6 88
12 01 96	2400	640 04	3 75	12 01 96	3912	566 88	6 9
13 01 96	2384	651 6	3 66	13 01 96	3928	566 88	6 93
14 01 96	2424	648 67	3 73	14 01 96	3912	565 17	6 92
15 01 96	2456	638 83	3 84	15 01 96	3832	566 88	6 72
16 01 96	2304	654 19	3 52	16 01 96	2384	348 4	6 84
17 01 96	2800	654 48	4 27	17 01 96	-	-	-
18 01 96	2584	657 93	3 92	18 01 96	-	-	-
19 01 96	2400	621 67	3 86	19 01 96	-	-	-
20 01 96	2464	652 05	3 77	20 01 96	-	-	-
21 01 96	2520	649 57	3 87	21 01 96	-	-	-
22 01 96	2352	627 88	3 74	22 01 96	3272	297 9	10 98
23 01 96	2128	563 7	3 77	23 01 96	5048	561 22	8 99
24 01 96	2128	569 3	3 73	24 01 96	4472	551 1	8 11
25 01 96	2176	593 41	3 66	25 01 96	5024	543 5	9 24
26 01 96	2232	587 51	3 79	26 01 96	4576	556 29	8 22
27 01 96	2168	612 07	3 54	27 01 96	4912	552 83	8 88
28 01 96	2344	629 02	3 72	28 01 96	4936	562 54	8 77
29 01 96	2352	606 21	3 88	29 01 96	5120	568 49	9 0
30 01 96	2328	601 33	3 87	30 01 96	5024	571 8	8 79
31 01 96	2456	639 95	3 84	31 01 96	4920	567 76	8 67
	68176	17245 5	3 95		85904	10757 8	8 0

Appendix D

Power Consumption in KWHR per Gcal of Heat Generated for Boilers K-13 and 14 (Oct 1997 to Jan 1998)

Характеристика расходов электроэнергии на котлах ГМ-50-14/250 ст.N 13,14 после установки на Д, В частотных преобразователей.

ОКТЯБРЬ 1997 год

КОТЕЛ N 13				КОТЕЛ N 14			
ДАТА	кВт час	Гкал	кВт ч/Гкал	ДАТА	кВт час	Гкал	кВт ч/Гкал
01 10 97	-	-	-	01 10 97	-	-	-
02 10 97	-	-	-	02 10 97	-	-	-
03 10 97	-	-	-	03 10 97	-	-	-
04 10 97	-	-	-	04 10 97	-	-	-
05 10 97	-	-	-	05 10 97	-	-	-
06 10 97	-	-	-	06 10 97	-	-	-
07 10 97	-	-	-	07 10 97	-	-	-
08 10 97	-	-	-	08 10 97	-	-	-
09 10 97	-	-	-	09 10 97	-	-	-
10 10 97	-	-	-	10 10 97	-	-	-
11 10 97	-	-	-	11 10 97	-	-	-
12 10 97	-	-	-	12 10 97	-	-	-
13 10 97	-	-	-	13 10 97	-	-	-
14 10 97	-	-	-	14 10 97	-	-	-
15 10 97	-	-	-	15 10 97	-	-	-
16 10 97	-	-	-	16 10 97	-	-	-
17 10 97	-	-	-	17 10 97	-	-	-
18 10 97	-	-	-	18 10 97	-	-	-
19 10 97	-	-	-	19 10 97	-	-	-
20 10 97	-	-	-	20 10 97	-	-	-
21 10 97	-	-	-	21 10 97	-	-	-
22 10 97	-	-	-	22 10 97	-	-	-
23 10 97	-	-	-	23 10 97	-	-	-
24 10 97	-	-	-	24 10 97	-	-	-
25 10 97	-	-	-	25 10 97	2280	586 79	3 89
26 10 97	-	-	-	26 10 97	2256	585 71	3 85
27 10 97	-	-	-	27 10 97	2376	621 65	3 82
28 10 97	2120	596 81	3 55	28 10 97	2520	602 05	4 19
29 10 97	1848	587 45	3 15	29 10 97	2624	596 73	4 4
30 10 97	1844	563 2	3 27	30 10 97	2280	586 79	3 89
31 10 97	2008	585 4	3 43	31 10 97	-	-	-

3,35 4

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Характеристика расходов электроэнергии на котлах ГМ-50-14/250 ст.N 13,14 после установки на Д, В частотных преобразователей.

НОЯБРЬ 1997 год

КОТЕЛ N 13				КОТЕЛ N 14			
ДАТА	кВт час	Гкал	кВт ч/Гкал	ДАТА	кВт час	Гкал	кВт ч/Гкал
01 11 97	1920	568 1	3 38	01 11 97	2368	618 28	3 83
02 11 97	1680	550 98	3 05	02 11 97	2382	609 2	3 91
03 11 97	1760	560 50	3 14	03 11 97	2268	581 54	3 9
04 11 97	1823	567 91	3 21	04 11 97	2240	570 2	3 93
05 11 97	1864	598 54	3 11	05 11 97	2268	590 61	4 01
06 11 97	1712	562 55	3 04	06 11 97	2096	527 96	3 97
07 11 97	1824	562 64	3 24	07 11 97	2280	567 35	4 02
08 11 97	1608	556 37	2 89	08 11 97	2272	585 65	3 88
09 11 97	1649	551 24	2 99	09 11 97	2088	553 92	3 77
10 11 97	1504	550 57	2 73	10 11 97	1912	568 33	3 36
11 11 97	1616	551 16	2 93	11 11 97	2304	563 67	4 09
12 11 97	1632	561 9	2 9	12 11 97	2224	572 42	3 89
13 11 97	1680	549 62	3 06	13 11 97	2032	550 45	3 69
14 11 97	1832	562 54	3 26	14 11 97	2304	571 73	4 03
15 11 97	1784	553 54	3 22	15 11 97	2272	564 24	4 03
16 11 97	1624	558 97	2 91	16 11 97	2272	571 8	3 97
17 11 97	1648	565 4	2 91	17 11 97	2248	581 41	3 87
18 11 97	1800	558 68	3 22	18 11 97	2408	572 59	4 21
19 11 97	1656	559 91	2 96	19 11 97	2496	590 11	4 23
20 11 97	1632	557 19	2 93	20 11 97	2432	583 95	4 16
21 11 97	1928	596 51	3 23	21 11 97	2656	607 27	4 37
22 11 97	1656	568 53	2 91	22 11 97	2272	575 15	3 95
23 11 97	1683	571 3	2 95	23 11 97	2432	588	4 14
24 11 97	1752	574 12	3 05	24 11 97	2600	572 81	4 54
25 11 97	1592	561 3	2 84	25 11 97	2368	581 03	4 08
26 11 97	1600	564 71	2 83	26 11 97	2320	584 7	3 97
27 11 97	1744	574 34	3 04	27 11 97	2376	588 76	4 04
28 11 97	1696	570 85	2 97	28 11 97	2224	576 05	3 86
29 11 97	1824	576 54	3 16	29 11 97	2544	606 82	4 19
30 11 97	1248	409 97	3 04	30 11 97	2216	578 42	3 83

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Характеристика расходов электроэнергии на котлах ГМ-50-14/250 ст.N 13,14 после установки на Д, В частотных преобразователей.

ДЕКАБРЬ 1997 год

КОТЕЛ N 13				КОТЕЛ N 14			
ДАТА	кВт час	Гкал	кВт ч/Гкал	ДАТА	кВт час	Гкал	кВт ч/Гкал
01 12 97	568	159 03	3 57	01 12 97	2368	594 45	3 98
02 12 97	2016	609 46	3 31	02 12 97	2392	589 94	4 05
03 12 97	1960	600 54	3 26	03 12 97	2360	583 37	4 05
04 12 97	2096	655 03	3 2	04 12 97	2600	625 07	4 16
05 12 97	1936	610 12	3 17	05 12 97	2456	582 68	4 22
06 12 97	1608	609 8	2 64	06 12 97	2592	590 04	4 39
07 12 97	1872	566 43	3 3	07 12 97	2408	583 55	4 13
08 12 97	1968	575 96	3 42	08 12 97	2488	583 59	4 26
09 12 97	1776	560 51	3 17	09 12 97	2376	569 93	4 17
10 12 97	1608	554 07	2 9	10 12 97	2176	568 16	3 83
11 12 97	1744	586 61	2 97	11 12 97	2660	574 47	3 76
12 12 97	1896	592 74	3 2	12 12 97	2472	586 44	4 22
13 12 97	2016	591 85	3 41	13 12 97	1752	590 13	2 97
14 12 97	2096	590 7	3 55	14 12 97	3016	596 4	5 06
15 12 97	1392	410 08	3 39	15 12 97	2264	589 16	3 84
16 12 97	-	-	-	16 12 97	2376	605 17	3 93
17 12 97	-	-	-	17 12 97	2392	614 64	3 89
18 12 97	1568	488 77	3 21	18 12 97	2416	611 3	3 95
19 12 97	1936	615 75	3 14	19 12 97	2472	620 08	3 99
20 12 97	1784	593 75	3 00	20 12 97	2376	609 88	3 9
21 12 97	1952	620 13	3 15	21 12 97	2336	618 88	3 77
22 12 97	1840	618 72	2 97	22 12 97	2432	619 72	3 92
23 12 97	2056	603 11	3 41	23 12 97	2608	611 8	4 26
24 12 97	2600	603 72	4 31	24 12 97	2216	609 41	3 64
25 12 97	1816	585 54	3 1	25 12 97	2448	610 21	4 01
26 12 97	1912	597 76	3 2	26 12 97	2280	604 72	3 77
27 12 97	1912	600 22	3 19	27 12 97	2192	595 9	3 68
28 12 97	1760	580 74	3 03	28 12 97	2208	590 5	3 74
29 12 97	1936	589 8	3 28	29 12 97	2088	593 46	3 52
30 12 97	2008	590 4	3 4	30 12 97	2176	594 01	3 66
31 12 97	2312	601 14	3 85	31 12 97	2832	598 54	4 73
			3,266				3 98

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Характеристика расходов электроэнергии на котлах ГМ-50-14/250 ст.N 13,14 после установки на Д, 8 частотных преобразователей.

ЯНВАРЬ 1998 год

КОТЕЛ N 13				КОТЕЛ N 14			
ДАТА	кВт час	Гкал	кВт ч/Гкал	ДАТА	кВт час	Гкал	кВт ч/Гкал
01 01 98	1632	579 41	2 82	01 01 98	1400	593 86	2 36
02 01 98	1728	576 69	3 0	02 01 98	2072	593 0	3 49
03 01 98	1888	595 49	3 17	03 01 98	2136	599	3 57
04 01 98	2056	601 38	3 42	04 01 98	-	-	-
05 01 98	2088	601 68	3 47	05 01 98	-	-	-
06 01 98	2056	602 7	3 41	06 01 98	-	-	-
07 01 98	2088	601 9	3 47	07 01 98	-	-	-
08 01 98	2056	598 04	3 44	08 01 98	-	-	-
09 01 98	1768	592 39	2 98	09 01 98	-	-	-
10 01 98	1848	594 03	3 11	10 01 98	2000	586 44	3 41
11 01 98	1912	596 26	3 2	11 01 98	2048	588 84	3 48
12 01 98	1864	598 3	3 12	12 01 98	-	-	-
13 01 98	1864	602 4	3 09	13 01 98	-	-	-
14 01 98	1904	598 3	3 18	14 01 98	-	-	-
15 01 98	1952	602 4	3 24	15 01 98	-	-	-
16 01 98	2024	595 1	3 4	16 01 98	-	-	-
17 01 98	2200	602 67	3 65	17 01 98	-	-	-
18 01 98	2152	598 65	3 59	18 01 98	-	-	-
19 01 98	1888	596	3 17	19 01 98	-	-	-
20 01 98	2008	594 15	3 38	20 01 98	2416	572 64	4 22
21 01 98	1896	591 33	3 21	21 01 98	2096	594 0	3 53
22 01 98	1864	595 3	3 13	22 01 98	2088	595 01	3 51
23 01 98	1960	602 5	3 25	23 01 98	2096	601 4	3 49
24 01 98	1992	588 37	3 39	24 01 98	2208	592 17	3 73
25 01 98	1760	582 38	3 02	25 01 98	2024	587 5	3 45
26 01 98	1864	578 83	3 22	26 01 98	2240	589 16	3 8
27 01 98	2216	610 34	3 63	27 01 98	2384	605 04	3 94
28 01 98	2080	601 18	3 46	28 01 98	2360	599 57	3 94
29 01 98	1960	594 64	3 3	29 01 98	2256	595 84	3 79
30 01 98	1984	601 24	3 3	30 01 98	2200	604 05	3 64
31 01 98	1936	609 8	3 17	31 01 98	2176	603 7	3 6

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3.585

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Appendix E

List of Contacts

1 Igor V Saburov, Technical Manager, Tel 7 815 2 33-15-58 Fax 32-02-17

2 Alexander P Gusev, Director, Tel 7 815 2 33-15-48 Fax 32-02-17

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Russia

Appendix F

COMBUSTION CALCULATIONS FOR MAZUT

W O 05917-001

COMBUSTION CALCULATIONS FOR MAZUT

Given a mazut (residual heavy oil), having an Ultimate Analysis by weight as follows

Carbon	84 50 %
Hydrogen	11 70
Oxygen	0 18
Sulphur	3 44
Nitrogen	0 18
total	100 00 %

LCV 9,880 kcal/kg
NB mazut usually contains a very small percentage of moisture

(a) With **stoichiometric** combustion air, the oxygen and combustion air required, kg per kg of mazut, and the products of combustion, kg per kg of mazut will be

	kg/kg	O2	Air	CO2	O2	N2	H2O	SO2
C	0 845	2 26	9 71	3 10	--	7 45	-	--
H2	0 117	0 94	4 03	-	--	3 10	1 05	-
O2	0 0018	--	--	--	0 0018	--	--	-
S	0 0344	0 0344	0 148	--	--	0 114	--	0 069
N2	0 0018	--	-	--	-	0 0018	--	-
subtotals	1 00	3 2344	13 888	3 10	0 0018	10 666	1 05	0 069
	O2 in m	0 0018	0 008	-	0 0018	0 006	--	--
	totals	**3 2326**	**13 880**	**3 10**	**0**	**10 660**	**1 05**	**0 069**

In words every 1 0 kg of mazut combusted will produce 3 10 kg of CO2 and 0 069 kg of SO2

(b) With **25% excess combustion air,** the oxygen and combustion air required, kg per kg of mazut, and the products of combustion, kg per kg of mazut will be

	kg prod of comb /kg mazut with stoichiometric comb air	kg prod of comb /kg mazut with 25% excess comb air
CO2	3 10	3 10
O2	0 00	0 805
N2	10 66	13 325
H2O	1 05	1 05
SO2	0 069	0 069
totals	**14 880**	**18 349**

Appendix G

ENVIRONMENTAL COSTS

An Introductory Note on

Environmental Externalities and Costs in the Context of Global Climate Change

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What Are Externalities and Externality Costs?

Externalities are defined as benefits or costs, generated as a byproduct of economic activity, that do not accrue to the parties involved in the activity Environmental externalities are benefits and costs that manifest themselves through changes in the physical/biological environment Electric power plants that burn fossil fuels emit several pollutants linked to environmental problems of acid rain, urban smog and, possibly, of global climate change Damages caused by those emissions are viewed by many economists as environmental externalities resulting from an inefficient market, in which electricity rates do not reflect, and ratepayers do not directly pay, the social costs associated with negative impacts on the physical/biological environment The simplest approach to address these environmental impacts is to characterize and describe qualitatively the environmental resource options A somewhat more complicated approach is to rank and weigh air, water, and land impacts of individual options Finally, one could quantify and *monetize* (assign a dollar value to) the externalities associated with resource options

The costs or economic value of the environmental impact or harm are referred to as *environmental costs* or *externality costs* To the extent that the energy industry does not pay these externality costs and consumers do not pay the full cost of energy they consume, energy resources are not allocated efficiently Estimates of externality costs require quantification of emissions (e g , tons of sulfur dioxide per ton of coal) and monetization of these emissions (e g , dollars of environmental damage per pound of carbon dioxide) These externality costs are generally expressed in "per ton emissions" or "per kilowatt-hour of electricity " These monetary values are incorporated in the economic analysis of resource options from the societal perspective, such as by electric utilities and state regulatory agencies (public service commissions) in the United States

The theory and application of externality costs covers all types of environmental impacts on land, water, and air, as well as those originating from all anthropogenic sources, ranging from power generation to cattle dung production to rice cultivation They are manifested in a variety of ways, such as acid rain and urban smog The following discussion is limited to air emissions occurring from energy sources, primarily electricity generation processes, that may lead to global

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climate change

Global Climate Change

Greenhouse gases (GHGs) are necessary for life on earth because they keep ambient temperatures well above what they would otherwise be Many scientists believe that anthropogenic additions to the earth's natural complement of GHGs are augmenting this greenhouse effect and thus raising global temperatures The principle GHGs are carbon dioxide (CO_2), water vapor, methane, nitrous oxides, and chlorofluorocarbons Of the fossil fuels, coal has the highest carbon content Oil and natural gas have approximately 80 and 60 percent, respectively, of the carbon content of coal on an energy-equivalency basis

Although CO_2 is not a regulated pollutant in most countries, the reduction of GHG gases in general, including those of CO_2, is the focus of several international efforts

Approaches for Valuation of Externalities

There are several methods used to monetize environmental externalities Each technique has its pros and cons, thus there remains a large amount of uncertainty and disagreement among economists and policy makers regarding values that are determined and used for planning practices and policy development purposes Externality costs are estimated using the following common approaches

- Damage Cost Approach
- Control or Mitigation Cost Approach
- Revealed Preferences Approach

Damage Cost Approach

Damage costing determines environmental externality costs by monetizing the effect of their impacts (or re-mediating their impacts) This would include impacts on (1) human health (e g , increase in cancer and infant mortality rates or decrease in life expectancy), (2) infrastructure (e g , metal oxidation and limestone dissolution), (3) agriculture (e g , soil chemistry changes, changing precipitation patterns, temperatures, length of seasons, storm severity, or incidence of ultra-violet light), as well as (4) bio-diversity (loss of animal species, deforestation, etc)

It is very difficult to accurately monetize the cost of the impact (such as, the value of human life lost as a result of environmental impact) This approach is not only complex but fraught with uncertainty It is also very difficult to determine the boundaries of any impacts In short, the uncertainty, the lack of accurate data, the response to the perturbation (which may include non-linear responses as well as feedback effects), and other factors could confound the damage cost

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estimation method

Control Cost Approach

The *control cost*, or *mitigation*, approach determines an externality cost by using the cost of reducing or preventing the emissions as proxy for damage costs Usually, the cost of the most stringent emissions control technique is used For example, How much does it cost to reduce emissions of sulfur dioxide by use of flue-gas desulfurization techniques or emissions of CO_2 through reforestation mechanisms? As can be expected, this results in a range of externality cost estimates, but the range is tighter than that found through the damage cost approach

The implicit assumption in control costing is that society controls pollution until the benefits of additional controls will be outweighed by costs However, there is no direct relationship between the control cost estimates and the real environmental externality costs

In the context of electric utilities, when the control cost approach is applied (e g , by state utility commissions in the US), the rationale is that it is appropriate to promote investments in those control measures that will reduce the emissions For instance, in the early 1990s New York and California used control cost method to develop externality costs (for use during integrated resource planning in the electricity sector)

Revealed Preferences Method

Externality costs developed using the *revealed preferences* method (or *shadow pricing* approach) are based on the value that the public places on specific environmental impacts For example, in the case of SO_2 (an important acid rain precursor), the highest (or marginal) cost reduction strategy in response to new legislation is taken as the (marginal) value that society places on reducing SO_2 emissions Of course, this means externality costs are determined, in large measure, by those who develop environmental legislation One can argue that legislators are not fully aware of the reduction costs when legislation is being developed

Discounting Externality Costs

An important issue, which has significant impact on the externality cost, is the applied discount rate Many externalities have impacts, particularly in case of greenhouse gases, over long periods of time For instance, the atmospheric life of CO_2 is between 200 and 500 years In these cases, the choice of discount rate (which, in general financial analysis and practice, is applied to value costs and benefits occurring at a future point in time) has significant impact on the externality cost A positive discount rate would imply that costs occurring far into the future are of no concern to us, even if they are substantial Environmental economists argue against this inter-generational bias in terms of handling externality costs

Spatial Variation of Externality Costs

The environment can absorb a certain level of pollution without damage This threshold, below which control is not warranted, may be uniform throughout the country or may vary from region to region, depending on the pollutant and the environmental concern in question Uniformly mixed pollutants have the same effect on the environment regardless of their geographic point of origin or impact For example, emissions of CO_2 from anywhere in the country or the world have uniform impacts on climate change The effects of non-uniformly mixed pollutants, such as acid rain or urban smog causing pollutants, are very sensitive to conditions around the point of impact This spatial variation of impacts of externalities on the environment causes bias in the valuation and uncertainty in the range of externality costs

Estimates of Externality Costs

In a recent study (EC, 1995) that reviews and compares valuation of externality resulting from electricity generation, the following damage cost-based estimates are provided for assessing the impact on global climate arising from coal use under various discount rates

Discount rate	Externality Cost Estimate (cents/kWh)
0%	1 3 - 2 29
3%	0 19 - 0 33
10%	0 05-0 08

However, each of the studies reviewed concludes that it is not possible to use an impact pathway approach to provide reliable estimates of damages, and they assign a very low level of confidence to these estimates Several researchers use this rule of thumb each $1 of damage estimated or assumed to result per ton of CO_2 translates roughly to 0 1 cent per kWh

Some other estimates from specific studies are given below for CO_2 and other GHGs The date when the cost estimate was developed is also provided Adjusting the costs to current values just by adjusting for inflation, would be too simplistic This is because both the values placed on the environment (as represented by our environmental legislation) and the changes in the cost of control will not necessarily track inflation In fact, the cost of technical control measure should decline through normal technical advancements

Carbon Dioxide

Estimate	$ basis	method	location	source
$22/ton	1988	control[1]	US	Chernick & Caverhill, 1988
$7/ton	1989	legislation	California	Puta, 1989
$9/ton	1992	legislation	California	EIA, 1995
$1 2/ton	1989	legislation	New York state	NYSEO, 1989
$14/ton	1990	control[1]	US	Calwell 1990
$14 2/ton	1990	control	New York state	PACE 1990
$15/ton	1992	legislation[4]	Wisconsin	PSCW, 1992
$75-150/ton[2]	1993	control[3]	US	Haraden, 1993
$24/ton	1992	legislation	Massachusetts	EIA, 1995
$9 8/ton	1992	legislation	Minnesota	EIA, 1995
$24/ton	1992	legislation	Nevada	EIA, 1995
$25/ton	1992	legislation	Oregon	EIA, 1995

Notes
(1) CO_2 uptake through reforestation
(2) per ton carbon
(3) CO_2 removal at coal gasification power plants
(4) based on control

Methane

Estimate	$ basis	method	location	source
$0 11/lb	1989	based on CO2[1]	US	Tellus, 1990
$0 35/lb	1988	control	US	Chernick & Caverhill, 1988
$0 75/lb	1992	legislation[2]	Wisconsin	PSCW, 1992

Notes
(1) As the global warming potential (GWP) is estimated to be 10 times that of CO_2 its externality cost is 10 times that of CO_2 (note the GWP used by Tellus is outdated)
(2) based on control

NOx - Also leads to Acid Rain

Estimate	$ basis	method	location	source
	$3 50/lb	1989	perceived	NE US Tellus, 1990
$131/lb	1989	perceived	S California	Tellus, 1990
$1 50/lb	1988	control	Massachusetts	Chernick & Caverhill, 1988
$0 6/lb	1989	control	New York state	Putta 1989
8 15/lb	1989	control	California	Therkelsen 1989
$4 45/lb	1989	legislation	California	SCAG 1989
$0 86/lb	1990	control	New York state	PACE, 1990
$3 6/lb	1992	legislation	Massachusetts	EIA, 1995
$0 425/lb	1992	legislation	Minnesota	EIA, 1995
$3 92/lb	1992	legislation	Nevada	EIA, 1995
$1 75/lb	1992	legislation	Oregon	EIA, 1995

Nitrous Oxide

Estimate	$ basis	method	location	source
$1 98/lb	1989	based on CO2[1]	US	Tellus, 1990
$1 35/lb	1992	legislation[2]	Wisconsin	PSCW, 1992

Notes
(1) As the GWP is 180 times that of CO_2 its externality cost is estimated at 180 times that of CO_2 (note the GWP used by Tellus is outdated)
(2) based on control

SOx - Also Causes Acid Rain and Smog

Estimate	$ basis	method	location	source
$0 88/lb	1988	perceived	Massachusetts	Chernick & Caverhill, 1988
$0 75/lb	1989	perceived	US	Tellus, 1990
$37 50	1989	perceived	S California	Tellus, 1990
$0 27/lb	1989	control	New York state	Putta 1989
$8 68/lb	1989	legislation	California	SCAG 1989
$2 13/lb	1990	control	New York state	PACE, 1990
$2 24/lb	1992	legislation	California	EIA, 1995
$0 85/lb	1992	legislation	Massachusetts	EIA, 1995
$0 075/lb	1992	legislation	Minnesota	EIA, 1995
$0 72/lb	1992	legislation	New York state	EIA, 1995

$0 86/lb	1992	legislation	Nevada	EIA, 1995

CO_2 - Also Causes Smog

Estimate	$ basis	method	location	source
$0 43/lb	1989	perceived	S California	Tellus, 1990
$0 9/lb	1989	control[1]	Rhode Island	Tellus, 1990
$0 043/lb	1989	control[1]	US	Tellus, 1990
$0 375/lb	1989	perceived	S California	Chernick & Caverhill, 1988

Notes
(1) As the GWP is 2 2 times that of CO_2, its externality cost is estimated to be 2 2 times that of CO_2 (note the GWP used by Tellus is outdated)

Valuing externalities is an inexact science, and estimates of externality costs vary widely as shown in the tables above Also, many environmental externality estimates are very site-specific The following table shows the externality costs of major air pollutants associated with coal plants that are actually used in practice by the regulatory agencies and electric utilities in different states in the US

	SO_2		*NO_x*		*CO_2*	
	$/kg	*$/kWh*	*$/kg*	*$/kWh*	*$/kg*	*$/kWh*
Massachusetts	1 65	0 0046	7 15	0 0201	0 024	0 0244
New York	0 92	0 0025	2 02	0 0055	0 001	0 0010
Nevada	1 72	0 0014	7 48	0 0165	0 024	0 0244
Minnesota	0 30	0 0005	1 64	0 0048	0 013	0 0136
Wisconsin	NA	NA	NA	NA	0 015	0 0150
Bonneville Power	1 65	0 0016	0 93	0 0024	NA	NA
Pacific Gas & Elec	4 47	0 0244	7 81	0 0213	0 029	0 0267

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