

Waste Heat Recovery Using “Alfa Laval” Heat Exchangers at OJSC “Ilim Group” Branch
in the Town of Ust-Ilimsk, Russian Federation

MONITORING REPORT

**“Waste Heat Recovery Using “Alfa Laval” Heat Exchangers at
OJSC “Ilim Group” Branch in the Town of Ust-Ilimsk,
Russian Federation”**

**Version 2.2
12 July 2010**

Monitoring period: 01.01.2008 – 31.12.2009

Executed by CCGS LLC

CONTENTS

- A. General project activity and monitoring information
- B. Key monitoring activities
- C. Quality assurance and quality control measures
- D. Calculations of GHG reductions

ANNEXES

- Annex 1. Selection of the emission factor for coal combustion at Ust-Ilimsk CHPP
- Annex 2. Regulations on quality check and control of GHG emission reduction project design documents (PDD) and monitoring reports at CCGS LLC
- Annex 3. Calculation of heat losses to the environment for wide gap 350s heat exchanger
- Annex 4. Primary data during the time period from 01.01.2008 till 16.04.2009 (separate file)
- Annex 5. Primary data during the time period from 17.04.2009 till 31.12.2009 (separate file)
- Annex 6. Calculation model (separate Excel-file)

SECTION A. General Project activity information

A.1. Title of the project activity

Waste Heat Recovery Using “Alfa Laval” Heat Exchangers at OJSC “Ilim Group” Branch in the Town of Ust-Ilimsk, Russian Federation.

A.2. Short description of the project activity

The aim of the project is to recover low-grade heat of acid and alkaline waste streams from the pulp bleaching process at OJSC “Ilim Group” Branch in the town of Ust-Ilimsk (the former OJSC “Production Association “Ust-Ilimsk Timber Processing Complex”), the Irkutsk Region, Russia.

The central project measure is installation of coolers for bleaching waste streams – four plate heat exchangers manufactured by “Alfa Laval” with the total thermal capacity of about 50 MW, designed for cooling of acid and alkaline streams at two bleached pulp production lines. The cooling medium is water which is fed to the heat exchangers from the evaporator plant at 40°C. The water is heated up to 55°C by the heat of the waste streams and is further used for process needs in the Cooking-and-Washing (CWD), Bleaching-and-Cleaning (BCD) and in the Drying Departments.

At the same time the installation of bleaching waste stream coolers affected the operation of the heat exchangers designed for black liquor cooling and for condensation of waste gas-vapour streams from digesters in the CWD. Since the water temperature at the inlet to the heat exchangers has increased from 40°C to 55°C, the heat-exchange surface area is no longer adequate for efficient and stable performance of the equipment. Therefore, the project also involves replacing twelve shell-and-tube and plate-type coolers for black liquor and condensers for waste gas-vapour streams from the 1st and the 2nd digesters. These are to be replaced with Alfa Laval heat-exchangers that can ensure the required heat flow at a higher inlet temperature of water.

Besides, the installation of new heat exchangers caused the hydraulic resistance of water and waste streams to rise. Therefore the project implementation necessitated replacement of some pumps with more powerful ones.

The first step in the project implementation was signing by the First Deputy Director General of the order “On implementation of the BCD alkaline waste streams cooling project” No.252-a dated 02.12.2004.

The next step was signing a contract with “Alfa Laval“. It should be noted that the contract with OJSC “Alfa Laval Potok” No.705-06/62 for the first supply of heat exchangers was entered into on February 25, 2005 – just a week after the Kyoto Protocol came into effect.

From October 2005 till February 2007 four narrow channels plate heat exchangers of M30 type manufactured by Alfa Laval were put into operation in the BCD for cooling of acid and alkaline bleaching waste streams. However, in the course of operation the narrow channels heat exchangers got clogged with tar and lignin contained in bleaching waste streams (especially in alkaline streams). This necessitated carrying out frequent and labour-intensive cleanouts of the heat exchangers. Therefore it was necessary to alter the project and replace the narrow channels heat exchangers with wide-gap channels heat exchangers of WideGap 350S type by the same manufacturer. By the end of 2008 wide-gap channels heat exchangers had been put into operation at both alkaline waste stream flows. The narrow channels exchangers installed at the acid waste stream flows are planned to be replaced in 2010.

A.3. Monitoring period

- Monitoring period starting date: 01/01/2008;
- Monitoring period closing date: 31/12/2009.

A.4. Methodology applied to the project activity (incl. version number)

A.4.1. Baseline methodology

The developer proposes his own approach [R1] to the baseline setting and GHG emission reductions calculation and does not agree it with any methodologies for the clean development mechanism (CDM), but he certainly makes his approach consistent with the requirements of *Decision 9/CMP.1, Appendix B* [R2].

A.4.2. Monitoring methodology

The monitoring plan was developed following our own approach [R1] in accordance with the project specifics and requirements of *Decision 9/CMP.1, Appendix B* [R2] without using any approved CDM methodologies.

A.5. Status of implementation including time table for major project parts

Bleaching-and-Cleaning Department

Place of installation	Type of heat exchanger	Mark of heat exchanger	Number, nos.	Thermal capacity, kW	Commissioning date
Alkaline waste streams, the 1 st flow	Narrow channels, plate-type	M30	1	12060	15.07.2006, replaced with wide-gap channels exchanger
Alkaline waste streams, the 2 nd flow	Narrow channels, plate-type	M30	1	12060	22.02.2007, replaced with wide-gap channels exchanger
Acid waste streams, the 1 st flow	Narrow channels, plate-type	M30	1	12060	08.10.2005, Planned to be replaced with wide-gap channels exchanger in 2010
Acid waste streams, the 2 nd flow	Narrow channels, plate-type	M30	1	12060	22.02.2007, Planned to be replaced with wide-gap channels exchanger in 2010
Alkaline waste streams, the 1 st flow	Wide-gap channels, plate-type	WideGap 350S	1	13250	26.12. 2008
Alkaline waste streams, the 2 nd flow	Wide-gap channels, plate-type	WideGap 350S	1	13250	06.11.2008

Acid waste streams, the 1 st flow	Wide-gap channels, plate-type	WideGap 350S	1	13250	Planned to be installed in 2010
Acid waste streams, the 2 nd flow	Wide-gap channels, plate-type	WideGap 350S	1	13250	

Cooking-and-Washing Department

Place of installation	Type of heat exchanger	Mark of heat exchanger	Number, nos.	Thermal capacity, kW	Commissioning date
Cooling of black liquor from cooking boiler No.2	Spiral	1H-L-2T	1	12800	02.12.2008
Primary condenser of the first stage of cooking boiler No.2	Spiral	2V-C-1T	1	7514	29.05.2008
Primary condenser of the second stage of cooking boiler No.2	Spiral	2V-C-1T	1	7514	29.05.2008
Primary condenser of the second stage of cooking boiler No.2	Spiral	2V-C-1T	1	3579	29.05.2008
Secondary condenser of the first stage of cooking boiler No.2	Spiral	ALSHE COND 14L	1	383.1	29.05.2008
Secondary condenser of the second stage of cooking boiler No.2	Spiral	ALSHE COND 14L	1	383.1	29.05.2008
Cooling of black liquor from cooking boiler No.1	Spiral	1H-L-2T	1	13420	30.11.2009
Primary condenser of the first stage of cooking boiler No.1	Spiral	2V-C-1T	1	5670	Installed in 2009. Planned to be launched in 2010.
Primary condenser of the second stage of cooking boiler No.1	Spiral	2V-C-1T	2	5822	Installed in 2009. Planned to be launched in 2010.

Secondary condenser of the first stage of cooking boiler No.1	Spiral	2V-C-1T	1	164.9	Installed in 2009. Planned to be launched in 2010.
Secondary condenser of the second stage of cooking boiler No.1	Spiral	2V-C-1T	1	193.4	Installed in 2009. Planned to be launched in 2010.

A.6. Intended deviations or revisions to the registered PDD

Deviations affected the monitoring plan only.

A.7. Intended deviations or revisions to the registered monitoring plan

In accordance with the PDD, calculation of GHG emission reductions is based on water flow data and water temperatures before and after the heat exchangers. The deviations from the monitoring plan were as follows: from 01.01.2008 till 16.04.2009 GHG emission reductions were calculated based on effluents but not on water. This was due to incompleteness of installation of the measuring system on the water flows.

It is crucial to note that for plate-type heat exchangers losses to ambient medium are negligible and therefore monitoring can be based on effluents and water alike. As calculations show (see Annex 3), heat losses to the environment amount to 0.16 %.

It should be also noted that after measuring instruments had been installed on the water side, a comparative check of heat savings calculated based on measurements on the effluents side (old measuring instruments) and on the water side (new measuring instruments) was carried out on site. The results of this comparative check are recorded in the Certificate of Instruments Inspection dated May 26, 2009. The comparative check showed that the discrepancies in the numerical values of heat calculated based on the readings of the measuring equipment installed on the water and on the effluents side do not exceed 1%.

Therefore it was decided to reduce heat savings from operation of plate-type heat exchangers over the entire period of effluents monitoring (from 01.01.2008 till 16.04.2009) by 1%.

This deviation from the registered monitoring plan was analyzed and taken into account within troubleshooting and emergency procedures.

On 17.04.2009 all instrumentation and the automatic readings recording system were installed on water flows, and from this moment on monitoring was carried out pursuant to the registered measurement scheme.

All deviations from the monitoring plan were taken into account and described in Section D.

A.8. Changes since last verification

There are no changes as this is the first monitoring verification.

A.9. Person(s) responsible for the preparation and submission of the monitoring report

The person (s) responsible for the preparation and submission of the monitoring report are:

OJSC “Ilim Group” Branch in Ust-Ilimsk”

- Alexander Genze, Deputy Chief Power Engineer.

CCGS LLC

- Vladimir Dyachkov, Director of Project Implementation Department
- Evgeniy Zhuravskiy, Specialist of Project Implementation Department.

SECTION B. Key monitoring activities according to the monitoring plan for the monitoring period stated in A.3

B.1. Monitoring equipment types

The measuring devices are provided in accordance with the official rules. The devices have to undergo regular inspection and supervision under the Federal Law “On Uniformity of Measurements”.

Tables B.1.1, B.1.2 show metrological performance of the measuring devices used for monitoring.

Table B.1.1. Data on metering devices employed for parameter monitoring from 01.01.2008 till 16.04.2009

Location	Measured parameters	Mark and type of the instrument	Serial number	Measurement range	Error, accuracy class	Unit	Last check (calibration) date	Origination responsible for check (calibration)
Heat exchanger for acid waste streams of the 1 st flow, position 51.117A	Parameters of acid waste streams at the outlet from the heat exchanger of the 1st flow	Temperature gauge: TSP - 9201	521	-50....+500	A	Degrees of C	03.2008	Service Repair Workshop LLC “Avtomatika”
	Parameters of acid waste streams at the inlet to the heat exchanger of the 1st flow	Temperature gauge: TSPU-276	580550	-50....+500	0.5	Degrees of C	02.2007	Service Repair Workshop LLC “Avtomatika”
		Flow meter: EJA(dP)110	DK 256	0-800	1.0	m3/h	02.2009	Service Repair Workshop LLC “Avtomatika”
Heat exchanger for acid waste streams of the 2 nd flow, position 52.117A	Parameters of acid waste streams at the outlet from the heat exchanger of the 2nd flow	Temperature gauge: TSP - 9201	520	-50....+500	A	Degrees of C	03.2008	Service Repair Workshop LLC “Avtomatika”
	Parameters of acid waste streams at the inlet to the heat exchanger of the 2nd flow	Temperature gauge: TSPU-276	580549	-50....+500	0.5	Degrees of C	02.2007	Service Repair Workshop LLC “Avtomatika”
		Flow meter:	KC 139	0-1000	1.0	m3/h	09.2009	Service Repair Workshop LLC

Waste Heat Recovery Using “Alfa Laval” Heat Exchangers at OJSC “Ilim Group” Branch
in the Town of Ust-Ilimsk, Russian Federation

		UNE 11						“Avtomatika”
Heat exchanger for alkaline waste streams of the 1 st flow, position 51.117B	Parameters alkaline waste streams at the outlet from the heat exchanger of the 1st flow	Temperature gauge: TSP - 9201	715	-50....+500	A	Degrees of C	06.2008	Service Repair Workshop LLC
	Parameters alkaline waste streams at the inlet to the heat exchanger of the 1st flow	Temperature gauge: TSP - 9201	053	-50....+500	A	Degrees of C	01.2008	Service Repair Workshop LLC “Avtomatika”
		Flow meter: EJA(dP)110	DA 840	0-800	1.0	m3/h	04.2009	Service Repair Workshop LLC “Avtomatika”
Heat exchanger for alkaline waste streams of the 2 nd flow, position 52.117B	Parameters of alkaline waste streams at the outlet from the heat exchanger of the 2nd flow	Temperature gauge: TSP - 9201	052	-50....+500	A	Degrees of C	01.2008	Service Repair Workshop LLC “Avtomatika”
	Parameters of alkaline waste streams at the inlet to the heat exchanger of the 2nd flow	Temperature gauge: TSP - 9201	005	-50....+500	A	Degrees of C	01.2007	Service Repair Workshop LLC “Avtomatika”
		Flow meter: UNE 11	KC 146	0-1000	1.0	m3/h	04.2009	Service Repair Workshop LLC “Avtomatika”

Table B.1.2. Data on metering devices employed for parameter monitoring from 17.04.2009 no 31.12.2009

Location	Measured parameters	Mark and type of the instrument	Serial number	Measurement range	Error, accuracy class	Unit	Last check (calibration) date	Origination responsible for check (calibration)
Heat exchanger for acid waste streams of the 1 st flow, position 51.117A	Parameters of cooling water at the outlet from the heat exchanger for acid waste streams of the 1 st flow	Temperature gauge: TSP 9201	522	-50...+500	A	Degrees of C	11.03.2008	Service Repair Workshop LLC “Avtomatika”
		Flow meter: EJA(dP)110	634881	0-800	0.5	m3/h	04.06.2009	Service Repair Workshop LLC “Avtomatika”
	Parameters of cooling water at the inlet to the heat exchangers for acid and alkaline waste streams	Temperature gauge: TSP 9201	052	-50...+500	A	Degrees of C	19.01.2008	Service Repair Workshop LLC “Avtomatika”
Heat exchanger for alkaline waste streams of the 1 st flow, position 51.117B	Parameters of cooling water at the outlet from the heat exchanger for alkaline waste streams of the 1 st flow	Temperature gauge: TSP 9201	053	-50...+500	A	Degrees of C	19.01.2008	Service Repair Workshop LLC “Avtomatika”
		Flow meter: EJA(dP)110	634886	0-800	0.5	m3/h	04.06.2009	Service Repair Workshop LLC “Avtomatika”
Heat exchanger for acid waste streams of the 2 nd flow, position 52.117A	Parameters of cooling water after the heat exchangers for acid and alkaline waste streams of the 2 nd flow (total)	Temperature gauge: TSP 9201	329	-50...+500	A	Degrees of C	11.03.2009	Service Repair Workshop LLC “Avtomatika”

Waste Heat Recovery Using “Alfa Laval” Heat Exchangers at OJSC “Ilim Group” Branch
in the Town of Ust-Ilimsk, Russian Federation

Heat exchanger for alkaline waste streams of the 2 nd flow, position 52.117B	Parameters of cooling water fed to the heat exchangers for acid and alkaline waste streams (total)	Temperature gauge: TSP 9201	326	-50...+500	A	Degrees of C	11.03.2009	Service Repair Workshop LLC “Avtomatika”
	Parameters of cooling water after the heat exchangers of the 2 nd flow fed to reservoir No.209 (FI 1004), to the drying department (FI 1007), to the CWD (FI 1006)	Flow meter of stream fed to the BCD: UNE 11	KC 129	0-1000	1.0	m3/h	17.02.2009	Service Repair Workshop LLC “Avtomatika”
		Flow meter of stream fed to the CWD: EJA(dP)110	05422	0-1400	1.0	m3/h	13.04.2009	Service Repair Workshop LLC “Avtomatika”
		Flow meter of stream fed to the drying department: EJA(dP)110	11380	0-1000	1.0	m3/h	13.04.2009	Service Repair Workshop LLC “Avtomatika”

B.2. Monitored data

For the time period from 01.01.2008 till 16.04.2009 the data were monitored in accordance with the scheme shown in Fig. B.2.1.

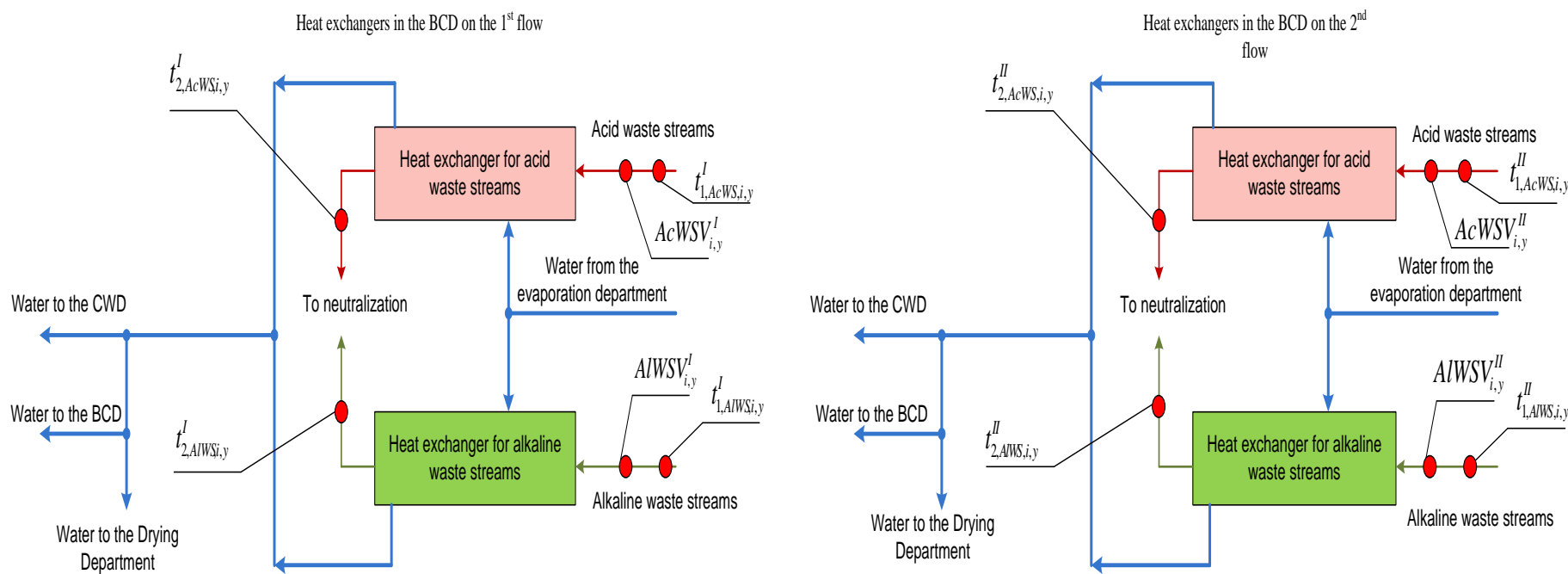


Fig B.2.1. Location of the monitoring points for the time period from 01.01.2008 till 16.04.2009

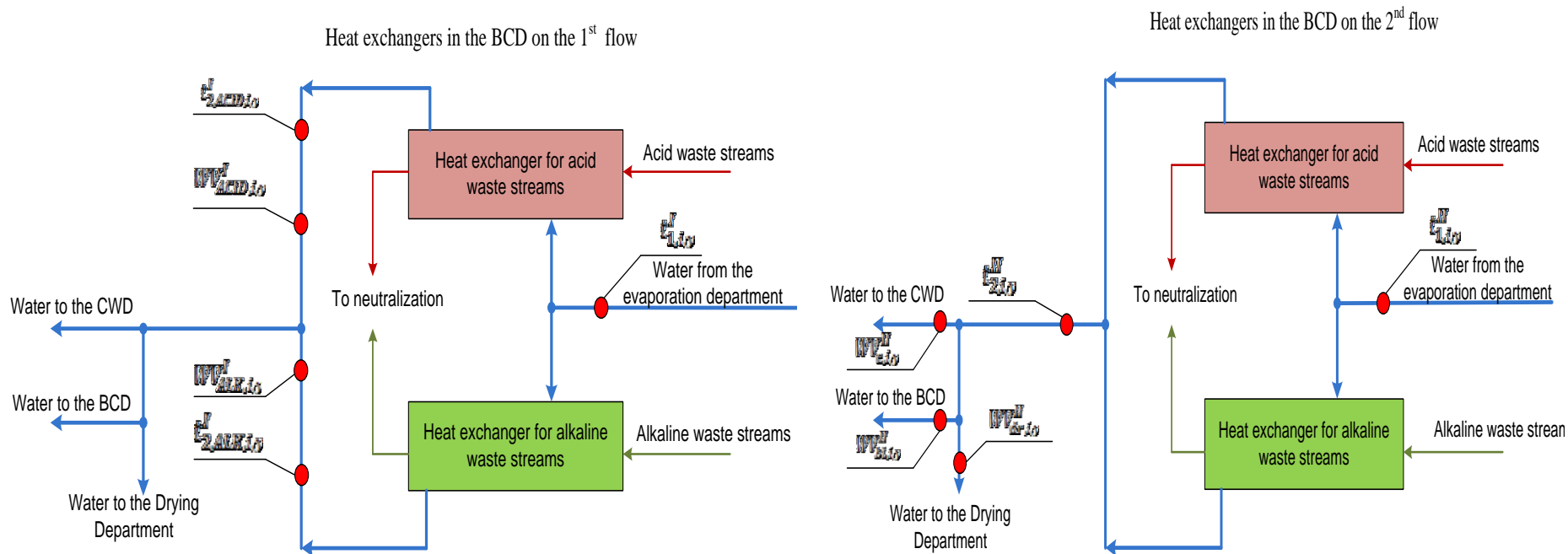
According to Fig. B.2.1. the following twelve parameters should be controlled (see Table B.2.1).

Table B.2.1. Data to be collected in order to monitor emissions from the project, and how these data is archived									
ID number	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e)	Recording frequency	Proportion of data to be monitored	How is the data archived? (electronic/paper)	Numerical value	
1.	$AcWSV_{i,y}^I$	The volume of acid waste streams passing through the heat exchanger of the 1 st flow	Bleaching and Cleaning Department	m ³	m	Daily	100%	Electronic and paper	See Annex 4
2.	$t_{1,AcWS,i,y}^I$	The temperature of acid waste streams of the 1 st flow at the inlet to the heat exchanger	Bleaching and Cleaning Department	°C	m	Daily	100%	Electronic and paper	See Annex 4
3.	$t_{2,AcWS,i,y}^I$	The temperature of acid waste streams of the 1 st flow at the outlet from the heat exchanger	Bleaching and Cleaning Department	°C	m	Daily	100%	Electronic and paper	See Annex 4
4.	$AIWSV_{i,y}^I$	The volume of alkaline waste streams passing through the heat exchanger of the 1 st flow	Bleaching and Cleaning Department	m ³	m	Daily	100%	Electronic and paper	See Annex 4
5.	$t_{1,AIWS,i,y}^I$	The temperature of alkaline waste streams of the 1 st flow at the inlet to the heat exchanger	Bleaching and Cleaning Department	°C	m	Daily	100%	Electronic and paper	See Annex 4
6.	$t_{2,AIWS,i,y}^I$	The temperature of alkaline waste streams of the 1 st flow at the outlet from the heat exchanger	Bleaching and Cleaning Department	m ³	m	Daily	100%	Electronic and paper	See Annex 4

Waste Heat Recovery Using “Alfa Laval” Heat Exchangers at OJSC “Ilim Group” Branch
in the Town of Ust-Ilimsk, Russian Federation

7. $AcWSV_{i,y}^{II}$	The volume of acid waste streams passing through the heat exchanger of the 2 nd flow	Bleaching and Cleaning Department	m^3	m	Daily	100%	Electronic and paper	See Annex 4
8. $t_{1,AcWS,i,y}^{II}$	The temperature of acid waste streams of the 2 nd flow at the inlet to the heat exchanger	Bleaching and Cleaning Department	m^3	m	Daily	100%	Electronic and paper	See Annex 4
9. $t_{2,AcWS,i,y}^{II}$	The temperature of acid waste streams of the 2 nd flow at the outlet from the heat exchanger	Bleaching and Cleaning Department	$^{\circ}C$	m	Daily	100%	Electronic and paper	See Annex 4
10. $AIWSV_{i,y}^{II}$	The volume of alkaline waste streams passing through the heat exchanger of the 2 nd flow	Bleaching and Cleaning Department	m^3	m	Daily	100%	Electronic and paper	See Annex 4
11. $t_{1,AIWS,i,y}^{II}$	The temperature of alkaline waste streams of the 2 nd flow at the inlet to the heat exchanger	Bleaching and Cleaning Department	m^3	m	Daily	100%	Electronic and paper	See Annex 4
12. $t_{2,AIWS,i,y}^{II}$	The temperature of alkaline waste streams of the 2 nd flow at the outlet from the heat exchanger	Bleaching and Cleaning Department	$^{\circ}C$	m	Daily	100%	Electronic and paper	See Annex 4

For the time period from 17.04.2009 till 31.12.2009 the data were monitored in accordance with the scheme shown in Fig. B.2.2.



FigB.2.2. Location of the monitoring points for the time period from 17.04.2009 till 31.12.2009

According to Fig. B.2.2. the following ten parameters should be controlled (see Table B.2.2).

Table B.2.2. Data to be collected in order to monitor emission reductions from the project, and how these data is archived								
ID number	Data variable	Source of data	Data unit	Measured (m), calculated (c), estimated (e)	Recording frequency	Proportion of data to be monitored	How is the data archived? (electronic/ paper)	Numerical value
1. $WV_{ACID,i,y}^I$	The volume of cooling water passing through the heat exchanger for acid waste streams of the 1 st flow	Bleaching and Cleaning Department	m^3	m	Continuously	100%	Electronic and paper	See Annex 5
2. $t_{1,i,y}^I$	The temperature of cooling water at the inlet of the heat exchangers for acid and alkaline waste streams of the 1 st flow	Bleaching and Cleaning Department	$^{\circ}C$	m	Continuously	100%	Electronic and paper	See Annex 5
3. $t_{2,ACID,i,y}^I$	The temperature of cooling water at the outlet from the heat exchanger for acid waste streams of the 1 st flow	Bleaching and Cleaning Department	$^{\circ}C$	m	Continuously	100%	Electronic and paper	See Annex 5
4. $WV_{ALK,i,y}^I$	The volume of cooling water passing through the heat exchanger for alkaline waste streams of the 1 st flow	Bleaching and Cleaning Department	m^3	m	Continuously	100%	Electronic and paper	See Annex 5

Waste Heat Recovery Using “Alfa Laval” Heat Exchangers at OJSC “Ilim Group” Branch
in the Town of Ust-Ilimsk, Russian Federation

5. $t_{2,ALK,i,y}^I$	The temperature of cooling water at the outlet from the heat exchanger for alkaline waste streams of the 1 st flow	Bleaching and Cleaning Department	°C	m	Continuously	100%	Electronic and paper	See Annex 5
6. $WV_{bl,i,y}^{II}$	The volume of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2 nd flow and fed to the BCD	Bleaching and Cleaning Department	m ³	m	Continuously	100%	Electronic and paper	See Annex 5
7. $WV_{dr,i,y}^{II}$	The volume of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2 nd flow and fed to the Drying Department	Bleaching and Cleaning Department	m ³	m	Continuously	100%	Electronic and paper	See Annex 5
8. $WV_{c,i,y}^{II}$	The volume of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2 nd flow and fed to the CWD	Bleaching and Cleaning Department	m ³	m	Continuously	100%	Electronic and paper	See Annex 5

9. $t_{1,i,y}$	The temperature of cooling water at the inlet to the heat exchangers for acid and alkaline waste streams of the 2 nd flow	Bleaching and Cleaning Department	°C	m	Continuously	100%	Electronic and paper	See Annex 5
10. $t_{2,i,y}$	The temperature of cooling water at the outlet from the heat exchangers for acid and alkaline waste streams of the 2 nd flow	Bleaching and Cleaning Department	°C	m	Continuously	100%	Electronic and paper	See Annex 5

B.3. The environmental service

The Environment and Production Control Department is in charge of industrial environmental monitoring at the Mill. It is accountable to the Health, Safety and Environment Directorate. The Directorate consists of:

- Safety and Production Control Department;
- Department of Industrial Environmental Monitoring;
- Gas Rescue Plant;
- Radiation Safety Service;
- Sanitary Industrial Laboratory;
- Civil Defense and Emergency Headquarters.

The programme of industrial environmental monitoring that is currently implemented by the Mill is not undergo any major changes after the project implementation and has been fulfilled according to the established scheme and schedule.

The sanitary industrial laboratory is adequately equipped. Its ability to take measurements in all sectors, which fall under their responsibility, is confirmed by Calibration Certificates.

The industrial environmental monitoring covers the following:

- Analytical control of compliance with the prescribed pollutant emission standards in accordance with the laboratory control charts;
- Monitoring of the impact of waste disposal sites on underground and surface waters, atmospheric air and soil;
- Control of pollutants content in the atmospheric air on the border of the sanitary protection zone, etc.

The data obtained by the analytical laboratory are processed and summarized in monthly and annual reports, which contain all required detailed data

The enterprise has the following reporting obligations as per official annual statistic forms:

- 2-tp (air) Data on Atmospheric Air containing information on the quantities of trapped and destroyed air pollutants, detailed emissions of specific pollutants, number of emission sources, emission reduction actions and emissions from separate groups of pollutant sources;
- 2-tp (water) Data on Water Use, containing information on water consumption from natural sources, discharges of effluents and their pollutant content, capacity of wastewater treatment facilities, etc.;
- 2-tp (wastes) Data on generation, utilization, destruction, transportation and disposal of production and consumption residues, containing an annual balance of wastes flows by their types and hazard classes.

In compliance with the Russian legislation, every year the enterprise has to develop and implement environment protection measures.

Quality, environment and industrial safety management systems at Ust-Ilimsk Branch comply with the international standards of ISO 9001, ISO 14001 and OHSAS 18001. The enterprise manufactures products certified for compliance with the requirements of the Forest Stewardship Council (FSC).

B.4. Data processing and archiving (incl. software used)

All data will be stored in the Mill’s archive in electronic and paper form for at least 2 years after the end of the crediting period or the last issue of ERUs.

SECTION C. Quality assurance and quality control measures

C.1. Quality control (QC) and quality assurance (QA) procedures undertaken for data monitored

Table C.1.1. Quality control (QC) and quality assurance (QA) procedures undertaken for data monitored

Data (Indicate table and ID number)	Uncertainty level of data (high/medium/low)	Explain QA/QC procedures planned for these data, or why such procedures are not necessary.
Table B.2.1. ID 1	Low	The flow rate of acid waste streams of the first flow is monitored by a waste stream flow meter EJA(dP)110. Serial number DK 256. Measurement range 0-800 m ³ /h. Measurement error 1.0 %. Calibration frequency: once every three years. The signal from the instrument goes to the control panel of the bleaching department operator.
Table B.2.1. ID 2	Low	The temperature of acid waste streams at the inlet to the heat exchanger of the first flow is monitored by a temperature sensor TSPU-276. Serial number 580550. Operating range of temperature measurement: -50... +500 °C. Measurement error 0.5 %. Calibration frequency: once every three years. The signal from the instrument goes to the control panel of the bleaching department operator.
Table B.2.1. ID 3	Low	The temperature of acid waste streams at the outlet from the heat exchanger of the first flow is monitored by a temperature sensor TSP -9201. Serial number 521. Operating range of temperature measurement: -50... +500 °C. Accuracy class A. Calibration frequency: once every three years. The signal from the instrument goes to the control panel of the bleaching department operator.
Table B.2.1. ID 4	Low	The flow rate of alkaline waste streams of the first flow is monitored by a waste stream flow meter EJA(dP)110. Serial number DA 840. Measurement range 0-800 m ³ /h. Measurement error 1.0 %. Calibration frequency: once every three years. The signal from the instrument goes to the control panel of the bleaching department operator.
Table B.2.1. ID 5	Low	The temperature of alkaline waste streams at the inlet to the heat exchanger of the first flow is monitored by a temperature sensor TSP -9201. Serial number 053. Operating range of temperature measurement: -50... +500 °C. Accuracy class A. Calibration frequency: once every three years. The signal from the instrument goes to the control panel of the bleaching department operator.
Table B.2.1. ID 6	Low	The temperature of alkaline waste streams at the outlet from the heat exchanger of the first flow is monitored by a temperature sensor TSP -9201. Serial number 715. Operating range of temperature measurement: -50... +500 °C. Accuracy class A. Calibration frequency: once every three years. The signal from the instrument goes to the control panel of the bleaching department operator.

Waste Heat Recovery Using “Alfa Laval” Heat Exchangers at OJSC “Ilim Group” Branch
in the Town of Ust-Ilimsk, Russian Federation

Table B.2.1. ID 7	Low	The flow rate of acid waste streams of the second flow is monitored by a waste stream flow meter UNE 11. Serial number KC 139. Measurement range 0-1000 m ³ /h. Measurement error 1.0 %. Calibration frequency: once every two years. The signal from the instrument goes to the control panel of the bleaching department operator.
Table B.2.1. ID 8	Low	The temperature of acid waste streams at the inlet to the heat exchanger of the second flow is monitored by a temperature sensor TSPU-276. Serial number 580549. Operating range of temperature measurement: -50... +500 °C. Measurement error 0.5 %. Calibration frequency: once every three years. The signal from the instrument goes to the control panel of the bleaching department operator.
Table B.2.1. ID 9	Low	The temperature of acid waste streams at the outlet from the heat exchanger of the second flow is monitored by a temperature sensor TSP -9201. Serial number 520. Operating range of temperature measurement: -50... +500 °C. Accuracy class A. Calibration frequency: once every three years. The signal from the instrument goes to the control panel of the bleaching department operator.
Table B.2.1. ID 10	Low	The flow rate of alkaline waste streams of the second flow is monitored by a waste stream flow meter UNE 11. Serial number KC 146. Measurement range 0-1000 m ³ /h. Measurement error 1.0 %. Calibration frequency: once every two years. The signal from the instrument goes to the control panel of the bleaching department operator.
Table B.2.1. ID 11	Low	The temperature of alkaline waste streams at the inlet to the heat exchanger of the second flow is monitored by a temperature sensor TSP -9201. Serial number 005. Operating range of temperature measurement: -50... +500 °C. Accuracy class A. Calibration frequency: once every three years. The signal from the instrument goes to the control panel of the bleaching department operator.
Table B.2.1. ID 12	Low	The temperature of alkaline waste streams at the outlet from the heat exchanger of the second flow is monitored by a temperature sensor TSP -9201. Serial number 052. Operating range of temperature measurement: -50... +500 °C. Accuracy class A. Calibration frequency: once every three years. The signal from the instrument goes to the control panel of the bleaching department operator.
Table B.2.2. ID 1	Low	The volumetric flow rate of cooling water passing through the heat exchanger for acid waste streams of the 1 st flow is measured with EJA(dP)110 flow meter, serial number 634881. Measurement range 0-800 m ³ /h. Measurement error 0.5%. Calibration frequency: once every three years. Output signal from the flow meter is sent to the automated operating dispatch control system (ADCS).
Table B.2.2. ID 2	Low	Temperature converter TSP9201 is used for measurement of cooling water temperature at the inlet to the heat exchangers for acid and alkaline waste streams of the 1 st flow. Serial number 052. Operating range of temperature measurement: -50... +500 °C. Accuracy class A. Calibration frequency: once every three years. The signals from the temperature converter are sent to the ADCS.

Waste Heat Recovery Using “Alfa Laval” Heat Exchangers at OJSC “Ilim Group” Branch
in the Town of Ust-Ilimsk, Russian Federation

Table B.2.2. ID 3	Low	Temperature converter TSP9201 is used for measurement of cooling water temperature at the outlet from the heat exchanger for acid waste streams of the 1 st flow. Serial number 522. Operating range of temperature measurement: -50... +500 °C. Accuracy class A. Calibration frequency: once every three years. The signals from the temperature converter are sent to the ADCS.
Table B.2.2. ID 4	Low	The volumetric flow rate of cooling water passing through the heat exchanger for alkaline waste streams of the 1 st flow is measured with a flow meter EJA(dP)110, serial number 634886. Measurement range 0-800 m ³ /h. Measurement error 0.5%. Calibration frequency: once every three years. Output signal from the flow meter is sent to the ADCS.
Table B.2.2. ID 5	Low	Temperature converter TSP9201 is used for measurement of cooling water temperature at the outlet from the heat exchanger for alkaline waste streams of the 1 st flow. Serial number 053. Operating range of temperature measurement: -50... +500 °C. Accuracy class A. Calibration interval – 3 years. The signals from the temperature converter are sent to the ADCS.
Table B.2.2. ID 6	Low	The volumetric flow rate of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2 nd flow and fed to the BCD is measured with a flow meter UNE 11, serial number KC129. Measurement range 0-1000 m ³ /h. Measurement error 1.0%. Calibration frequency: once every two years. Output signal from the flow meter is sent to the ADCS.
Table B.2.2. ID 7	Low	The volumetric flow rate of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2 nd flow and fed to the drying department is measured with a flow meter EJA (dP), serial number 11380. Measurement range 0-1000 m ³ /h. Measurement error 1.0%. Calibration frequency: once every three years. Output signal from the flow meter is sent to the ADCS.
Table B.2.2. ID 8	Low	The volumetric flow rate of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2 nd flow and fed to the CWD is measured with a flow meter EJA (dP), serial number 05422. Measurement range 0-1400 m ³ /h. Measurement error 1.0%. Calibration frequency: once every three years. Output signal from the flow meter is sent to the ADCS.
Table B.2.2. ID 9	Low	Temperature converter TSP9201 is used for measurement of cooling water temperature at the inlet to the heat exchangers for acid and alkaline waste streams of the 2 nd flow. Serial number 326. Operating range of temperature measurement: -50... +500 °C. Accuracy class A. Calibration frequency: once every three years. The signals from the temperature converter are sent to the ADCS.
Table B.2.2. ID 10	Low	Temperature converter TSP9201 is used for measurement of cooling water temperature at the outlet from the heat exchangers for acid and alkaline waste streams of the 2 nd flow. Serial number 329. Operating range of temperature measurement: -50... +500 °C. Accuracy class A. Calibration frequency: once every three years. The signals from the temperature converter are sent to the ADCS.

Internal verification

Internal verification of primary data and findings is carried out at “Ilim Group” Branch in Ust-Ilimsk by the Deputy Head of the Bleaching and Cleaning Department, V. Tsapov and/or Deputy Chief Power Engineer, A. Genze. In any case the Deputy Chief Power Engineer, A. Genze, is responsible for collection, verification and transfer of information related to monitoring of GHG emission reductions.

Cross-check

Verification of the monitoring report is carried out by the Director of the Project Implementation Department of CCGS LLC or, on his instructions, by other specialist of the said Department who is not directly related to preparation of this report.

The additional cross-check is made by the Director of the Project Preparation Department of CCGS LLC or, on his instructions, by other specialist of this Department. The quality control procedure is explained in more detailed in “Regulations on quality check and control of GHG emission reduction project design documents (PDD) and monitoring reports at CCGS LLC” (Annex 2).

C.2. Operational and administrative structure

C.2.1. Monitoring procedures

Data transfer

Original request for primary GHG emission reductions monitoring data is made by the Director of the Project Implementation Department of CCGS LLC to the Central Office of “Ilim” Group in St.-Petersburg, namely to the Director for Labour Protection, Fire Safety and Environment, who in his turn gives instructions to a certain enterprise to collect the requested data. Each enterprise that is implementing projects within the framework of the Kyoto Protocol has specific persons (a working group) that responsible for collection, control and transfer of monitoring data. The responsibility of these persons is specified in corresponding orders. At “Ilim” Group Branch in Ust-Ilimsk the responsibility of such persons are set forth in Order No. FU/662 of 21.08.2009. The information collected at the enterprise is transferred to the Central Office, namely to the Director for Labour Protection, Fire Safety and Environment, who in his turn transfers it to the Director of the Project Implementation Department of CCGS LLC. All information is transferred by e-mail.

On the basis of the received data the Department of Project Implementation of CCGS LLC prepares a GHG emission reduction monitoring report and submits it for additional cross-check to the Project Preparation Department of CCGS LLC. As soon as all comments made by the Project Preparation Department are incorporated or resolved the monitoring report is submitted for verification to the enterprise where the project is implemented.

At CCGS LLC the procedure for verification of the monitoring reports are laid down in “Regulations on quality check and control of GHG emission reduction project design documents (PDD) and monitoring reports at CCGS LLC” (Annex 2).

After the report is verified and amended as necessary, the Director of the Project Implementation Department of CCGS LLC informs the Director for Labour Protection, Fire Safety and Environment of “Ilim” Group’s Central Office in St.-Petersburg about preliminary monitoring results and, if there are no comments on his part, the Director General of CCGS LLC takes the final decision to submit the monitoring report for verification to an independent expert organization.

Collection and storage of data

Collection and record of data required for calculation of GHG emission reductions have been carried out in accordance with the metering points scheme shown in Fig.B.2.1 and Fig.B.2.2.

The readings of the instruments used for monitoring of GHG emission reductions are recorded in the ADCS and are shown on the monitors of all computers with the required software installed. The data are printed on paper and are stored in the computer memory for three years, whereupon the data is transferred to the electronic archive of the Mill. The data will be kept in the Mill’s archives in electronic and paper form for at least two years after the end of the crediting period or after the last issue of ERUs.

The quarterly data for GHG emission reduction monitoring is furnish by the Deputy Chief Power Engineer of OJSC “Ilim Group” Branch in Ust-Ilimsk to the Project Implementation Department of CCGS LLC.

Table C.2.1. Monitoring procedures

Monitored parameters	Procedure for collection, registration, record and storage of data (including everyday monitoring)
Waste stream volumes	Volumes of acid and alkaline waste streams passing through the heat exchangers of the first and the second flows are continuously measured using flow meters. Data from the instruments are transmitted to the control panel of the bleaching department operator. The data are entered into the electronic log (electronic Excel table) on a daily basis. The waste stream volume data will be kept in the mill’s archives for at least two years after the end of the crediting period or after the last issue of ERUs.
Waste stream temperatures	Temperatures of acid and alkaline waste streams at the inlet to and at the outlet from the heat exchangers of the first and the second flows are continuously measured using temperature sensors. Data from the instruments are transmitted to the control panel of the bleaching department operator. The data are entered into the electronic log (electronic Excel table) on a daily basis. The waste stream temperature data will be kept in the mill’s archives for at least two years after the end of the crediting period or after the last issue of ERUs.

Water volumes	<p>Volumes of water passing through the heat exchangers of the first and the second flows are continuously measured using flow meters.</p> <p>Data from the instruments are transmitted to and displayed in the mill’s overall automated dispatch control system, are printed out on paper in the Energy Department of the Mill.</p> <p>The water volume data will be kept in the mill’s archives for at least two years after the end of the crediting period or after the last issue of ERUs.</p>
Water temperatures	<p>Temperatures of water at the inlet to and at the outlet from the heat exchangers of the first and the second flows are continuously measured using temperature sensors.</p> <p>Data from the instruments are transmitted to and displayed in the mill’s overall automated dispatch control system, are printed out on paper in the Energy Department of the Mill.</p> <p>The water temperature data will be kept in the mill’s archives for at least two years after the end of the crediting period or after the last issue of ERUs.</p>

Troubleshooting and emergency procedures

The GHG monitoring procedures use procedures applied under:

- ISO 9001:2008 “Quality Management Systems”;
- ISO 14001:2004 “Environmental Management Systems”;
- OHSAS 18001:2007 “Occupational Safety and Health Management Systems”.

The enterprise’s compliance with the three above mentioned standards has been officially certified.

According to procedures of these standards, if any non-compliance of the measuring processes with the standards specified in design documentation is identified, the situation is analyzed, alternative monitoring and measuring procedures are developed for the period of non-compliance as well as corrective actions are taken that allow to remedy any identified non-compliance.

Within these procedures for the first monitoring period (from 01.01.2008 till 16.04.2009), when the instrumentation for “water flows” was incomplete, an alternative measuring scheme by “effluents” (Fig B.2.1) and a respective calculation method were developed (Section D.1.1).

The preliminary analysis showed that the proposed alternative scheme of measurements was acceptable. Heat savings achieved under “effluents” monitoring scheme may be higher than the results achieved under “water” monitoring scheme by not more 0.17% (see Annex 3).

After measuring instruments had been installed on the water side, a comparative check of heat savings calculated based on measurements on the effluents side (old measuring instruments) and on the water side (new measuring instruments) was carried out on site. The results of this comparative check are recorded in the Certificate of Instruments Inspection dated May 26, 2009. The comparative check showed that the discrepancies in the numerical values of heat calculated based on the readings of the measuring equipment installed on the water and on the effluents side do not exceed 1%.

In the emission calculation methodology this probable inaccuracy was taken into account by introducing a special reduction factor $k=1\%$.

Actions during calibration and breakdown of measuring instruments and equipment

The measuring instruments are calibrated during scheduled shutdowns of the equipment. If necessary the removed measuring instrument is replaced with a gaged back up instrument. Operation of the equipment without measuring instruments is not allowed.

Shall any instrument fail, the respective parameters are to be monitored with a help of a duplicate instrument or, if such is not available, the failed instrument is to be replaced with a gaged back-up instrument. If the failed instrument cannot be replaced while the equipment is running, then the parameters shall be monitored for not more than 15 days in one year based on calculation of an average value of this instrument’s readings taken over the three days prior to the failure. This monitoring procedure is developed based on paragraph 9.8 of "The Rules for Heat and Heat Carrier Metering" [R7].

If the equipment is operated without instrument-based monitoring of any parameter for more than 15 days, then the calculations are made using:

- most conservative (in terms of GHG emission reductions) value from the start of the project monitoring according to the definitively approved monitoring scheme, that is from 17.04.2009.

C.2.2. Roles and responsibility
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The management of “Ilim” Group’s Central Office in St.-Petersburg is responsible for supervision of monitoring plan implementation at the enterprise (Director for Labour Protection, Fire Safety and Environment Andrey Andreev).

The management of OJSC “Ilim Group” Branch in Ust-Ilimsk is responsible for:

- normal operation of the equipment;
- timely calibration and proper maintenance of instrumentation (Chief Metrologist Nicolay Gnidenko);
- collection of all data required for calculation of GHG emission reductions under the project (Deputy Chief Power Engineer Alexander Genze);
- arranging and holding training sessions for the Mill’s personnel regarding collection of data required for the GHG emissions monitoring under the project (deputy chief power engineer Alexander Genze).

The management of CCGS LLC is responsible for:

- arranging and holding training sessions for the Mill’s personnel regarding collection of data required for the GHG emissions monitoring under the project (director of Project Implementation Department Vladimir Dyachkov);
- preparation of the monitoring report (director of Project Implementation Department Vladimir Dyachkov);
- checkout of the accuracy of the primary data and GHG emission reduction calculations (Director of Project Preparation Department, Alexander Samorodov);
- interaction with the independent auditor on the issues related to verification of GHG emission reductions (Director of Project Implementation Department, Vladimir Dyachkov).

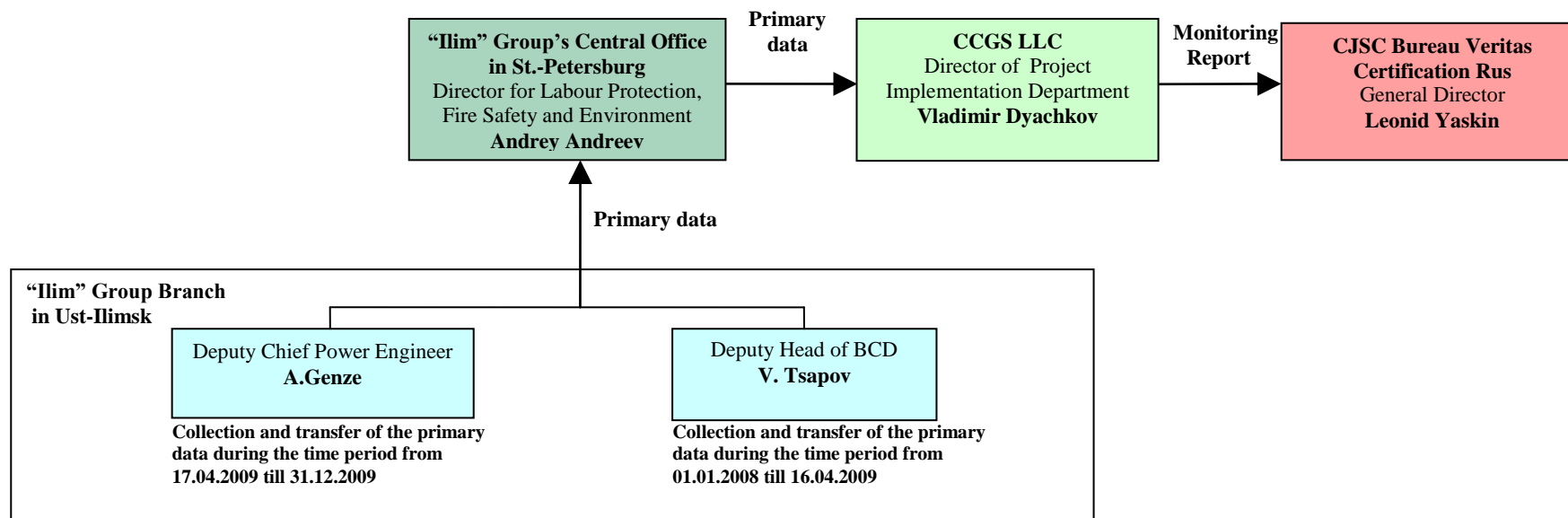


Fig. C.2.1. Data transfer scheme (from primary data to monitoring report)

The distribution of primary data collection and storage responsibilities is shown in Table C.2.2.

Table C.2.2. Personal responsibilities of primary data collection and storage		
Primary data	Document where the parameter is recorded	Responsible person
Monitoring parameters for the time period from 01.01.2008 till 16.04.2009		
The volume of acid waste streams passing through the heat exchanger of the 1 st flow	Electronic log	Deputy Chief Power Engineer, A. Genze Deputy Head of BCD, V.Tsapov
The temperature of acid waste streams of the 1 st flow at the inlet to the heat exchanger		
The temperature of acid waste streams of the 1 st flow at the outlet from the heat exchanger		
The volume of alkaline waste streams passing through the heat exchanger of the 1 st flow		
The temperature of alkaline waste streams of the 1 st flow at the inlet to the heat exchanger		
The temperature of alkaline waste streams of the 1 st flow at the outlet from the heat exchanger		
The volume of acid waste streams passing through the heat exchanger of the 2 nd flow		
The temperature of acid waste streams of the 2 nd flow at the inlet to the heat exchanger		
The temperature of acid waste streams of the 2 nd flow at the outlet from the heat exchanger		
The volume of alkaline waste streams passing through the heat exchanger of the 2 nd flow		
The temperature of alkaline waste streams of the 2 nd flow at the inlet to the heat exchanger		
The temperature of alkaline waste streams of the 2 nd flow at the outlet from the heat exchanger		
Monitoring parameters for the time period from 17.04.2009 till 31.12.2009		
The volume of cooling water passing through the heat exchanger for acid waste streams of the 1 st flow	Reporting form “Data on Heat Utilization in BCD ”	Deputy Chief Power Engineer, A. Genze
The volume of cooling water passing through the heat exchanger for alkaline waste streams of the 1 st flow		
The temperature of cooling water at the inlet of the heat exchangers for acid and alkaline waste streams of the 1 st flow		
The temperature of cooling water at the outlet from the heat exchanger for acid waste streams of the 1 st flow		
The temperature of cooling water at the outlet from the heat exchanger for alkaline waste streams of the 1 st flow		
The volume of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2 nd flow and fed to the BCD		
The volume of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2 nd flow and fed to the Drying Department		
The volume of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2 nd flow and fed to the CWD		
The temperature of cooling water at the inlet to the heat exchangers for acid and alkaline waste streams of the 2 nd flow		
The temperature of cooling water at the outlet from the heat exchangers for acid and alkaline waste streams of the 2 nd flow		

C.2.3. Training

All personnel of the BCD and CWD have undergone training and certification which covered the scope of the operation manual for the plate heat exchangers manufactured by Alfa Laval. An uncertified employee is not allowed to carry out maintenance or repair of the heat exchanging equipment.

The head of the BCD periodically holds examination to appraise the knowledge of the Instructions. Those employees who successfully passed the exam put their signatures in a special log and are allowed to operate the heat exchangers.

Regularly, minimum once a year, specialists of CCGS LLC carry out test verification with the purpose of checking out the observance of the monitoring plan at OJSC “Ilim Group” Branch in the town of Ust-Ilimsk. Verification of the equipment required for collection of monitoring data and staff training were carried out on January 27-29, 2009 and June 23-24, 2009.

C.2.4. Involvement of Third Parties

Service Repair Workshop “Avtomatika” LLC is the Third Party involved.

C.3. Influence estimation on environment

The project helps to reduce coal combustion at Ust-Ilimsk CHPP. It results in lower emissions of both greenhouse gases and pollutants produced from coal combustion.

Table C.3.1. shows calculation data on the variation of pollutant emissions as a result of the project implementation. The calculations were made in accordance with RD 34.02.305-98 “The Methodology for Calculation of Gross Pollutant Emissions from TPP Boilers” [R3], issued by VTI.

As a result of the project the coal consumption at Ust-Ilimsk CHPP in year 2008 reduces by an average of 55.3 thousand tons. The emissions of sulfur dioxide reduce by 303.7 t/year, carbon oxide – by 459.5 t/year, nitrogen oxides (calculated as nitrogen dioxide) – by 203.7 t/year, and suspended particles – by 725 t/year. The overall reduction of gross pollutant emissions to the atmosphere amounts to 1691.9 t/year.

As a result of the project the coal consumption at Ust-Ilimsk CHPP in year 2009 reduces by an average of 62.1 thousand tons. The emissions of sulfur dioxide reduce by 340.8 t/year, carbon oxide – by 515.6 t/year, nitrogen oxides (calculated as nitrogen dioxide) – by 228.6 t/year, and suspended particles – by 813.6 t/year. The overall reduction of gross pollutant emissions to the atmosphere amounts to 1898.6 t/year.

Furthermore, the disposal of coal ash to the ash disposal site reduces as well.

Table C.3.1. Variation of pollutant emissions at UI CHPP, t/year

Pollutant emissions	Value	
	Year 2008	Year 2009
Suspended particles	-725.0	-813.6
Sulfur dioxide (SO ₂)	-303.7	-340.8
Nitrogen oxides calculated as nitrogen dioxide (NO ₂)	-203.7	-228.6
Carbon oxide (CO)	-459.5	-515.6
Total emissions	-1691.9	-1898.6

SECTION D. Calculation of GHG emission reductions

D.1. Calculation of the project GHG emission reductions

D.1.1 Calculation of the project GHG emission reductions during the time period from 01.01.2008 till 16.04.2009

The GHG emission reduction due to the project during the year y , tCO₂e:

$$ER_y = ER_{UICHPP,y} - LE_y,$$

where $ER_{UICHPP,y}$ is the reduction of CO₂ emissions from UI CHPP as a result of the project during the year y , tCO₂;

$$ER_{UICHPP,y} = \Delta FC_{coal,UICHPP,y} \cdot EF_{CO_2,coal} \cdot 10^{-3}$$

where $EF_{CO_2,coal}$ is the CO₂ emission factor for coal combustion, kg CO₂/GJ. $EF_{CO_2,coal} = 98.92$ kg CO₂/GJ (see Annex 1);

$\Delta FC_{coal,UICHPP,y}$ is the reduction of coal combustion at UI CHPP as a result of the project during the year y , GJ.

$$\Delta FC_{coal,UICHPP,y} = \frac{1.31 \cdot \Delta HC_y}{\eta_{boiler,UICHPP} \cdot (1 - \varepsilon_{heat}^{aux}) \cdot (1 - \varepsilon_{sl}) \cdot k_{HF}}$$

where $\eta_{boiler,UI\ CHPP}$ is the efficiency of steam boilers at UI CHPP. Assumed constant and equal to $\eta_{boiler,UI\ CHPP} = 0.917$. [R9, page 417];

ε_{heat}^{aux} is the relative heat consumption for auxiliary needs of UI CHPP. Assumed constant and equal to $\varepsilon_{UI\ CHPP}^{aux} = 0.05$ [R12, Annex 2, tabl.7];

ε_{sl} is the relative heat losses in the steam line from UI CHPP to UI PPM. Assumed constant and equal to $\varepsilon_{sl} = 0.05$ [R11, page 348];

k_{HF} is the heat flow factor at UI CHPP. Assumed constant and equal to $k_{HF} = 0.98$ [R8, page 135, fig. 10.2];

1.31 is the factor that shows the relation between the variation of heat flow to the turbine and the variation of production steam extraction from the turbines [R10, page 95, table.4.6];

ΔHC_y is the reduction of heat (steam) consumption for UI PPM’s process needs from the outside as a result of the project during the year y , GJ.

$$\Delta HC_y = (1 - K_{los}) (HS_{ACID,y}^I + HS_{ALK,y}^I + HS_{ACID,y}^{II} + HS_{ALK,y}^{II}),$$

where K_{los} is the factor of heat losses to the environment for plate-type heat exchangers, assumed equal to 0.01 (see Section A.7).

$HS_{ACID,y}^I$ is the heat recovered by the heat exchanger for acid waste streams of the 1st flow, GJ;

$$HS_{ACID,y}^I = \sum_{i=1}^n \frac{24 \cdot \rho_{wastes} \cdot c_{p,wastes} \cdot AcWSV_{i,y}^I \cdot (t_{1,AcWS,i,y}^I - t_{2,AcWS,i,y}^I)}{10^6}$$

where i is the index that shows that calculations use daily data;

n is the operating days of the heat exchanger in the year y ;

$\sum_{i=1}^n$ is the sum of all values of the given parameter over the year y (determined every day and then summed up);

ρ_{wastes} is the wastes density, kg/m³. Assumed constant and equal to $\rho_{wastes} = 1000$ kg/m³;

$c_{p,wastes}$ is the specific isobaric heat capacity of wastes, $\frac{kJ}{kg \cdot ^\circ C}$. Assumed constant and equal to $c_{p,wastes} = 4.187 \frac{kJ}{kg \cdot ^\circ C}$.

In accordance with the heat exchanger specifications provided by Alfa Laval, heat capacity of effluents varies between 4.17 and 4.18 kJ/(kg*K). It means that the average heat capacity of effluents is =4.175 kJ/(kg*K).

The difference between the average heat capacity of effluents according to specification and heat capacity of water ($4.187 \frac{\text{kJ}}{\text{kg} \cdot ^\circ\text{C}}$) is very low (0.287%). Therefore heat capacity of effluents and heat capacity of water can be considered identical.

$AcWSV_{i,y}^I$ is the volume of acid waste streams passing through the heat exchanger of the 1st flow during the i -day of its operation from the beginning of the year y , m³/hour;

$t_{2,AcWS,i,y}^I$ is the temperature of the acid waste streams of the 1st flow at the outlet from the heat exchanger during the i -day of its operation from the beginning of the year y , °C;

$t_{1,AcWS,i,y}^I$ is the temperature of the acid waste streams of the 1st flow at the inlet to the heat exchanger during the i -day of its operation from the beginning of the year y , °C.

$HS_{ALK,y}^I$ is the heat recovered by the heat exchanger for alkaline waste streams of the 1st flow, GJ;

$$HS_{ALK,y}^I = \sum_{i=1}^n \frac{24 \cdot \rho_{wastes} \cdot c_{p,wastes} \cdot AlWSV_{i,y}^I \cdot (t_{1,AlWS,i,y}^I - t_{2,AlWS,i,y}^I)}{10^6}$$

where $AlWSV_{i,y}^I$ is the volume of alkaline waste streams passing through the heat exchanger of the 1st flow during the i -day of its operation from the beginning of the year y , m³/hour;

$t_{2,AlWS,i,y}^I$ is the temperature of alkaline waste streams of the 1st flow at the outlet from the heat exchanger during the i -day of its operation from the beginning of the year y , °C.

$t_{1,AlWS,i,y}^I$ is the temperature of alkaline waste streams of the 1st flow at the inlet to the heat exchanger during the i -day of its operation from the beginning of the year y , °C.

$$HS_{ACID,y}^{II} = \sum_{i=1}^n \frac{24 \cdot \rho_{wastes} \cdot c_{p,wastes} \cdot AcWSV_{i,y}^{II} \cdot (t_{1,AcWS,i,y}^{II} - t_{2,AcWS,i,y}^{II})}{10^6}$$

where $AcWSV_{i,y}^{II}$ is the volume of acid waste streams passing through the heat exchanger of the 2nd flow during the i -day of its operation from the beginning of the year y , m³/hour;

$t_{2,AcWS,i,y}^{\prime\prime}$ is the temperature of the acid waste streams of the 2nd flow at the outlet from the heat exchanger during the i -day of its operation from the beginning of the year y , °C;

$t_{1,AcWS,i,y}^{\prime\prime}$ is the temperature of the acid waste streams of the 2nd flow at the inlet to the heat exchanger during the i -day of its operation from the beginning of the year y , °C.

$$HS_{ALK,y}^{\prime\prime} = \sum_{i=1}^n \frac{24 \cdot \rho_{wastes} \cdot c_{p,wastes} \cdot AIWSV_{i,y}^{\prime\prime} \cdot (t_{1,AIWS,i,y}^{\prime\prime} - t_{2,AIWS,i,y}^{\prime\prime})}{10^6}$$

where $AIWSV_{i,y}^{\prime\prime}$ is the volume of alkaline waste streams passing through the heat exchanger of the 2nd flow during the i -day of its operation from the beginning of the year y , m³/hour;

$t_{2,AIWS,i,y}^{\prime\prime}$ is the temperature of alkaline waste streams of the 2nd flow at the outlet from the heat exchanger during the i -day of its operation from the beginning of the year y , °C.

$t_{1,AIWS,i,y}^{\prime\prime}$ is the temperature of alkaline waste streams of the 2nd flow at the inlet to the heat exchanger during the i -day of its operation from the beginning of the year y , °C.

LE_y is the leakages during the year y , tCO₂e, See section D.2.

D.1.2. Calculation of the project GHG emission reductions during the time period from 17.04.2009 till 31.12.2009

The GHG emission reduction due to the project during the year y , tCO₂e:

$$ER_y = ER_{UICHPP,y} - LE_y$$

where $ER_{UICHPP,y}$ is the reduction of CO₂ emissions from UI CHPP as a result of the project during the year y , tCO₂;

$$ER_{UICHPP,y} = \Delta FC_{coal,UICHPP,y} \cdot EF_{CO_2,coal} \cdot 10^{-3}$$

where $EF_{CO_2,coal}$ is the CO₂ emission factor for coal combustion, kg CO₂/GJ. $EF_{CO_2,coal} = 98.92$ kg CO₂/GJ. See Annex 1;

$\Delta FC_{coal,UICHPP,y}$ is the reduction of coal combustion at UI CHPP as a result of the project during the year y , GJ.

$$\Delta FC_{coal,UICHPP,y} = \frac{1.31 \cdot \Delta HC_y}{\eta_{boiler,UICHPP} \cdot (1 - \varepsilon_{heat}^{aux}) \cdot (1 - \varepsilon_{sl}) \cdot k_{HF}}$$

where $\eta_{boiler,UICHPP}$ is the efficiency of steam boilers at UI CHPP. Assumed constant and equal to $\eta_{boiler,UICHPP} = 0.917$. [R9, page 417];

ε_{heat}^{aux} is the relative heat consumption for auxiliary needs of UI CHPP. Assumed constant and equal to $\varepsilon_{UICHPP}^{aux} = 0.05$ [R12, Annex 2, tabl.7];

ε_{sl} is the relative heat losses in the steam line from UI CHPP to UI PPM. Assumed constant and equal to $\varepsilon_{sl} = 0.05$ [R11, page 348];

k_{HF} is the heat flow factor at UI CHPP. Assumed constant and equal to $k_{HF} = 0.98$ [R8, page 135, fig. 10.2];

1.31 is the factor that shows the relation between the variation of heat flow to the turbine and the variation of production steam extraction from the turbines [R10, page 95, table.4.6];

ΔHC_y is the reduction of heat (steam) consumption for UI PPM’s process needs from the outside as a result of the project during the year y , GJ.

$$\Delta HC_y = HS_{ACID,y}^I + HS_{ALK,y}^I + HS_{ACID,y}^{II} + HS_{ALK,y}^{II}$$

where $HS_{ACID,y}^I$ is the heat recovered by the heat exchanger for acid waste streams of the 1st flow, GJ;

$$HS_{ACID,y}^I = \sum_{i=1}^n \frac{\rho_{water} \cdot c_{p,water} \cdot WV_{ACID,i,y}^I \cdot (t_{2,ACID,i,y}^I - t_{1,i,y}^I)}{10^6},$$

where i is the index that shows that calculations use hourly data;

n is the operating hours of the heat exchanger in the year y ;

$\sum_{i=1}^n$ is the sum of all values of the given parameter over the year y (determined every hour and then summed up);

ρ_{water} is the water density, kg/m³. Assumed constant and equal to $\rho_{water} = 1000$ kg/m³;

$c_{p,water}$ is the specific isobaric heat capacity of water, $\frac{kJ}{kg \cdot ^\circ C}$. Assumed constant and equal to $c_{p,water} = 4.187 \frac{kJ}{kg \cdot ^\circ C}$;

$WV_{ACID,i,y}^I$ is the volume of cooling water passing from the heat exchanger for acid waste streams of the 1st flow during the i -hour of its operation from the beginning of the year y , m³;

$t_{2,ACID,i,y}^I$ is the average temperature of the cooling water at the outlet from the heat exchanger for acid waste streams of the 1st flow during the i -hour of its operation from the beginning of the year y , °C;

$t_{1,i,y}^I$ is the average temperature of the cooling water at the inlet to the heat exchangers for acid and alkaline waste streams of the 1st flow during the i -hour of its operation from the beginning of the year y , °C.

$HS_{ALK,y}^I$ is the heat recovered by the heat exchanger for alkaline waste streams of the 1st flow, GJ;

$$HS_{ALK,y}^I = \sum_{i=1}^n \frac{\rho_{water} \cdot c_{p,water} \cdot WV_{ALK,i,y}^I \cdot (t_{2,ALK,i,y}^I - t_{1,i,y}^I)}{10^6},$$

where $WV_{ALK,i,y}^I$ is the volume of cooling water passing through the heat exchanger for alkaline waste streams of the 1st flow during the i -hour of its operation from the beginning of the year y , m³;

$t_{2,ALK,i,y}^I$ is the average temperature of cooling water at the outlet from the heat exchanger for alkaline waste streams of the 1st flow during the i -hour of its operation from the beginning of the year y , °C.

$HS_{ACID,y}^{II} + HS_{ALK,y}^{II}$ is the heat recovered by the heat exchangers for acid and alkaline waste streams of the 2nd flow, GJ.

$$HS_{ACID,y}^{II} + HS_{ALK,y}^{II} = \sum_{i=1}^n \frac{\rho_{water} \cdot c_{p,water} \cdot WV_{i,y}^{II} \cdot (t_{2,i,y}^{II} - t_{1,i,y}^{II})}{10^6},$$

where $WV_{i,y}^{II}$ is the volume of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2nd flow during the i -hour of operation of heat exchangers from the beginning of the year y , m³;

$$WV_{i,y}^{II} = WV_{bl,i,y}^{II} + WV_{dr,i,y}^{II} + WV_{c,i,y}^{II},$$

where $WV_{bl,i,y}^{II}$ is the volume of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2nd flow and fed to the BCD during the i -hour of operation of the heat exchangers from the beginning of the year y , m³;

$WV_{dr,i,y}^{II}$ is the volume of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2nd flow and fed to the drying department during the i -hour of operation of the heat exchangers from the beginning of the year y , m³;

$WV_{c,i,y}^{II}$ is the volume of cooling water passing through the heat exchangers for acid and alkaline waste streams of the 2nd flow and fed to the CWD during the i -hour of operation of the heat exchangers from the beginning of the year y , m³.

$t_{2,i,y}^{II}$ is the average temperature of cooling water at the outlet from the heat exchangers for acid and alkaline waste streams of the 2nd flow during the i -hour of their operation from the beginning of the year y , °C;

$t_{1,i,y}^H$ is the average temperature of cooling water at the inlet to the heat exchangers for acid and alkaline waste streams of the 2nd flow during the i -hour of their operation from the beginning of the year y , °C.

LE_y is the leakages during the year y , tCO_{2e}, See section D.2.

D.2. Calculation of the GHG Leakages

The leakages during the year y , tCO_{2e}:

$$LE_y = LE_{ES,y}$$

where $LE_{ES,y}$ is the leakages from combustion of fossil fuel by the grid power plants to compensate for the reduction of electricity supply to the grid as a result of the project during the year y , tCO₂.

$$LE_{ES,y} = \Delta ES_{UICHPP,y} \cdot EF_{CO_2,grid}^y$$

where $EF_{CO_2,grid}^y$ is the CO₂ emission factor for electricity consumed from the grid during the year y , tCO₂/MWh. According to “Operational Guidelines for Project Design Documents of Joint Implementation Projects” this factor for Russia is specified depending on the year under consideration as follows: $EF_{CO_2,grid}^{2008} = 0,565$ tCO₂/MWh, $EF_{CO_2,grid}^{2009} = 0,557$ tCO₂/MWh; [R4, page 43]

$\Delta ES_{UICHPP,y}$ is the reduction of heat-consumption-based electricity supply from UI CHPP as a result of the project during the year y , MWh.

$$\Delta ES_{UICHPP,y} = \frac{0.305 \cdot \Delta HC_y \cdot (1 - \varepsilon_{el}^{aux})}{3.6 \cdot (1 - \varepsilon_{el})},$$

where 0.305 is the factor that shows the relation between the variation of heat-consumption-based electricity generation and the variation of production steam extraction from the turbine [R10, page 95, table.4.6].

ε_{el}^{aux} is the relative electricity consumption for auxiliary needs of UI CHPP. Assumed constant and equal to $\varepsilon_{el}^{aux} = 0.05$ [R8, page 18].

D.3. Calculation of the project GHG emission reductions

The GHG emission reduction due to the project during the year y , tCO_{2e}:

$$ER_y = ER_{UICHPP_y} - LE_y$$

The calculation method of GHG emission reductions was implemented in the computational model in the form of excel-file (Annex 6).

The calculation results are presented in the Table D.3.1.

Table D.3.1. Calculation of reduction of emissions GHG				
Parameter	Symbol	Unit	Value	
			Year 2008	Year 2009
Project emissions				
The reduction of coal consumption at UI CHPP	$\Delta FC_{coal,UI\ CHPP,y}$	GJ	935 960	1 049 855
The CO ₂ emission factor for coal	$EF_{CO_2,coal}$	t CO ₂ /GJ	0.09892	0.09892
The reduction of CO₂ emissions from UI CHPP	$ER_{UI\ CHPP,y}$	t CO₂e	92 585	103 852
Leakages				
Reduction of heat-consumption-based electricity supply from UI CHPP	$\Delta ES_{UI\ CHPP,y}$	MWh	49 094	55 068
CO ₂ emission factor for electricity consumed from the grid	$EF_{CO_2,grid}^y$	t CO ₂ /MWh	0.565	0.557
The leakages from combustion of fossil fuel by the grid power plants to compensate for the reduction of electricity supply to the grid	$LE_{ES,y}$	t CO₂e	27 738	30 673
GHG emission reductions				
GHG emission reductions	ER_y	t CO₂e	64 847	73 179

In accordance with the PDD, the projected GHG emission reductions amount to 118 072 and 142 545 t CO₂e over the years 2008 and 2009, respectively.

The primary cause of lower actual GHG emission reductions as compared with the projected value is the fact that a heat load on the heat exchangers was less.

CCGS LLC
12.07.2010



V. Dyachkov - Director of Project Implementation Department



Evgeniy Zhuravskiy, Specialist of Project Implementation Department

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Annex 1. Selection of the emission factor for coal combustion at Ust-Ilimsk CHPP

Ust-Ilimsk CHPP is firing two grades of coal¹, their characteristics² are shown in the table below.

Characteristics of fuel combusted at Ust-Ilimsk CHPP				
Parameter	Designation	Unit	Irsha-Borodinsky coal (Kansko-Achinsky coal field)	Zheronsky coal (Tungusky coal field)
Net calorific value on as-received basis	NCV_{Coal}	kcal/kg	3 650	4 430
		MJ/kg	15.28	18.55
Ash content on dry basis	A^d	%	11	24
Moisture content on as-received basis	W_t^r	%	33	18
Carbon content on dry ash-free basis	C^{daf}	%	71.5	80.3

GHG emission factors for fuel combustion, in general case, account for emissions of CO₂, CH₄ and N₂O. However the contribution of CH₄ and N₂O to the total amount of GHG emissions from fuel combustion is negligibly small³ (considering their Global Warming Potentials), therefore they are neglected in our calculations.

The $EF_{CO_2,coal}$ factor was determined on the basis of the data available. The CO₂ emission factors directly depend on the carbon content of a fuel and can be calculated as follows, kg/GJ:

$$EF_{CO_2,coal} = \frac{44}{12} \cdot K_C$$

where K_C is the factor of carbon content per energy unit of fuel on as-received basis, kg C/GJ;

$$K_C = 10 \cdot \frac{C^r}{NCV_{Coal}}$$

where NCV_{Coal} is the net calorific value of fuel on as-received basis, MJ/kg.

C^r is the carbon content of fuel on as-received basis, %,

$$C^r = C^{daf} \cdot \frac{100 - A^r - W_t^r}{100}$$

where W_t^r is the moisture content of fuel on as-received basis, %;

C^{daf} is the carbon content of fuel on dry ash-free basis, %;

A^r is the ash content of fuel on as-received basis, %;

¹ <http://www.irkutskenergo.ru/qa/968.2.html>

² According to the Reference Book *Energy Fuel of the USSR, M. Energoatomizdat, 1991* [R5].

³ 2006 IPCC Guidelines for National Greenhouse Gas Inventories. Volume 2, Energy [R6].

$$A^r = A^d \cdot \frac{100 - W_t^r}{100}$$

where A^d is the ash content of fuel on dry basis, %.

The calculation results are given in the table below.


Emission factors for coal grades combusted at Ust-Ilimsk CHPP			
Emission factor	Unit	Irsha-Borodinsky coal (Kansko-Achinsky coal field)	Zheronsky coal (Tungusky coal field)
$EF_{CO_2,coal}$	kgCO ₂ /GJ	102.31	98.92

Since the exact ratio of these coal grades is not known for each year of the crediting period, we conservatively assumed the minimum emission factor of 98.92 kg CO₂/GJ for the entire period of 2008-2012.

**Annex 2. Regulations on quality check and control of GHG emission reduction project
design documents (PDD) and monitoring reports at CCGS LLC**



Approved by
Director General

A circular official stamp of CCGS LLC with a signature over it. The signature is in cursive and appears to be "M. Yulkin".
M. Yulkin
December 8, 2009

REGULATIONS

**on quality check and control of GHG emission reduction project
design documents (PDD) and monitoring reports at CCGS LLC**

1. GENERAL PROVISIONS

- 1.1. These regulations specify the quality control procedure for development of project design documents (PDDs) and monitoring reports for the projects aimed at GHG emission reduction from sources and/or increase of removal by sinks (hereinafter the “Projects”).
- 1.2. The quality control of PDDs and monitoring reports is carried out in conjunction with the structural subdivisions (departments) of CCGS LLC (hereinafter the “Company”) and the Project Owners (hereinafter the “Client”).
- 1.3. The quality control of PDDs and monitoring reports precedes their submission to an independent auditor for review.

2. QUALITY CONTROL OF PROJECT DESIGN DOCUMENTS

- 2.1. The PDD developed by a specialist of the Project Development Department shall undergo the following quality control procedure:
 - 2.1.1. The PDD shall be checked up by the Director of the Project Development Department or, on his instructions, by other specialist of the Project Development Department who was not directly involved in development of this PDD;
 - 2.1.2. Corrective actions shall be taken by the PDD developer and all corrections and amendments shall be agreed with the Director of the Project Development Department;
 - 2.1.3. The PDD shall be checked up by the Director of the Project Implementation Department or, on his instructions, by other specialist of the Project Implementation Department;
 - 2.1.4. Corrective actions shall be taken by the PDD developer and all corrections and amendments shall be agreed with the Director of the Project Implementation Department;

2

- 2.1.5. Final check-up and correction of the PDD shall be made by the Director of the Project Development Department;
- 2.1.6. The PDD shall be submitted to the Client for review;
- 2.1.7. Corrective actions shall be taken by the PDD developer and all corrections and amendments shall be agreed with the Client and the Director of the Project Development Department and if necessary with the Director of the Project Implementation Department;
- 2.1.8. The PDD shall be furnished to the Director General and the Client.
- 2.2. Upon completion of the above-described procedure and if there are no comments from the Director General and/or from the Client the PDD shall be deemed ready for determination by an independent auditor. Otherwise the procedure shall be repeated.
- 2.3. The Director of the Project Development Department shall check all sections of the PDD.
- 2.4. The Director of the Project Implementation Department shall check those sections of the PDD which describe the project monitoring plan and procedure. Other sections shall be checked by the Director of the Project Implementation Department if necessary or at his discretion.
- 2.5. The Director General shall take the final decision regarding submission of the PDD for determination to an independent auditor.

3. QUALITY CONTROL OF PROJECT MONITORING REPORTS

- 3.1. The project monitoring report prepared by a specialist of the Project Implementation Department shall undergo the following quality control procedure:
 - 3.1.1. The project monitoring report shall be checked up by the Director of the Project Implementation Department or, on his instructions, by other specialist of the Project Implementation Department who was not directly involved in preparation of this project monitoring report;
 - 3.1.2. Corrective actions shall be taken by the monitoring report developer and all corrections and amendments shall be agreed with the Director of the Project Implementation Department;
 - 3.1.3. The project monitoring report shall be checked up by the Director of the Project Development Department or, on his instructions, by other specialist of the Project Development Department;
 - 3.1.4. Corrective actions shall be taken by the monitoring report developer and all corrections and amendments shall be agreed with the Director of the Project Development Department;
 - 3.1.5. Final check-up and correction of the monitoring report shall be made by the Director of the Project Implementation Department;
 - 3.1.6. The monitoring report shall be submitted to the Client for review;
 - 3.1.7. Corrective actions shall be taken by the monitoring report developer and all corrections and amendments shall be agreed with the Client and the Director of the Project Implementation Department and, if necessary, with the Director of the Project Development Department;
 - 3.1.8. The monitoring report shall be submitted to the Director General and the Client.

3

- 3.2. Upon completion of the above-described procedure and if there are no comments from the Director General and/or from the Client the monitoring report shall be deemed ready for verification by an independent auditor. Otherwise the procedure shall be repeated.
- 3.3. The Director of the Project Implementation Department shall check all sections of the monitoring report.
- 3.4. The Director of the Project Development Department shall check those sections of the monitoring report which contain results of calculations of GHG emission reductions from sources and/or increase of GHG removals by sinks. Other sections shall be checked up by the Director of the Project Development Department if necessary or at his discretion.
- 3.5. The Director General shall take the final decision regarding submission of the monitoring report for verification to an independent auditor.

Annex 3. Calculation of heat losses to the environment for wide gap 350s heat exchanger

Heat losses to the environment are due to heat transfer through natural convection of air and radiation.

Calculation of heat transfer by natural convection

The quantity of heat which is lost by the heat exchanger through convection, W ([1], p.156, Section 2-3-1):

$$Q = \alpha \cdot \Delta t \cdot F,$$

where α is the heat-transfer factor, $W/(m^2 \cdot ^\circ C)$;

Δt is the temperature head, $^\circ C$:

$$\Delta t = t_c - t_o,$$

where t_c is the temperature of the outer wall of the heat exchanger, $^\circ C$;

t_o is the temperature of air surrounding the heat exchanger, $^\circ C$;

F is the square area of the outer surface of the heat exchanger, m^2 .

The heat-transfer factor can be calculated from Nusselt number $\overline{Nu} = \frac{\overline{\alpha} \cdot l}{\lambda}$.

Nusselt number for heat transfer through free motion of the liquid ([1], p. 177, formula 2-133):

$$\overline{Nu} = C \cdot (Gr \cdot Pr)^n,$$

where C , n is the constants, herein $C=0.15$; $n=1/3$ ([1], p. 177, Table 2-33);

Gr is the Grashof number determined by the formula $Gr = \frac{g \cdot \beta \cdot \Delta t \cdot l^3}{\nu^2}$;

Pr is the Prandtl number determined by the formula $Pr = \frac{\nu}{a}$;

ν is the coefficient of kinematic viscosity, herein $\nu = 17.57 \cdot 10^{-6} m^2 / s$ ([1], p.163, Table 2-25)⁴;

λ is the coefficient of heat conductivity, herein $\lambda = 2.72 \cdot 10^{-2} \frac{W}{m \cdot ^\circ C}$ ([1], p.163, Table 2-25);

a is the thermal diffusivity, herein $a = 24.8 \cdot 10^{-6} m^2 / s$ ([1], p.163, Table 2-25);

l is the typical size – the height of the heat exchanger, m ;

β is the coefficient of volumetric expansion, K^{-1} :

$$\beta = \frac{1}{273 + t_{cp}}.$$

⁴ Values are assumed at the temperature of $t_{cp} = \frac{1}{2} \cdot (t_c + t_o)$

Calculation of heat transfer by radiation

The quantity of heat transferred by radiation, W ([1], p. 189, formula 2-158):

$$Q = 5,67 \cdot \left[\left(\frac{T_c}{100} \right)^4 - \left(\frac{T_o}{100} \right)^4 \right] \cdot F .$$

The results of calculations are given in Table below.

Parameter	Designation	Unit	Value
Heat transfer through convection			
Prandtl number	<i>Pr</i>	-	0.708
Kinematical viscosity	<i>ν</i>	m ² /s	1.757E-05
Thermal diffusivity	<i>a</i>	m ² /s	2.480E-05
Grashof number	<i>Gr</i>	-	8.124E+09
Gravitational acceleration	<i>g</i>	m/s ²	9.810
Coefficient of volumetric expansion	<i>β</i>	K ⁻¹	0.0032
Typical size	<i>l</i>	m	1.260
Temperature of heat carrier	<i>t_c</i>	°C	60
Temperature of air in the workshop	<i>t_o</i>	°C	20
Temperature head	<i>Δt</i>	°C	40
Constants:			
	<i>C</i>	-	0.150
	<i>n</i>	-	0.333
Nusselt number	<i>Nu</i>	-	268.81
Heat-transfer factor	<i>α</i>	W/(m ² °C)	5.803
Coefficient of heat conductivity	<i>λ</i>	W/(m°°C)	0.027
Outer surface area of heat exchanger	<i>F</i>	m ²	42.21
Quantity of heat lost with convection	<i>Q_{conv.}</i>	kW	9.798
Heat transfer by radiation			
Temperature of heat carrier	<i>T_c</i>	K	333
Temperature of air in the workshop	<i>T_o</i>	K	293
Quantity of heat transferred by radiation	<i>Q_{rad.}</i>	W	11.791
Total heat losses			
Total heat losses to the environment	<i>Q_{conv.+rad.}</i>	kW	21.589
Nameplate capacity of heat exchanger	<i>Q</i>	kW	13 250
Proportion of losses in to the overall capacity of heat exchanger	<i>Δ</i>	%	<u>0.163</u>

[1] V.N.Urenev, P.D.Lebedev Reference Book on Heat Engineering. In two volumes. Volume 2 – 2nd edition, revised. – M.: Energia, 1976