

MONITORING REPORT

**JOINT STOCK COMPANY
“ARKHANGELSK PULP AND PAPER MILL”**

Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (town of Novodvinsk, Russia)

PDD REFERENCE NO: 0005

Monitoring period: **1st January 2001 – 31st December 2001**

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Introduction

The document is executed according to the developed PDD “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)” [R1]. The PDD is placed at website UNFCCC (ji.unfccc.int/JI_Projects/Verification/PDD) under reference number 0005.

The project is implemented at the territory of JSC “Arkhangelsk Pulp and Paper Mill”, town of Novodvinsk, Arkhangelsk region, Russia.

The project is aimed at increasing the share of biomass waste in the APPM fuel balance, which will allow reducing consumption of expensive and environmentally dirtier fossil fuel, as well as decrease the amount of dumped biomass waste.

With reference to the project, biomass waste is bark and wood waste (BWW) and waste water sludge (WWS). BWW includes bark, sawdust, slivers, substandard chips, as well as building waste wood, logging waste, etc. The bulk of BWW is formed at the stage of preparing pulp chips in the APPM wood-preparation shops and delivered from neighboring saw-mills, which have no their own facilities for utilization of their BWW. WWS is formed at the station of biological treatment of industrial and household waste of APPM and the town of Novodvinsk.

The project implies implementation of the following engineering solutions in two stages:

Stage I:

- Reconstruction of the obsolete and inefficient utilizing boiler KM-75-40 (St. No. 2) at TPP-3¹, with switching to BWW combustion in the fluidized bed;
- Modernization of WPS-3² with installation of advanced equipment for chopping and dewatering BWW.

Stage II:

- Replacement of an old utilizing boiler KM-75-40 (St. No. 1) at TPP-3 with a new utilizing boiler E-75-3,9-440 DFT, with biomass waste combustion in the fluidized bed;
- Assembly of a new unit for receiving and preparation BWW and WWS delivered by motor transport, to be burnt in utilizing boilers of TPP-3.

Construction and assembly operations for the first stage of the project were carried out from February to December of 2000, and for the second stage – from April of 2004 to July of 2005. According to *Decision 9/CMP.1* [R2], the project may be recognized as a joint implementation project, if its technical implementation began not earlier than in the year 2000.

Thus only the first stage of the project and the associated reductions of GHG emissions are considered for 2001.

Technology employed according to Stage I

Reconstruction of the KM-75-40 boiler St. No. 2

In 2000, Joint Venture Energosofin and OJSC Belenergomash performed reconstruction of the KM-75-40 boiler St. No. 2, with switching to the fluidized bed technology.

¹ TPP-3 – thermal power plant No. 3

² WPS-3 – wood-preparation shop No. 3

Burning of waste in the fluidized bed provides efficient, economical and environmentally safe combustion of high-humidity and low-calorie fuels. The fluidized bed is made of quartz sand by means of feeding air at a high pressure under the filling layer. The process of combustion is partly taking place in the fluidized bed, and partly – above it. The temperature of the fluidized bed is about 700-800°C and can be adjusted by air distribution.

In the nominal operating mode, the modernized KM-75-40S boiler allows burning BWW with humidity of 57%, with steam capacity equal to 66 tons per hour, without fuel oil flame stabilization. The superheated steam pressure is 4.0 MPa, its temperature being 440 °C. The boiler efficiency factor is about 85%. After the reconstruction, the hourly consumption of BWW has become twice as high, reaching 30 tons an hour.

The trials held within the second stage of the project showed that it is also possible to obtain stable and economical combustion of the BWW/WWS mixture, with the latter accounting for up to 20-25% of the weight of BWW. However WWS combustion was not practiced in 2001 yet and therefore it is not reviewed here.

WPS-3 modernization

WPS-3 modernization was performed for the purpose of improving the BWW quality in accordance with requirements set for the fuel combusted through the fluidized bed technology. The modernization was carried out in 2000, simultaneously with reconstruction of boiler St. No. 2 of TPP-3.

As a result of modernization, three independent fuel flows were replaced with a single centralized bark preparation unit equipped with a Saalasti 0912 rotor crusher and two Bark Master 1620 bark drum presses (also made by Saalasti). The equipment proved to be efficient at a number of the industry enterprises.

Modernization of WPS-3 made it possible to ensure a more homogenous breakup of BWW (pieces not larger than 75 mm) and lower their humidity down to the level of about 50%, which substantially increased the low calorific value and allowed stable combustion of BWW in boiler St. No. 2 in the fluidized bed without fuel oil flame stabilization. Besides, electric power consumption required for BWW preparation was reduced by 6-8%, due to its centralization.

On the whole, implementation of measures of the first stage enabled to make the amount of BWW burnt in boiler St. No. 2 of TPP-3 more than double, while having increased significantly the efficiency of their combustion and reduced fuel oil consumption.

Monitoring Period

The monitoring period is chosen from **1st January 2001 to 31st December 2001** (both days included).

Monitored data

Collection of all the key parameters required for greenhouse emissions to be determined, both under the project and for the baseline, is performed according to the practice established at APPM on accounting of fuel, energy, waste, and assessment of environmental impacts. Monitoring under the project requires no changes to be introduced in the existing system of accounting and collection of information. All the necessary data are determined and registered in any case.

Description of monitoring plan of all data required to calculate GHG emissions reductions is represented in Section D and Annex 3 of PDD [R1]. Table 1 and 2 below represents yearly values of project and

baseline data for 2001. It should be mentioned that it was not necessary to define some data for 2001 as WWS was not burnt and no change in biomass waste dumping occurred.³

Table 1. Values of data collected in order to monitor emissions from the project over the year $y = 2001$

ID number and symbol	Data name	Data unit	Value	Comment
1. $FC_{oil,3,PJ,y}^m$	Mass fuel oil consumption at TPP-3	t	52 288	
2. $FC_{oil,1mp,PJ,y}^m$	Mass fuel oil consumption in medium pressure boilers of TPP-1	t	20 932	
3. $NCV_{oil,y}$	Net calorific value of fuel oil	GJ/t	38.91	The weighted annual average

Table 2. Values of relevant data necessary for determining the baseline of anthropogenic emissions of greenhouse gases by sources within the project boundary over the year $y = 2001$

ID number and symbol	Data name	Data unit	Data value	Comment
4. $FC_{BWW,3ub,PJ,y}^m$	Mass BWW consumption in utilizing boilers of TPP-3	t	300 844	
5. $FC_{BWW,1mp,PJ,y}^m$	Mass BWW consumption in medium pressure boilers of TPP-1	t	220 317	
6. $BWW_{dump,PJ,y}^m$	Mass BWW removal to the landfill	t		Not necessary for 2001
7. $BWW_{side,PJ,y}^m$	Mass BWW delivery from the outside	t		Not necessary for 2001
8. $WWS_{dump,PJ,y}^m$	Wet mass WWS removal to the landfill	t		Not necessary for 2001
9. $FC_{WWS,3ub,PJ,y}^m$	Wet mass WWS consumption in utilizing boilers of TPP-3	t	0	

³ PDD shows that dumped BWW is proportional to dumped WWS to provide bearing capacity of the landfill without dependence on the project. Stipulated that WWS is not burnt volumes of dumping of both kinds of biomass waste remain the same as without the project. Due to this reason reductions of methane landfill emissions from the project equal zero in 2001.

ID number and symbol	Data name	Data unit	Data value	Comment
10. $W_{WWS,y}$	WWS humidity	%		Not necessary for 2001
11. $FC_{liq,3rb,y}^{dm}$	Dry mass black liquor consumption in recovery boilers of TPP-3	t a.d.m.	421 089	Including 3 645 t of sulfate soap
12. $FC_{oil,3rb,PJ,y}^m$	Mass fuel oil consumption in recovery boilers of TPP-3	t	48 760	
13. $NCV_{BWW,3ub,y}$	Net calorific value of BWW combusted in utilizing boilers of TPP-3	GJ/t	8.11	The weighted annual average
14. $NCV_{liq,3rb,y}$	Net calorific value of black liquor combusted in recovery boilers of TPP-3	GJ/t a.d.m.	10.32	The weighted annual average
15. $HG_{3,PJ,y}$	Total gross steam generation at TPP-3	GJ	6 585 854	
16. $HS_{3,PJ,y}$	Total useful supply of heat from TPP-3	GJ	5 132 868	
17. $HS_{3backpress,PJ,y}$	Useful supply of heat from TPP-3 with backpressure steam	GJ	5 132 868	It is equal to total useful supply because no steam supply through the PRC in 2001
18. $HG_{3rb,PJ,y}$	Gross steam generation in recovery boilers of TPP-3	GJ	5 134 677	
19. $HG_{1mp,PJ,y}$	Gross steam generation in medium pressure boilers of TPP-1	GJ	1 580 618	
20. $EF_{CO2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	91.27	Results of GHG inventory at APPM for 2001 [R3]

Calculation of emission reductions

According to formulae described in Section D [R1] calculations of project and baseline emissions have been done (see Tables 3 and 4). As shown in Section B.3 [R1] all of the leakages can be neglected. Calculation of emission reductions are presented in Table 5.

Thus, total GHG emission reductions for 2001 amounted 77 699 tCO₂e.

Table 3. Calculation of project emissions over the year $y = 2001$

Symbol	Name	Unit	Formula or grounds	Value
PE_y	Total greenhouse gas emissions under the project	t CO ₂	$PE_y = PE_{oil,3,y} + PE_{oil,1mp,y}$	219 743
$PE_{oil,3,y}$	CO ₂ emission from burning fuel oil at TPP-3 under the project	t CO ₂	$PE_{oil,3,y} = FC_{oil,3,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	156 923
$PE_{oil,1mp,y}$	CO ₂ emission from burning fuel oil in boilers of the medium pressure station of TPP-1 under the project	t CO ₂	$PE_{oil,1mp,y} = FC_{oil,1mp,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	62 820
$FC_{oil,3,PJ,y}$	Amount of fuel oil burnt at TPP-3 under the project	GJ	$FC_{oil,3,PJ,y} = FC_{oil,3,PJ,y}^m \times NCV_{oil,y}$	2 034 526
$FC_{oil,1mp,PJ,y}$	Amount of fuel oil burnt in boilers of the medium pressure station of TPP-1 under the project	GJ	$FC_{oil,1mp,PJ,y} = FC_{oil,1mp,PJ,y}^m \times NCV_{oil,y}$	814 464
$FC_{oil,3,PJ,y}^m$	Mass of fuel oil burnt at TPP-3 under the project	t	See Table 1	52 288
$FC_{oil,1mp,PJ,y}^m$	Mass of fuel oil burnt in MP boilers of TPP-1 under the project	t	See Table 1	20 932
$NCV_{oil,y}$	Weighted average net calorific value of fuel oil	GJ/t	See Table 1	38.91
$EF_{CO_2,oil}$	Emission factor of CO ₂ from burning fuel oil	kg CO ₂ /GJ	Taken as constant according to the Inventory of GHG emissions at APPM [R3] (with the fraction of carbon oxidized taken into account)	77.13

Table 4. Calculation of baseline emissions over the year $y = 2001$

Symbol	Name	Unit	Formula or grounds	Value
BE_y	Total greenhouse gas emissions under the baseline	t CO ₂ e	$BE_y = BE_{ff,y} + \Delta BE_{dump,y}$	297 441
$BE_{ff,y}$	CO ₂ emissions from burning fossil fuel under the baseline	t CO ₂	$BE_{ff,y} = BE_{oil,3,y} + BE_{oil,1mp,y} + \Delta BE_{coal,y}$	297 441

Symbol	Name	Unit	Formula or grounds	Value
$BE_{oil,3,y}$	CO ₂ emissions from burning fuel oil at TPP-3 under the baseline	t CO ₂	$BE_{oil,3,y} = FC_{oil,3,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	234 622
$BE_{oil,1mp,y}$	CO ₂ emissions from burning fuel oil in boilers of the MP station of TPP-1 under the baseline	t CO ₂	$BE_{oil,1mp,y} = FC_{oil,1mp,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	62 820
$\Delta BE_{coal,y}$	Change in CO ₂ emissions from burning coal in boilers of the HP station of TPP-1 compared to the project	t CO ₂	$\Delta BE_{coal,y} = \Delta FC_{coal,y} \times EF_{CO_2,coal,y} \times 10^{-3}$	0
$EF_{CO_2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	See Table 2	91.27
$FC_{oil,3,BL,y}$	Amount of fuel oil burnt at TPP-3 under the baseline	GJ	$FC_{oil,3,BL,y} = FC_{oil,3ub,BL,y} + FC_{oil,3rb,BL,y}$	3 041 899
$FC_{oil,3ub,BL,y}$	Amount of fuel oil burnt in utilizing boilers of TPP-3 under the baseline	GJ	$FC_{oil,3ub,BL,y} = FC_{3ub,BL,y} - FC_{BWW,3ub,BL,y}$	960 912
$FC_{oil,3rb,BL,y}$	Amount of fuel oil burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{oil,3rb,BL,y} = FC_{3rb,BL,y} - FC_{liq,3rb,y}$	2 080 986
$FC_{3ub,BL,y}$	Total amount of fuel burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{3ub,BL,y} = \frac{100 \times FC_{BWW,3ub,BL,y}}{100 - \beta_{oil,3ub,BL}}$	2 826 212
$\beta_{oil,3ub,BL}$	Share of fuel oil in total consumption of equivalent fuel in the utilizing boilers of TPP-3 under the baseline	%	According to Section B [R1] it is taken as constant	34.00
$FC_{BWW,3ub,BL,y}$	Amount of BWW burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{BWW,3ub,BL,y} = FC_{BWW,3ub,BL,y}^m \times NCV_{BWW,3ub,y}$	1 865 300
$FC_{BWW,3ub,BL,y}^m$	Mass of BWW burnt in the utilizing boilers of TPP-3 under the baseline	t	According to Section B [R1] it is taken as constant	230 000
$NCV_{BWW,3ub,y}$	Actual average weighted net calorific value of BWW at TPP-3	GJ/t	See Table 2	8.11
$FC_{3rb,BL,y}$	Total amount of fuel burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{3rb,BL,y} = \frac{100 \times HG_{3rb,BL,y}}{\eta_{3rb,y}}$	6 426 625

Symbol	Name	Unit	Formula or grounds	Value
$HG_{3rb,BL,y}$	Gross steam generation in the recovery boilers of TPP-3 under the baseline	GJ	$HG_{3rb,BL,y} = HG_{3,BL,y} - HG_{3ub,BL,y}$	5 285 796
$HG_{3,BL,y}$	Total gross steam generation at TPP-3 under the baseline	GJ	$HG_{3,BL,y} = HG_{3,PJ,y} - \frac{100 \times HS_{3bypass,PJ,y}}{(100 - \varepsilon_{3bypass})}$	6 585 854
$HG_{3,PJ,y}$	Total actual gross steam generation at TPP-3	GJ	See Table 2	6 585 854
$\varepsilon_{3bypass}$	Relative heat losses and consumption on the plant's auxiliary needs related to the steam flow passing through the PRC (by-passing the turbines)	%	According to Section B [R1] it is taken as constant	5.00
$HS_{3bypass,PJ,y}$	Actual useful steam supply from TPP-3 by-passing the turbines, via the PRC	GJ	$HS_{3bypass,PJ,y} = HS_{3,PJ,y} - HS_{3backpress,PJ,y}$	0
$HS_{3,PJ,y}$	Actual total useful heat supply from TPP-3	GJ	See Table 2	5 132 868
$HS_{3backpress,PJ,y}$	Actual useful heat supply from TPP-3 with the steam spent in the turbines	GJ	See Table 2	5 132 868
$HG_{3ub,BL,y}$	Gross steam generation in the utilizing boilers of TPP-3 under the baseline	GJ	$HG_{3ub,BL,y} = FC_{3ub,BL,y} \times \eta_{3ub,BL,y} / 100$	1 300 058
$\eta_{3ub,BL,y}$	Average efficiency factor of utilizing boilers under the baseline	%	According to Section B [R1] it is taken as constant	46,00
$\eta_{3rb,y}$	Actual average weighted efficiency factor of recovery boilers of TPP-3	%	$\eta_{3rb,y} = 100 \times HG_{3rb,PJ,y} / FC_{3rb,PJ,y}$	82.25
$HG_{3rb,PJ,y}$	Actual gross steam generation in the recovery boilers of TPP-3	GJ	See Table 2	5 134 677
$FC_{3rb,PJ,y}$	Actual total fuel consumption in the recovery boilers of TPP-3	GJ	$FC_{3rb,PJ,y} = FC_{oil,3rb,PJ,y} + FC_{liq,3rb,y}$	6 242 890
$FC_{oil,3rb,PJ,y}$	Actual consumption of fuel oil in the recovery boilers of TPP-3	GJ	$FC_{oil,3rb,PJ,y} = FC_{oil,3rb,PJ,y}^m \times NCV_{oil,y}$	1 897 252

Symbol	Name	Unit	Formula or grounds	Value
$FC_{oil,3rb,PJ,y}^m$	Actual mass consumption of fuel oil in the recovery boilers of TPP-3	t	See Table 2	48 760
$FC_{liq,3rb,y}$	Actual amount of black liquor burnt at TPP-3	GJ	$FC_{liq,3rb,y} = FC_{liq,3rb,y}^{dm} \times NCV_{liq,3rb,y}$	4 345 638
$FC_{liq,3rb,y}^{dm}$	Actual amount of absolutely dry black liquor burnt in the recovery boilers of TPP-3	t a.d.m.	See Table 2	421 089
$NCV_{liq,3rb,y}$	Actual average weighted net calorific value of black liquor at TPP-3	GJ/t a.d.m.	See Table 2	10.32
$FC_{oil,1mp,BL,y}$	Amount of fuel oil burnt in MP boilers of TPP-1 under the baseline	GJ	$FC_{oil,1mp,BL,y} = FC_{oil,1mp,PJ,y} \times \frac{FC_{BWW,1mp,BL,y}^m}{FC_{BWW,1mp,PJ,y}^m}$	814 464
$FC_{BWW,1mp,BL,y}^m$	Mass of BWW burnt in the MP boiler room of TPP-1 under the baseline	t	According to Section B [R1] implementation of the project had not influence on BWW consumption in MP boilers of TPP-1 in 2001. Thus: $FC_{BWW,1mp,BL,y}^m = FC_{BWW,1mp,PJ,y}^m$	220 317
$FC_{BWW,1mp,PJ,y}^m$	Actual mass of BWW burnt in the MP boiler room of TPP-1	t	See Table 2	220 317
$\Delta FC_{coal,y}$	Change in amount of coal burnt at TPP-1 compared to the project	GJ	$\Delta FC_{coal,y} = \frac{100 \times \Delta HG_{1hp,y}}{\eta_{coal}}$	0
η_{coal}	Average gross coal boiler efficiency factor	%	According to Section B [R1] it is taken as constant	90.00
$\Delta HG_{1hp,y}$	Change in steam generation by HP boilers of TPP-1 compared to the project	GJ	$\Delta HG_{1hp,y} = \Delta HG'_{1hp,y} \frac{100}{100 - \epsilon_{aux}}$	0
ϵ_{aux}	Relative heat losses and consumption for the auxiliary needs related to additional generation of steam in HP boilers of TPP-1	%	According to Section B [R1] it is taken as constant	5.00
$\Delta HG'_{1hp,y}$	Change in live steam delivery to the HP turbines of TPP-1 compared to the project	GJ	$\Delta HG'_{1hp,y} = 0.665 \Delta HS_{1hp,y}$	0
$\Delta HS_{1hp,y}$	Change in steam supply from the HP station of TPP-1 compared to the project	GJ	$\Delta HS_{1hp,y} = \Delta HS_{1,y} - \Delta HS_{1mp,y}$	0

Symbol	Name	Unit	Formula or grounds	Value
$\Delta HS_{1,y}$	Additional annual steam supply for cellulose production from TPP-1, with losses in steam network taken into account, compared to the project scenario	GJ	$\Delta HS_{1,y} = \Delta HS_{3,y} \frac{100}{100 - \epsilon_{nw}}$	0
ϵ_{nw}	Relative heat losses in steam network (from TPP-1 to cellulose production)	%	According to Section B [R1] it is taken as constant	3.00
$\Delta HS_{3,y}$	Useful steam supply via PRC at TPP-3 under the project scenario	GJ	$\Delta HS_{3,y} = HS_{3bypass,PJ,y}$	0
$\Delta HS_{1mp,y}$	Change in steam supply from the MP station of TPP-1 compared to the project	GJ	$\Delta HS_{1mp,y} = HS_{1mp,BL,y} - HS_{1mp,PJ,y}$	0
$HS_{1mp,BL,y}$	Useful supply of thermal power from the MP station of TPP-1 under the baseline	GJ	$HS_{1mp,BL,y} = HS_{1mp,PJ,y} \times FC_{BWW,1mp,BL,y}^m / FC_{BWW,1mp,PJ,y}^m$	1 422 556
$HS_{1mp,PJ,y}$	Useful supply of thermal power from the MP station of TPP-1 under the project	GJ	$HS_{1mp,PJ,y} = HG_{1mp,PJ,y} \times (100 - \alpha) / 100$	1 422 556
α	Relative consumption of heat of live steam for the auxiliary needs and electric power generation at the MP station of TPP-1	%	According to Section B [R1] it is taken as constant	10.00
$HG_{1mp,PJ,y}$	Actual gross steam generation in boilers of the MP station of TPP-1	GJ	See Table 2	1 580 618
$\Delta BE_{dump,y}$	Additional CH ₄ emissions from the landfill compared to the project	t CO ₂ e	$\Delta BE_{dump,y} = \Delta BE_{BWW,dump,y} + \Delta BE_{WWS,dump,y}$	0
$\Delta BE_{BWW,dump,y}$	Additional emissions of CH ₄ from the landfill because of BWW anaerobic decomposition, compared to the project	t CO ₂ e	Equal to zero for 2001 as BWW dumping is considered proportional to WWS dumping. WWS dumping is equal under baseline and project in 2001 (see also [R1] and text above).	0
$\Delta BE_{WWS,dump,y}$	Additional emissions of CH ₄ from the landfill because of WWS anaerobic decomposition, compared to the project	t CO ₂ e	Equal to zero for 2001 as WWS combustion had not place in 2001, thus WWS dumping is equal under baseline and project.	0

Table 5. Calculation of emission reductions over the year $y = 2001$

Symbol	Name	Unit	Formula or grounds	Value
ER_y	Total emission reductions	t CO₂e	$ER_y = BE_y - PE_y$ or $ER_y = ER_{CO_2,y} + ER_{CH_4,y}$	77 699
$ER_{CO_2,y}$	Emission reductions of carbon dioxide	t CO₂	$ER_{CO_2,y} = ER_{CO_2,oil,3,y} + ER_{CO_2,oil,1mp,y} + ER_{CO_2,coal,1hp,y}$	77 699
$ER_{CO_2,oil,3,y}$	Emission reductions of carbon dioxide from fuel oil combustion at TPP-3	t CO ₂	$ER_{CO_2,oil,3,y} = BE_{oil,3,y} - PE_{oil,3,y}$	77 699
$ER_{CO_2,oil,1mp,y}$	Emission reduction of carbon dioxide from fuel oil combustion at the boiler-house of medium pressure TPP-1	t CO ₂	$ER_{CO_2,oil,1mp,y} = BE_{oil,1mp,y} - PE_{oil,1mp,y}$	0
$ER_{CO_2,coal,1hp,y}$	Emission reduction of carbon dioxide from coal combustion at the boiler-house of high pressure TPP-1	t CO ₂	$ER_{CO_2,coal,1hp,y} = \Delta BE_{coal,y}$	0
$ER_{CH_4,y}$	Emission reduction of methane	t CO₂e	$ER_{CH_4,y} = ER_{CH_4,BWW,y} + ER_{CH_4,WWS,y}$	0
$ER_{CH_4,BWW,y}$	Reduction of methane emissions from the landfill because of BWW anaerobic decomposition	t CO ₂ e	$ER_{CH_4,BWW,y} = \Delta BE_{BWW,dump,y}$	0
$ER_{CH_4,WWS,y}$	Reduction of methane emissions from the landfill because of WWS anaerobic decomposition	t CO ₂ e	$ER_{CH_4,WWS,y} = \Delta BE_{WWS,dump,y}$	0

Environmental monitoring

In process of the project implementation, analytical control over various effects on the environment is exercised in compliance with the existing regulation. In particular, control over emissions of harmful substances into the atmosphere is performed according to the "Schedule of laboratory control of standard MPE at stationary emission sources of JSC Arkhangelsk PPM".

The data obtained by the analytical laboratory are processed and brought together in monthly and annual reports, which specify all the required itemized data, including those for the sections affected by the Project.

Table 6 represents calculated data for the changes in the amount of harmful substances thrown into the atmosphere under the project as compared to the baseline.

Table 6. Alterations in the harmful substance emissions into the atmosphere against the baseline over the year $y = 2001$, t; (+) - increase, (-) - decrease)

Harmful emissions	Fuel oil	Coal	BWW	WSS	Total
Fluidised substances	-2	0	67	0	65
Sulphur dioxide (SO ₂)	-1 083	0	0	0	-1 083
Nitrous dioxide (NO ₂)	-100	0	11	0	-89
Nitrous oxide (NO)	-16	0	2	0	-15
Carbon oxide (CO)	-328	0	174	0	-154
Total emissions	-1 529	0	254	0	-1 276

Emergencies

No emergencies occurred during the period under verification which could have given rise to emissions.

Conclusion

The implementation of the first stage of the project “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)” allowed preventing emissions into the atmosphere in 2001:

- **greenhouse gases – by 77 699 tons CO₂e**,
- **polluting substances – by 1 276 t.**

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- [R3] Inventory of greenhouse gas emissions at OJSC „Arkhangelsk PPM“ for the years 1990-2002 on annual basis. Environmental investment centre, Arkhangelsk, 2003.

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The project is implemented at the territory of JSC “Arkhangelsk Pulp and Paper Mill”, town of Novodvinsk, Arkhangelsk region, Russia.

The project is aimed at increasing the share of biomass waste in the APPM fuel balance, which will allow reducing consumption of expensive and environmentally dirtier fossil fuel, as well as decrease the amount of dumped biomass waste.

With reference to the project, biomass waste is bark and wood waste (BWW) and waste water sludge (WWS). BWW includes bark, sawdust, slivers, substandard chips, as well as building waste wood, logging waste, etc. The bulk of BWW is formed at the stage of preparing pulp chips in the APPM wood-preparation shops and delivered from neighboring saw-mills, which have no their own facilities for utilization of their BWW. WWS is formed at the station of biological treatment of industrial and household waste of APPM and the town of Novodvinsk.

The project implies implementation of the following engineering solutions in two stages:

Stage I:

- Reconstruction of the obsolete and inefficient utilizing boiler KM-75-40 (St. No. 2) at TPP-3¹, with switching to BWW combustion in the fluidized bed;
- Modernization of WPS-3² with installation of advanced equipment for chopping and dewatering BWW.

Stage II:

- Replacement of an old utilizing boiler KM-75-40 (St. No. 1) at TPP-3 with a new utilizing boiler E-75-3,9-440 DFT, with biomass waste combustion in the fluidized bed;
- Assembly of a new unit for receiving and preparation BWW and WWS delivered by motor transport, to be burnt in utilizing boilers of TPP-3.

Construction and assembly operations for the first stage of the project were carried out from February to December of 2000, and for the second stage – from April of 2004 to July of 2005. According to *Decision 9/CMP.1* [R2], the project may be recognized as a joint implementation project, if its technical implementation began not earlier than in the year 2000.

Thus only the first stage of the project and the associated reductions of GHG emissions are considered for 2002.

Technology employed according to Stage I

Reconstruction of the KM-75-40 boiler St. No. 2

In 2000, Joint Venture Energosofin and OJSC Belenergomash performed reconstruction of the KM-75-40 boiler St. No. 2, with switching to the fluidized bed technology.

¹ TPP-3 – thermal power plant No. 3

² WPS-3 – wood-preparation shop No. 3

Burning of waste in the fluidized bed provides efficient, economical and environmentally safe combustion of high-humidity and low-calorie fuels. The fluidized bed is made of quartz sand by means of feeding air at a high pressure under the filling layer. The process of combustion is partly taking place in the fluidized bed, and partly – above it. The temperature of the fluidized bed is about 700-800°C and can be adjusted by air distribution.

In the nominal operating mode, the modernized KM-75-40S boiler allows burning BWW with humidity of 57%, with steam capacity equal to 66 tons per hour, without fuel oil flame stabilization. The superheated steam pressure is 4.0 MPa, its temperature being 440 °C. The boiler efficiency factor is about 85%. After the reconstruction, the hourly consumption of BWW has become twice as high, reaching 30 tons an hour.

The trials held within the second stage of the project showed that it is also possible to obtain stable and economical combustion of the BWW/WWS mixture, with the latter accounting for up to 20-25% of the weight of BWW. However WWS combustion was not practiced in 2002 yet and therefore it is not reviewed here.

WPS-3 modernization

WPS-3 modernization was performed for the purpose of improving the BWW quality in accordance with requirements set for the fuel combusted through the fluidized bed technology. The modernization was carried out in 2000, simultaneously with reconstruction of boiler St. No. 2 of TPP-3.

As a result of modernization, three independent fuel flows were replaced with a single centralized bark preparation unit equipped with a Saalasti 0912 rotor crusher and two Bark Master 1620 bark drum presses (also made by Saalasti). The equipment proved to be efficient at a number of the industry enterprises.

Modernization of WPS-3 made it possible to ensure a more homogenous breakup of BWW (pieces not larger than 75 mm) and lower their humidity down to the level of about 50%, which substantially increased the low calorific value and allowed stable combustion of BWW in boiler St. No. 2 in the fluidized bed without fuel oil flame stabilization. Besides, electric power consumption required for BWW preparation was reduced by 6-8%, due to its centralization.

On the whole, implementation of measures of the first stage enabled to make the amount of BWW burnt in boiler St. No. 2 of TPP-3 more than double, while having increased significantly the efficiency of their combustion and reduced fuel oil consumption.

Monitoring Period

The monitoring period is chosen from **1st January 2002 to 31st December 2002** (both days included).

Monitored data

Collection of all the key parameters required for greenhouse emissions to be determined, both under the project and for the baseline, is performed according to the practice established at APPM on accounting of fuel, energy, waste, and assessment of environmental impacts. Monitoring under the project requires no changes to be introduced in the existing system of accounting and collection of information. All the necessary data are determined and registered in any case.

Description of monitoring plan of all data required to calculate GHG emissions reductions is represented in Section D and Annex 3 of PDD [R1]. Table 1 and 2 below represents yearly values of project and

baseline data for 2002. It should be mentioned that it was not necessary to define some data for 2002 as WWS was not burnt and no change in biomass waste dumping occurred.³

Table 1. Values of data collected in order to monitor emissions from the project over the year $y = 2002$

ID number and symbol	Data name	Data unit	Value	Comment
1. $FC_{oil,3,PJ,y}^m$	Mass fuel oil consumption at TPP-3	t	30 663	
2. $FC_{oil,1mp,PJ,y}^m$	Mass fuel oil consumption in medium pressure boilers of TPP-1	t	19 042	
3. $NCV_{oil,y}$	Net calorific value of fuel oil	GJ/t	39.58	The weighted annual average

Table 2. Values of relevant data necessary for determining the baseline of anthropogenic emissions of greenhouse gases by sources within the project boundary over the year $y = 2002$

ID number and symbol	Data name	Data unit	Data value	Comment
4. $FC_{BWW,3ub,PJ,y}^m$	Mass BWW consumption in utilizing boilers of TPP-3	t	335 607	
5. $FC_{BWW,1mp,PJ,y}^m$	Mass BWW consumption in medium pressure boilers of TPP-1	t	266 242	
6. $BWW_{dump,PJ,y}^m$	Mass BWW removal to the landfill	t		Not necessary for 2002
7. $BWW_{side,PJ,y}^m$	Mass BWW delivery from the outside	t		Not necessary for 2002
8. $WWS_{dump,PJ,y}^m$	Wet mass WWS removal to the landfill	t		Not necessary for 2002
9. $FC_{WWS,3ub,PJ,y}^m$	Wet mass WWS consumption in utilizing boilers of TPP-3	t	0	

³ PDD shows that dumped BWW is proportional to dumped WWS to provide bearing capacity of the landfill without dependence on the project. Stipulated that WWS is not burnt volumes of dumping of both kinds of biomass waste remain the same as without the project. Due to this reason reductions of methane landfill emissions from the project equal zero in 2002.

ID number and symbol	Data name	Data unit	Data value	Comment
10. $W_{WWS,y}$	WWS humidity	%		Not necessary for 2002
11. $FC_{liq,3rb,y}^{dm}$	Dry mass black liquor consumption in recovery boilers of TPP-3	t a.d.m.	435 058	
12. $FC_{oil,3rb,PJ,y}^m$	Mass fuel oil consumption in recovery boilers of TPP-3	t	28 042	
13. $NCV_{BWW,3ub,y}$	Net calorific value of BWW combusted in utilizing boilers of TPP-3	GJ/t	8.48	The weighted annual average
14. $NCV_{liq,3rb,y}$	Net calorific value of black liquor combusted in recovery boilers of TPP-3	GJ/t a.d.m.	10.19	The weighted annual average
15. $HG_{3,PJ,y}$	Total gross steam generation at TPP-3	GJ	6 342 941	
16. $HS_{3,PJ,y}$	Total useful supply of heat from TPP-3	GJ	4 784 108	
17. $HS_{3backpress,PJ,y}$	Useful supply of heat from TPP-3 with backpressure steam	GJ	4 784 108	It is equal to total useful supply because no steam supply through the PRC in 2002
18. $HG_{3rb,PJ,y}$	Gross steam generation in recovery boilers of TPP-3	GJ	4 560 045	
19. $HG_{1mp,PJ,y}$	Gross steam generation in medium pressure boilers of TPP-1	GJ	1 724 546	
20. $EF_{CO2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	91.30	Results of GHG inventory at APPM for 2002 [R3]

Calculation of emission reductions

According to formulae described in Section D [R1] calculations of project and baseline emissions have been done (see Tables 3 and 4). As shown in Section B.3 [R1] all of the leakages can be neglected. Calculation of emission reductions are presented in Table 5.

Thus, total GHG emission reductions for 2002 amounted 109 204 tCO₂e.

Table 3. Calculation of project emissions over the year $y = 2002$

Symbol	Name	Unit	Formula or grounds	Value
PE_y	Total greenhouse gas emissions under the project	t CO ₂	$PE_y = PE_{oil,3,y} + PE_{oil,1mp,y}$	151 740
$PE_{oil,3,y}$	CO ₂ emission from burning fuel oil at TPP-3 under the project	t CO ₂	$PE_{oil,3,y} = FC_{oil,3,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	93 608
$PE_{oil,1mp,y}$	CO ₂ emission from burning fuel oil in boilers of the medium pressure station of TPP-1 under the project	t CO ₂	$PE_{oil,1mp,y} = FC_{oil,1mp,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	58 132
$FC_{oil,3,PJ,y}$	Amount of fuel oil burnt at TPP-3 under the project	GJ	$FC_{oil,3,PJ,y} = FC_{oil,3,PJ,y}^m \times NCV_{oil,y}$	1 213 642
$FC_{oil,1mp,PJ,y}$	Amount of fuel oil burnt in boilers of the medium pressure station of TPP-1 under the project	GJ	$FC_{oil,1mp,PJ,y} = FC_{oil,1mp,PJ,y}^m \times NCV_{oil,y}$	753 690
$FC_{oil,3,PJ,y}^m$	Mass of fuel oil burnt at TPP-3 under the project	t	See Table 1	30 663
$FC_{oil,1mp,PJ,y}^m$	Mass of fuel oil burnt in MP boilers of TPP-1 under the project	t	See Table 1	19 042
$NCV_{oil,y}$	Weighted average net calorific value of fuel oil	GJ/t	See Table 1	39.58
$EF_{CO_2,oil}$	Emission factor of CO ₂ from burning fuel oil	kg CO ₂ /GJ	Taken as constant according to the Inventory of GHG emissions at APPM [R3] (with the fraction of carbon oxidized taken into account)	77.13

Table 4. Calculation of baseline emissions over the year $y = 2002$

Symbol	Name	Unit	Formula or grounds	Value
BE_y	Total greenhouse gas emissions under the baseline	t CO ₂ e	$BE_y = BE_{ff,y} + \Delta BE_{dump,y}$	260 945
$BE_{ff,y}$	CO ₂ emissions from burning fossil fuel under the baseline	t CO ₂	$BE_{ff,y} = BE_{oil,3,y} + BE_{oil,1mp,y} + \Delta BE_{coal,y}$	260 945

Symbol	Name	Unit	Formula or grounds	Value
$BE_{oil,3,y}$	CO ₂ emissions from burning fuel oil at TPP-3 under the baseline	t CO ₂	$BE_{oil,3,y} = FC_{oil,3,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	202 812
$BE_{oil,1mp,y}$	CO ₂ emissions from burning fuel oil in boilers of the MP station of TPP-1 under the baseline	t CO ₂	$BE_{oil,1mp,y} = FC_{oil,1mp,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	58 132
$\Delta BE_{coal,y}$	Change in CO ₂ emissions from burning coal in boilers of the HP station of TPP-1 compared to the project	t CO ₂	$\Delta BE_{coal,y} = \Delta FC_{coal,y} \times EF_{CO_2,coal,y} \times 10^{-3}$	0
$EF_{CO_2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	See Table 2	91.30
$FC_{oil,3,BL,y}$	Amount of fuel oil burnt at TPP-3 under the baseline	GJ	$FC_{oil,3,BL,y} = FC_{oil,3ub,BL,y} + FC_{oil,3rb,BL,y}$	2 629 488
$FC_{oil,3ub,BL,y}$	Amount of fuel oil burnt in utilizing boilers of TPP-3 under the baseline	GJ	$FC_{oil,3ub,BL,y} = FC_{3ub,BL,y} - FC_{BWW,3ub,BL,y}$	1 004 752
$FC_{oil,3rb,BL,y}$	Amount of fuel oil burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{oil,3rb,BL,y} = FC_{3rb,BL,y} - FC_{liq,3rb,y}$	1 624 736
$FC_{3ub,BL,y}$	Total amount of fuel burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{3ub,BL,y} = \frac{100 \times FC_{BWW,3ub,BL,y}}{100 - \beta_{oil,3ub,BL}}$	2 955 152
$\beta_{oil,3ub,BL}$	Share of fuel oil in total consumption of equivalent fuel in the utilizing boilers of TPP-3 under the baseline	%	According to Section B [R1] it is taken as constant	34.00
$FC_{BWW,3ub,BL,y}$	Amount of BWW burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{BWW,3ub,BL,y} = FC_{BWW,3ub,BL,y}^m \times NCV_{BWW,3ub,y}$	1 950 400
$FC_{BWW,3ub,BL,y}^m$	Mass of BWW burnt in the utilizing boilers of TPP-3 under the baseline	t	According to Section B [R1] it is taken as constant	230 000
$NCV_{BWW,3ub,y}$	Actual average weighted net calorific value of BWW at TPP-3	GJ/t	See Table 2	8.48
$FC_{3rb,BL,y}$	Total amount of fuel burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{3rb,BL,y} = \frac{100 \times HG_{3rb,BL,y}}{\eta_{3rb,y}}$	6 057 977

Symbol	Name	Unit	Formula or grounds	Value
$HG_{3rb,BL,y}$	Gross steam generation in the recovery boilers of TPP-3 under the baseline	GJ	$HG_{3rb,BL,y} = HG_{3,BL,y} - HG_{3ub,BL,y}$	4 983 571
$HG_{3,BL,y}$	Total gross steam generation at TPP-3 under the baseline	GJ	$HG_{3,BL,y} = HG_{3,PJ,y} - \frac{100 \times HS_{3bypass,PJ,y}}{(100 - \varepsilon_{3bypass})}$	6 342 941
$HG_{3,PJ,y}$	Total actual gross steam generation at TPP-3	GJ	See Table 2	6 342 941
$\varepsilon_{3bypass}$	Relative heat losses and consumption on the plant's auxiliary needs related to the steam flow passing through the PRC (by-passing the turbines)	%	According to Section B [R1] it is taken as constant	5.00
$HS_{3bypass,PJ,y}$	Actual useful steam supply from TPP-3 by-passing the turbines, via the PRC	GJ	$HS_{3bypass,PJ,y} = HS_{3,PJ,y} - HS_{3backpress,PJ,y}$	0
$HS_{3,PJ,y}$	Actual total useful heat supply from TPP-3	GJ	See Table 2	4 784 108
$HS_{3backpress,PJ,y}$	Actual useful heat supply from TPP-3 with the steam spent in the turbines	GJ	See Table 2	4 784 108
$HG_{3ub,BL,y}$	Gross steam generation in the utilizing boilers of TPP-3 under the baseline	GJ	$HG_{3ub,BL,y} = FC_{3ub,BL,y} \times \eta_{3ub,BL,y} / 100$	1 359 370
$\eta_{3ub,BL,y}$	Average efficiency factor of utilizing boilers under the baseline	%	According to Section B [R1] it is taken as constant	46.00
$\eta_{3rb,y}$	Actual average weighted efficiency factor of recovery boilers of TPP-3	%	$\eta_{3rb,y} = 100 \times HG_{3rb,PJ,y} / FC_{3rb,PJ,y}$	82.26
$HG_{3rb,PJ,y}$	Actual gross steam generation in the recovery boilers of TPP-3	GJ	See Table 2	4 560 045
$FC_{3rb,PJ,y}$	Actual total fuel consumption in the recovery boilers of TPP-3	GJ	$FC_{3rb,PJ,y} = FC_{oil,3rb,PJ,y} + FC_{liq,3rb,y}$	5 543 143
$FC_{oil,3rb,PJ,y}$	Actual consumption of fuel oil in the recovery boilers of TPP-3	GJ	$FC_{oil,3rb,PJ,y} = FC_{oil,3rb,PJ,y}^m \times NCV_{oil,y}$	1 109 902

Symbol	Name	Unit	Formula or grounds	Value
$FC_{oil,3rb,PJ,y}^m$	Actual mass consumption of fuel oil in the recovery boilers of TPP-3	t	See Table 2	28 042
$FC_{liq,3rb,y}$	Actual amount of black liquor burnt at TPP-3	GJ	$FC_{liq,3rb,y} = FC_{liq,3rb,y}^{dm} \times NCV_{liq,3rb,y}$	4 433 241
$FC_{liq,3rb,y}^{dm}$	Actual amount of absolutely dry black liquor burnt in the recovery boilers of TPP-3	t a.d.m.	See Table 2	435 058
$NCV_{liq,3rb,y}$	Actual average weighted net calorific value of black liquor at TPP-3	GJ/t a.d.m.	See Table 2	10.19
$FC_{oil,1mp,BL,y}$	Amount of fuel oil burnt in MP boilers of TPP-1 under the baseline	GJ	$FC_{oil,1mp,BL,y} = FC_{oil,1mp,PJ,y} \times \frac{FC_{BWW,1mp,BL,y}^m}{FC_{BWW,1mp,PJ,y}^m}$	753 690
$FC_{BWW,1mp,BL,y}^m$	Mass of BWW burnt in the MP boiler room of TPP-1 under the baseline	t	According to Section B [R1] implementation of the project had not influence on BWW consumption in MP boilers of TPP-1 in 2002. Thus: $FC_{BWW,1mp,BL,y}^m = FC_{BWW,1mp,PJ,y}^m$	266 242
$FC_{BWW,1mp,PJ,y}^m$	Actual mass of BWW burnt in the MP boiler room of TPP-1	t	See Table 2	266 242
$\Delta FC_{coal,y}$	Change in amount of coal burnt at TPP-1 compared to the project	GJ	$\Delta FC_{coal,y} = \frac{100 \times \Delta HG_{1hp,y}}{\eta_{coal}}$	0
η_{coal}	Average gross coal boiler efficiency factor	%	According to Section B [R1] it is taken as constant	90.00
$\Delta HG_{1hp,y}$	Change in steam generation by HP boilers of TPP-1 compared to the project	GJ	$\Delta HG_{1hp,y} = \Delta HG'_{1hp,y} \frac{100}{100 - \epsilon_{aux}}$	0
ϵ_{aux}	Relative heat losses and consumption for the auxiliary needs related to additional generation of steam in HP boilers of TPP-1	%	According to Section B [R1] it is taken as constant	5.00
$\Delta HG'_{1hp,y}$	Change in live steam delivery to the HP turbines of TPP-1 compared to the project	GJ	$\Delta HG'_{1hp,y} = 0.665 \Delta HS_{1hp,y}$	0
$\Delta HS_{1hp,y}$	Change in steam supply from the HP station of TPP-1 compared to the project	GJ	$\Delta HS_{1hp,y} = \Delta HS_{1,y} - \Delta HS_{1mp,y}$	0

Symbol	Name	Unit	Formula or grounds	Value
$\Delta HS_{1,y}$	Additional annual steam supply for cellulose production from TPP-1, with losses in steam network taken into account, compared to the project scenario	GJ	$\Delta HS_{1,y} = \Delta HS_{3,y} \frac{100}{100 - \epsilon_{nw}}$	0
ϵ_{nw}	Relative heat losses in steam network (from TPP-1 to cellulose production)	%	According to Section B [R1] it is taken as constant	3.00
$\Delta HS_{3,y}$	Useful steam supply via PRC at TPP-3 under the project scenario	GJ	$\Delta HS_{3,y} = HS_{3bypass,PJ,y}$	0
$\Delta HS_{1mp,y}$	Change in steam supply from the MP station of TPP-1 compared to the project	GJ	$\Delta HS_{1mp,y} = HS_{1mp,BL,y} - HS_{1mp,PJ,y}$	0
$HS_{1mp,BL,y}$	Useful supply of thermal power from the MP station of TPP-1 under the baseline	GJ	$HS_{1mp,BL,y} = HS_{1mp,PJ,y} \times FC_{BWW,1mp,BL,y}^m / FC_{BWW,1mp,PJ,y}^m$	1 552 091
$HS_{1mp,PJ,y}$	Useful supply of thermal power from the MP station of TPP-1 under the project	GJ	$HS_{1mp,PJ,y} = HG_{1mp,PJ,y} \times (100 - \alpha) / 100$	1 552 091
α	Relative consumption of heat of live steam for the auxiliary needs and electric power generation at the MP station of TPP-1	%	According to Section B [R1] it is taken as constant	10.00
$HG_{1mp,PJ,y}$	Actual gross steam generation in boilers of the MP station of TPP-1	GJ	See Table 2	1 724 546
$\Delta BE_{dump,y}$	Additional CH ₄ emissions from the landfill compared to the project	t CO ₂ e	$\Delta BE_{dump,y} = \Delta BE_{BWW,dump,y} + \Delta BE_{WWS,dump,y}$	0
$\Delta BE_{BWW,dump,y}$	Additional emissions of CH ₄ from the landfill because of BWW anaerobic decomposition, compared to the project	t CO ₂ e	Equal to zero for 2002 as BWW dumping is considered proportional to WWS dumping. WWS dumping is equal under baseline and project in 2002 (see also [R1] and text above).	0
$\Delta BE_{WWS,dump,y}$	Additional emissions of CH ₄ from the landfill because of WWS anaerobic decomposition, compared to the project	t CO ₂ e	Equal to zero for 2002 as WWS combustion had not place in 2002, thus WWS dumping is equal under baseline and project.	0

Table 5. Calculation of emission reductions over the year $y = 2002$

Symbol	Name	Unit	Formula or grounds	Value
ER_y	Total emission reductions	t CO₂e	$ER_y = BE_y - PE_y$ or $ER_y = ER_{CO_2,y} + ER_{CH_4,y}$	109 204
$ER_{CO_2,y}$	Emission reductions of carbon dioxide	t CO₂	$ER_{CO_2,y} = ER_{CO_2,oil,3,y} + ER_{CO_2,oil,1mp,y} + ER_{CO_2,coal,1hp,y}$	109 204
$ER_{CO_2,oil,3,y}$	Emission reductions of carbon dioxide from fuel oil combustion at TPP-3	t CO ₂	$ER_{CO_2,oil,3,y} = BE_{oil,3,y} - PE_{oil,3,y}$	109 204
$ER_{CO_2,oil,1mp,y}$	Emission reduction of carbon dioxide from fuel oil combustion at the boiler-house of medium pressure TPP-1	t CO ₂	$ER_{CO_2,oil,1mp,y} = BE_{oil,1mp,y} - PE_{oil,1mp,y}$	0
$ER_{CO_2,coal,1hp,y}$	Emission reduction of carbon dioxide from coal combustion at the boiler-house of high pressure TPP-1	t CO ₂	$ER_{CO_2,coal,1hp,y} = \Delta BE_{coal,y}$	0
$ER_{CH_4,y}$	Emission reduction of methane	t CO₂e	$ER_{CH_4,y} = ER_{CH_4,BWW,y} + ER_{CH_4,WWS,y}$	0
$ER_{CH_4,BWW,y}$	Reduction of methane emissions from the landfill because of BWW anaerobic decomposition	t CO ₂ e	$ER_{CH_4,BWW,y} = \Delta BE_{BWW,dump,y}$	0
$ER_{CH_4,WWS,y}$	Reduction of methane emissions from the landfill because of WWS anaerobic decomposition	t CO ₂ e	$ER_{CH_4,WWS,y} = \Delta BE_{WWS,dump,y}$	0

Environmental monitoring

In process of the project implementation, analytical control over various effects on the environment is exercised in compliance with the existing regulation. In particular, control over emissions of harmful substances into the atmosphere is performed according to the “Schedule of laboratory control of standard MPE at stationary emission sources of JSC Arkhangelsk PPM”.

The data obtained by the analytical laboratory are processed and brought together in monthly and annual reports, which specify all the required itemized data, including those for the sections affected by the Project.

Table 6 represents calculated data for the changes in the amount of harmful substances thrown into the atmosphere under the project as compared to the baseline.

Table 6. Alterations in the harmful substance emissions into the atmosphere against the baseline over the year $y = 2002$, t; (+) - increase, (-) - decrease)

Harmful emissions	Fuel oil	Coal	BWW	WSS	Total
Fluidised substances	-2	0	110	0	108
Sulphur dioxide (SO ₂)	-1 545	0	0	0	-1 545
Nitrous dioxide (NO ₂)	-143	0	18	0	-125
Nitrous oxide (NO)	-23	0	3	0	-20
Carbon oxide (CO)	-468	0	288	0	-180
Total emissions	-2 181	0	419	0	-1 762

Emergencies

No emergencies occurred during the period under verification which could have given rise to emissions.

Conclusion

The implementation of the first stage of the project “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)” allowed preventing emissions into the atmosphere in 2002:

- **greenhouse gases – by 109 204 tons CO₂e**,
- **polluting substances – by 1 762 t.**

REFERENCES

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- [R2] Decision 9/CMP.1. Guidelines for the implementation of Article 6 of the Kyoto Protocol. FCCC/KP/CMP/2005/8/Add.2. 30 March 2006
- [R3] Inventory of greenhouse gas emissions at OJSC „Arkhangelsk PPM“ for the years 1990-2002 on annual basis. Environmental investment centre, Arkhangelsk, 2003.

MONITORING REPORT

**JOINT STOCK COMPANY
“ARKHANGELSK PULP AND PAPER MILL”**

Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (town of Novodvinsk, Russia)

PDD REFERENCE NO: 0005

Monitoring period: **1st January 2003 – 31st December 2003**

Prepared by: Environmental Investment Center (Arkhangelsk, Russia)

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Date: 26.03.2007

Introduction

The document is executed according to the developed PDD “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)” [R1]. The PDD is placed at website UNFCCC (ji.unfccc.int/JI_Projects/Verification/PDD) under reference number 0005.

The project is implemented at the territory of JSC “Arkhangelsk Pulp and Paper Mill”, town of Novodvinsk, Arkhangelsk region, Russia.

The project is aimed at increasing the share of biomass waste in the APPM fuel balance, which will allow reducing consumption of expensive and environmentally dirtier fossil fuel, as well as decrease the amount of dumped biomass waste.

With reference to the project, biomass waste is bark and wood waste (BWW) and waste water sludge (WWS). BWW includes bark, sawdust, slivers, substandard chips, as well as building waste wood, logging waste, etc. The bulk of BWW is formed at the stage of preparing pulp chips in the APPM wood-preparation shops and delivered from neighboring saw-mills, which have no their own facilities for utilization of their BWW. WWS is formed at the station of biological treatment of industrial and household waste of APPM and the town of Novodvinsk.

The project implies implementation of the following engineering solutions in two stages:

Stage I:

- Reconstruction of the obsolete and inefficient utilizing boiler KM-75-40 (St. No. 2) at TPP-3¹, with switching to BWW combustion in the fluidized bed;
- Modernization of WPS-3² with installation of advanced equipment for chopping and dewatering BWW.

Stage II:

- Replacement of an old utilizing boiler KM-75-40 (St. No. 1) at TPP-3 with a new utilizing boiler E-75-3,9-440 DFT, with biomass waste combustion in the fluidized bed;
- Assembly of a new unit for receiving and preparation BWW and WWS delivered by motor transport, to be burnt in utilizing boilers of TPP-3.

Construction and assembly operations for the first stage of the project were carried out from February to December of 2000, and for the second stage – from April of 2004 to July of 2005. According to *Decision 9/CMP.1* [R2], the project may be recognized as a joint implementation project, if its technical implementation began not earlier than in the year 2000.

Thus only the first stage of the project and the associated reductions of GHG emissions are considered for 2003.

Technology employed according to Stage I

Reconstruction of the KM-75-40 boiler St. No. 2

In 2000, Joint Venture Energosofin and OJSC Belenergomash performed reconstruction of the KM-75-40 boiler St. No. 2, with switching to the fluidized bed technology.

¹ TPP-3 – thermal power plant No. 3

² WPS-3 – wood-preparation shop No. 3

Burning of waste in the fluidized bed provides efficient, economical and environmentally safe combustion of high-humidity and low-calorie fuels. The fluidized bed is made of quartz sand by means of feeding air at a high pressure under the filling layer. The process of combustion is partly taking place in the fluidized bed, and partly – above it. The temperature of the fluidized bed is about 700-800°C and can be adjusted by air distribution.

In the nominal operating mode, the modernized KM-75-40S boiler allows burning BWW with humidity of 57%, with steam capacity equal to 66 tons per hour, without fuel oil flame stabilization. The superheated steam pressure is 4.0 MPa, its temperature being 440 °C. The boiler efficiency factor is about 85%. After the reconstruction, the hourly consumption of BWW has become twice as high, reaching 30 tons an hour.

The trials held within the second stage of the project showed that it is also possible to obtain stable and economical combustion of the BWW/WWS mixture, with the latter accounting for up to 20-25% of the weight of BWW. However WWS combustion was not practiced in 2003 yet and therefore it is not reviewed here.

WPS-3 modernization

WPS-3 modernization was performed for the purpose of improving the BWW quality in accordance with requirements set for the fuel combusted through the fluidized bed technology. The modernization was carried out in 2000, simultaneously with reconstruction of boiler St. No. 2 of TPP-3.

As a result of modernization, three independent fuel flows were replaced with a single centralized bark preparation unit equipped with a Saalasti 0912 rotor crusher and two Bark Master 1620 bark drum presses (also made by Saalasti). The equipment proved to be efficient at a number of the industry enterprises.

Modernization of WPS-3 made it possible to ensure a more homogenous breakup of BWW (pieces not larger than 75 mm) and lower their humidity down to the level of about 50%, which substantially increased the low calorific value and allowed stable combustion of BWW in boiler St. No. 2 in the fluidized bed without fuel oil flame stabilization. Besides, electric power consumption required for BWW preparation was reduced by 6-8%, due to its centralization.

On the whole, implementation of measures of the first stage enabled to make the amount of BWW burnt in boiler St. No. 2 of TPP-3 more than double, while having increased significantly the efficiency of their combustion and reduced fuel oil consumption.

Monitoring Period

The monitoring period is chosen from **1st January 2003 to 31st December 2003** (both days included).

Monitored data

Collection of all the key parameters required for greenhouse emissions to be determined, both under the project and for the baseline, is performed according to the practice established at APPM on accounting of fuel, energy, waste, and assessment of environmental impacts. Monitoring under the project requires no changes to be introduced in the existing system of accounting and collection of information. All the necessary data are determined and registered in any case.

Description of monitoring plan of all data required to calculate GHG emissions reductions is represented in Section D and Annex 3 of PDD [R1]. Table 1 and 2 below represents yearly values of project and

baseline data for 2003. It should be mentioned that it was not necessary to define some data for 2003 as WWS was not burnt and no change in biomass waste dumping occurred.³

Table 1. Values of data collected in order to monitor emissions from the project over the year $y = 2003$

ID number and symbol	Data name	Data unit	Value	Comment
1. $FC_{oil,3,PJ,y}^m$	Mass fuel oil consumption at TPP-3	t	33 146	
2. $FC_{oil,1mp,PJ,y}^m$	Mass fuel oil consumption in medium pressure boilers of TPP-1	t	20 692	
3. $NCV_{oil,y}$	Net calorific value of fuel oil	GJ/t	40.37	The weighted annual average

Table 2. Values of relevant data necessary for determining the baseline of anthropogenic emissions of greenhouse gases by sources within the project boundary over the year $y = 2003$

ID number and symbol	Data name	Data unit	Data value	Comment
4. $FC_{BWW,3ub,PJ,y}^m$	Mass BWW consumption in utilizing boilers of TPP-3	t	367 293	
5. $FC_{BWW,1mp,PJ,y}^m$	Mass BWW consumption in medium pressure boilers of TPP-1	t	263 637	
6. $BWW_{dump,PJ,y}^m$	Mass BWW removal to the landfill	t		Not necessary for 2003
7. $BWW_{side,PJ,y}^m$	Mass BWW delivery from the outside	t		Not necessary for 2003
8. $WWS_{dump,PJ,y}^m$	Wet mass WWS removal to the landfill	t		Not necessary for 2003
9. $FC_{WWS,3ub,PJ,y}^m$	Wet mass WWS consumption in utilizing boilers of TPP-3	t	0	

³ PDD shows that dumped BWW is proportional to dumped WWS to provide bearing capacity of the landfill without dependence on the project. Stipulated that WWS is not burnt volumes of dumping of both kinds of biomass waste remain the same as without the project. Due to this reason reductions of methane landfill emissions from the project equal zero in 2003.

ID number and symbol	Data name	Data unit	Data value	Comment
10. $W_{WWS,y}$	WWS humidity	%		Not necessary for 2003
11. $FC_{liq,3rb,y}^{dm}$	Dry mass black liquor consumption in recovery boilers of TPP-3	t a.d.m.	467 936	Including 4 636 t of sulfate soap
12. $FC_{oil,3rb,PJ,y}^m$	Mass fuel oil consumption in recovery boilers of TPP-3	t	31 129	
13. $NCV_{BWW,3ub,y}$	Net calorific value of BWW combusted in utilizing boilers of TPP-3	GJ/t	8.59	The weighted annual average
14. $NCV_{liq,3rb,y}$	Net calorific value of black liquor combusted in recovery boilers of TPP-3	GJ/t a.d.m.	10.19	The weighted annual average
15. $HG_{3,PJ,y}$	Total gross steam generation at TPP-3	GJ	6 755 038	
16. $HS_{3,PJ,y}$	Total useful supply of heat from TPP-3	GJ	4 986 093	
17. $HS_{3backpress,PJ,y}$	Useful supply of heat from TPP-3 with backpressure steam	GJ	4 986 093	It is equal to total useful supply because no steam supply through the PRC in 2003
18. $HG_{3rb,PJ,y}$	Gross steam generation in recovery boilers of TPP-3	GJ	4 870 574	
19. $HG_{1mp,PJ,y}$	Gross steam generation in medium pressure boilers of TPP-1	GJ	1 726 911	
20. $EF_{CO2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	91.49	Results of GHG inventory at APPM for 2003 [R3]

Calculation of emission reductions

According to formulae described in Section D [R1] calculations of project and baseline emissions have been done (see Tables 3 and 4). As shown in Section B.3 [R1] all of the leakages can be neglected. Calculation of emission reductions are presented in Table 5.

Thus, total GHG emission reductions for 2003 amounted 120 638 tCO₂e.

Table 3. Calculation of project emissions over the year $y = 2003$

Symbol	Name	Unit	Formula or grounds	Value
PE_y	Total greenhouse gas emissions under the project	t CO ₂	$PE_y = PE_{oil,3,y} + PE_{oil,1mp,y}$	167 638
$PE_{oil,3,y}$	CO ₂ emission from burning fuel oil at TPP-3 under the project	t CO ₂	$PE_{oil,3,y} = FC_{oil,3,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	103 208
$PE_{oil,1mp,y}$	CO ₂ emission from burning fuel oil in boilers of the medium pressure station of TPP-1 under the project	t CO ₂	$PE_{oil,1mp,y} = FC_{oil,1mp,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	64 430
$FC_{oil,3,PJ,y}$	Amount of fuel oil burnt at TPP-3 under the project	GJ	$FC_{oil,3,PJ,y} = FC_{oil,3,PJ,y}^m \times NCV_{oil,y}$	1 338 104
$FC_{oil,1mp,PJ,y}$	Amount of fuel oil burnt in boilers of the medium pressure station of TPP-1 under the project	GJ	$FC_{oil,1mp,PJ,y} = FC_{oil,1mp,PJ,y}^m \times NCV_{oil,y}$	835 348
$FC_{oil,3,PJ,y}^m$	Mass of fuel oil burnt at TPP-3 under the project	t	See Table 1	33 146
$FC_{oil,1mp,PJ,y}^m$	Mass of fuel oil burnt in MP boilers of TPP-1 under the project	t	See Table 1	20 692
$NCV_{oil,y}$	Weighted average net calorific value of fuel oil	GJ/t	See Table 1	40.37
$EF_{CO_2,oil}$	Emission factor of CO ₂ from burning fuel oil	kg CO ₂ /GJ	Taken as constant according to the Inventory of GHG emissions at APPM [R3] (with the fraction of carbon oxidized taken into account)	77.13

Table 4. Calculation of baseline emissions over the year $y = 2003$

Symbol	Name	Unit	Formula or grounds	Value
BE_y	Total greenhouse gas emissions under the baseline	t CO ₂ e	$BE_y = BE_{ff,y} + \Delta BE_{dump,y}$	288 277
$BE_{ff,y}$	CO ₂ emissions from burning fossil fuel under the baseline	t CO ₂	$BE_{ff,y} = BE_{oil,3,y} + BE_{oil,1mp,y} + \Delta BE_{coal,y}$	288 277

Symbol	Name	Unit	Formula or grounds	Value
$BE_{oil,3,y}$	CO ₂ emissions from burning fuel oil at TPP-3 under the baseline	t CO ₂	$BE_{oil,3,y} = FC_{oil,3,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	223 846
$BE_{oil,1mp,y}$	CO ₂ emissions from burning fuel oil in boilers of the MP station of TPP-1 under the baseline	t CO ₂	$BE_{oil,1mp,y} = FC_{oil,1mp,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	64 430
$\Delta BE_{coal,y}$	Change in CO ₂ emissions from burning coal in boilers of the HP station of TPP-1 compared to the project	t CO ₂	$\Delta BE_{coal,y} = \Delta FC_{coal,y} \times EF_{CO_2,coal,y} \times 10^{-3}$	0
$EF_{CO_2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	See Table 2	91.49
$FC_{oil,3,BL,y}$	Amount of fuel oil burnt at TPP-3 under the baseline	GJ	$FC_{oil,3,BL,y} = FC_{oil,3ub,BL,y} + FC_{oil,3rb,BL,y}$	2 902 197
$FC_{oil,3ub,BL,y}$	Amount of fuel oil burnt in utilizing boilers of TPP-3 under the baseline	GJ	$FC_{oil,3ub,BL,y} = FC_{3ub,BL,y} - FC_{BWW,3ub,BL,y}$	1 017 785
$FC_{oil,3rb,BL,y}$	Amount of fuel oil burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{oil,3rb,BL,y} = FC_{3rb,BL,y} - FC_{liq,3rb,y}$	1 884 412
$FC_{3ub,BL,y}$	Total amount of fuel burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{3ub,BL,y} = \frac{100 \times FC_{BWW,3ub,BL,y}}{100 - \beta_{oil,3ub,BL}}$	2 993 485
$\beta_{oil,3ub,BL}$	Share of fuel oil in total consumption of equivalent fuel in the utilizing boilers of TPP-3 under the baseline	%	According to Section B [R1] it is taken as constant	34.00
$FC_{BWW,3ub,BL,y}$	Amount of BWW burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{BWW,3ub,BL,y} = FC_{BWW,3ub,BL,y}^m \times NCV_{BWW,3ub,y}$	1 975 700
$FC_{BWW,3ub,BL,y}^m$	Mass of BWW burnt in the utilizing boilers of TPP-3 under the baseline	t	According to Section B [R1] it is taken as constant	230 000
$NCV_{BWW,3ub,y}$	Actual average weighted net calorific value of BWW at TPP-3	GJ/t	See Table 2	8.59
$FC_{3rb,BL,y}$	Total amount of fuel burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{3rb,BL,y} = \frac{100 \times HG_{3rb,BL,y}}{\eta_{3rb,y}}$	6 652 680

Symbol	Name	Unit	Formula or grounds	Value
$HG_{3rb,BL,y}$	Gross steam generation in the recovery boilers of TPP-3 under the baseline	GJ	$HG_{3rb,BL,y} = HG_{3,BL,y} - HG_{3ub,BL,y}$	5 378 035
$HG_{3,BL,y}$	Total gross steam generation at TPP-3 under the baseline	GJ	$HG_{3,BL,y} = HG_{3,PJ,y} - \frac{100 \times HS_{3bypass,PJ,y}}{(100 - \varepsilon_{3bypass})}$	6 755 038
$HG_{3,PJ,y}$	Total actual gross steam generation at TPP-3	GJ	See Table 2	6 755 038
$\varepsilon_{3bypass}$	Relative heat losses and consumption on the plant's auxiliary needs related to the steam flow passing through the PRC (by-passing the turbines)	%	According to Section B [R1] it is taken as constant	5.00
$HS_{3bypass,PJ,y}$	Actual useful steam supply from TPP-3 by-passing the turbines, via the PRC	GJ	$HS_{3bypass,PJ,y} = HS_{3,PJ,y} - HS_{3backpress,PJ,y}$	0
$HS_{3,PJ,y}$	Actual total useful heat supply from TPP-3	GJ	See Table 2	4 986 093
$HS_{3backpress,PJ,y}$	Actual useful heat supply from TPP-3 with the steam spent in the turbines	GJ	See Table 2	4 986 093
$HG_{3ub,BL,y}$	Gross steam generation in the utilizing boilers of TPP-3 under the baseline	GJ	$HG_{3ub,BL,y} = FC_{3ub,BL,y} \times \eta_{3ub,BL,y} / 100$	1 377 003
$\eta_{3ub,BL,y}$	Average efficiency factor of utilizing boilers under the baseline	%	According to Section B [R1] it is taken as constant	46.00
$\eta_{3rb,y}$	Actual average weighted efficiency factor of recovery boilers of TPP-3	%	$\eta_{3rb,y} = 100 \times HG_{3rb,PJ,y} / FC_{3rb,PJ,y}$	80.84
$HG_{3rb,PJ,y}$	Actual gross steam generation in the recovery boilers of TPP-3	GJ	See Table 2	4 870 574
$FC_{3rb,PJ,y}$	Actual total fuel consumption in the recovery boilers of TPP-3	GJ	$FC_{3rb,PJ,y} = FC_{oil,3rb,PJ,y} + FC_{liq,3rb,y}$	6 024 946
$FC_{oil,3rb,PJ,y}$	Actual consumption of fuel oil in the recovery boilers of TPP-3	GJ	$FC_{oil,3rb,PJ,y} = FC_{oil,3rb,PJ,y}^m \times NCV_{oil,y}$	1 256 678

Symbol	Name	Unit	Formula or grounds	Value
$FC_{oil,3rb,PJ,y}^m$	Actual mass consumption of fuel oil in the recovery boilers of TPP-3	t	See Table 2	31 129
$FC_{liq,3rb,y}$	Actual amount of black liquor burnt at TPP-3	GJ	$FC_{liq,3rb,y} = FC_{liq,3rb,y}^{dm} \times NCV_{liq,3rb,y}$	4 768 268
$FC_{liq,3rb,y}^{dm}$	Actual amount of absolutely dry black liquor burnt in the recovery boilers of TPP-3	t a.d.m.	See Table 2	467 936
$NCV_{liq,3rb,y}$	Actual average weighted net calorific value of black liquor at TPP-3	GJ/t a.d.m.	See Table 2	10.19
$FC_{oil,1mp,BL,y}$	Amount of fuel oil burnt in MP boilers of TPP-1 under the baseline	GJ	$FC_{oil,1mp,BL,y} = FC_{oil,1mp,PJ,y} \times \frac{FC_{BWW,1mp,BL,y}^m}{FC_{BWW,1mp,PJ,y}^m}$	835 348
$FC_{BWW,1mp,BL,y}^m$	Mass of BWW burnt in the MP boiler room of TPP-1 under the baseline	t	According to Section B [R1] implementation of the project had not influence on BWW consumption in MP boilers of TPP-1 in 2003. Thus: $FC_{BWW,1mp,BL,y}^m = FC_{BWW,1mp,PJ,y}^m$	263 637
$FC_{BWW,1mp,PJ,y}^m$	Actual mass of BWW burnt in the MP boiler room of TPP-1	t	See Table 2	263 637
$\Delta FC_{coal,y}$	Change in amount of coal burnt at TPP-1 compared to the project	GJ	$\Delta FC_{coal,y} = \frac{100 \times \Delta HG_{1hp,y}}{\eta_{coal}}$	0
η_{coal}	Average gross coal boiler efficiency factor	%	According to Section B [R1] it is taken as constant	90.00
$\Delta HG_{1hp,y}$	Change in steam generation by HP boilers of TPP-1 compared to the project	GJ	$\Delta HG_{1hp,y} = \Delta HG'_{1hp,y} \frac{100}{100 - \epsilon_{aux}}$	0
ϵ_{aux}	Relative heat losses and consumption for the auxiliary needs related to additional generation of steam in HP boilers of TPP-1	%	According to Section B [R1] it is taken as constant	5.00
$\Delta HG'_{1hp,y}$	Change in live steam delivery to the HP turbines of TPP-1 compared to the project	GJ	$\Delta HG'_{1hp,y} = 0.665 \Delta HS_{1hp,y}$	0
$\Delta HS_{1hp,y}$	Change in steam supply from the HP station of TPP-1 compared to the project	GJ	$\Delta HS_{1hp,y} = \Delta HS_{1,y} - \Delta HS_{1mp,y}$	0

Symbol	Name	Unit	Formula or grounds	Value
$\Delta HS_{1,y}$	Additional annual steam supply for cellulose production from TPP-1, with losses in steam network taken into account, compared to the project scenario	GJ	$\Delta HS_{1,y} = \Delta HS_{3,y} \frac{100}{100 - \epsilon_{nw}}$	0
ϵ_{nw}	Relative heat losses in steam network (from TPP-1 to cellulose production)	%	According to Section B [R1] it is taken as constant	3.00
$\Delta HS_{3,y}$	Useful steam supply via PRC at TPP-3 under the project scenario	GJ	$\Delta HS_{3,y} = HS_{3bypass,PJ,y}$	0
$\Delta HS_{1mp,y}$	Change in steam supply from the MP station of TPP-1 compared to the project	GJ	$\Delta HS_{1mp,y} = HS_{1mp,BL,y} - HS_{1mp,PJ,y}$	0
$HS_{1mp,BL,y}$	Useful supply of thermal power from the MP station of TPP-1 under the baseline	GJ	$HS_{1mp,BL,y} = HS_{1mp,PJ,y} \times FC_{BWW,1mp,BL,y}^m / FC_{BWW,1mp,PJ,y}^m$	1 554 220
$HS_{1mp,PJ,y}$	Useful supply of thermal power from the MP station of TPP-1 under the project	GJ	$HS_{1mp,PJ,y} = HG_{1mp,PJ,y} \times (100 - \alpha) / 100$	1 554 220
α	Relative consumption of heat of live steam for the auxiliary needs and electric power generation at the MP station of TPP-1	%	According to Section B [R1] it is taken as constant	10.00
$HG_{1mp,PJ,y}$	Actual gross steam generation in boilers of the MP station of TPP-1	GJ	See Table 2	1 726 911
$\Delta BE_{dump,y}$	Additional CH ₄ emissions from the landfill compared to the project	t CO ₂ e	$\Delta BE_{dump,y} = \Delta BE_{BWW,dump,y} + \Delta BE_{WWS,dump,y}$	0
$\Delta BE_{BWW,dump,y}$	Additional emissions of CH ₄ from the landfill because of BWW anaerobic decomposition, compared to the project	t CO ₂ e	Equal to zero for 2003 as BWW dumping is considered proportional to WWS dumping. WWS dumping is equal under baseline and project in 2003 (see also [R1] and text above).	0
$\Delta BE_{WWS,dump,y}$	Additional emissions of CH ₄ from the landfill because of WWS anaerobic decomposition, compared to the project	t CO ₂ e	Equal to zero for 2003 as WWS combustion had not place in 2003, thus WWS dumping is equal under baseline and project.	0

Table 5. Calculation of emission reductions over the year $y = 2003$

Symbol	Name	Unit	Formula or grounds	Value
ER_y	Total emission reductions	t CO₂e	$ER_y = BE_y - PE_y$ or $ER_y = ER_{CO_2,y} + ER_{CH_4,y}$	120 638
$ER_{CO_2,y}$	Emission reductions of carbon dioxide	t CO₂	$ER_{CO_2,y} = ER_{CO_2,oil,3,y} + ER_{CO_2,oil,1mp,y} + ER_{CO_2,coal,1hp,y}$	120 638
$ER_{CO_2,oil,3,y}$	Emission reductions of carbon dioxide from fuel oil combustion at TPP-3	t CO ₂	$ER_{CO_2,oil,3,y} = BE_{oil,3,y} - PE_{oil,3,y}$	120 638
$ER_{CO_2,oil,1mp,y}$	Emission reduction of carbon dioxide from fuel oil combustion at the boiler-house of medium pressure TPP-1	t CO ₂	$ER_{CO_2,oil,1mp,y} = BE_{oil,1mp,y} - PE_{oil,1mp,y}$	0
$ER_{CO_2,coal,1hp,y}$	Emission reduction of carbon dioxide from coal combustion at the boiler-house of high pressure TPP-1	t CO ₂	$ER_{CO_2,coal,1hp,y} = \Delta BE_{coal,y}$	0
$ER_{CH_4,y}$	Emission reduction of methane	t CO₂e	$ER_{CH_4,y} = ER_{CH_4,BWW,y} + ER_{CH_4,WWS,y}$	0
$ER_{CH_4,BWW,y}$	Reduction of methane emissions from the landfill because of BWW anaerobic decomposition	t CO ₂ e	$ER_{CH_4,BWW,y} = \Delta BE_{BWW,dump,y}$	0
$ER_{CH_4,WWS,y}$	Reduction of methane emissions from the landfill because of WWS anaerobic decomposition	t CO ₂ e	$ER_{CH_4,WWS,y} = \Delta BE_{WWS,dump,y}$	0

Environmental monitoring

In process of the project implementation, analytical control over various effects on the environment is exercised in compliance with the existing regulation. In particular, control over emissions of harmful substances into the atmosphere is performed according to the "Schedule of laboratory control of standard MPE at stationary emission sources of JSC Arkhangelsk PPM".

The data obtained by the analytical laboratory are processed and brought together in monthly and annual reports, which specify all the required itemized data, including those for the sections affected by the Project.

Table 6 represents calculated data for the changes in the amount of harmful substances thrown into the atmosphere under the project as compared to the baseline.

Table 6. Alterations in the harmful substance emissions into the atmosphere against the baseline over the year $y = 2003$, t; (+) - increase, (-) - decrease)

Harmful emissions	Fuel oil	Coal	BWW	WSS	Total
Fluidised substances	-3	0	144	0	141
Sulphur dioxide (SO ₂)	-1 714	0	0	0	-1 714
Nitrous dioxide (NO ₂)	-159	0	23	0	-135
Nitrous oxide (NO)	-26	0	4	0	-22
Carbon oxide (CO)	-519	0	375	0	-144
Total emissions	-2 420	0	546	0	-1 874

Emergencies

No emergencies occurred during the period under verification which could have given rise to emissions.

Conclusion

The implementation of the first stage of the project “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)” allowed preventing emissions into the atmosphere in 2003:

- **greenhouse gases – by 120 638 tons CO₂e,**
- **polluting substances – by 1 874 t.**

REFERENCES

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- [R2] Decision 9/CMP.1. Guidelines for the implementation of Article 6 of the Kyoto Protocol. FCCC/KP/CMP/2005/8/Add.2. 30 March 2006
- [R3] Inventory of greenhouse gas emissions at OJSC „Arkhangelsk PPM“ for 2003. Environmental investment centre, Arkhangelsk, 2004.

MONITORING REPORT

**JOINT STOCK COMPANY
“ARKHANGELSK PULP AND PAPER MILL”**

Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (town of Novodvinsk, Russia)

PDD REFERENCE NO: 0005

Monitoring period: 1st January 2004 – 31st December 2004

Prepared by: Environmental Investment Center (Arkhangelsk, Russia)

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Date: 26.03.2007

Introduction

The document is executed according to the developed PDD “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)” [R1]. The PDD is placed at website UNFCCC (ji.unfccc.int/JI_Projects/Verification/PDD) under reference number 0005.

The project is implemented at the territory of JSC “Arkhangelsk Pulp and Paper Mill”, town of Novodvinsk, Arkhangelsk region, Russia.

The project is aimed at increasing the share of biomass waste in the APPM fuel balance, which will allow reducing consumption of expensive and environmentally dirtier fossil fuel, as well as decrease the amount of dumped biomass waste.

With reference to the project, biomass waste is bark and wood waste (BWW) and waste water sludge (WWS). BWW includes bark, sawdust, slivers, substandard chips, as well as building waste wood, logging waste, etc. The bulk of BWW is formed at the stage of preparing pulp chips in the APPM wood-preparation shops and delivered from neighboring saw-mills, which have no their own facilities for utilization of their BWW. WWS is formed at the station of biological treatment of industrial and household waste of APPM and the town of Novodvinsk.

The project implies implementation of the following engineering solutions in two stages:

Stage I:

- Reconstruction of the obsolete and inefficient utilizing boiler KM-75-40 (St. No. 2) at TPP-3¹, with switching to BWW combustion in the fluidized bed;
- Modernization of WPS-3² with installation of advanced equipment for chopping and dewatering BWW.

Stage II:

- Replacement of an old utilizing boiler KM-75-40 (St. No. 1) at TPP-3 with a new utilizing boiler E-75-3,9-440 DFT, with biomass waste combustion in the fluidized bed;
- Assembly of a new unit for receiving and preparation BWW and WWS delivered by motor transport, to be burnt in utilizing boilers of TPP-3.

Construction and assembly operations for the first stage of the project were carried out from February to December of 2000, and for the second stage – from April of 2004 to July of 2005. According to *Decision 9/CMP.1* [R2], the project may be recognized as a joint implementation project, if its technical implementation began not earlier than in the year 2000.

Thus only the first stage of the project and the associated reductions of GHG emissions are considered for 2004.

Technology employed according to Stage I

Reconstruction of the KM-75-40 boiler St. No. 2

In 2000, Joint Venture Energosofin and OJSC Belenergomash performed reconstruction of the KM-75-40 boiler St. No. 2, with switching to the fluidized bed technology.

¹ TPP-3 – thermal power plant No. 3

² WPS-3 – wood-preparation shop No. 3

Burning of waste in the fluidized bed provides efficient, economical and environmentally safe combustion of high-humidity and low-calorie fuels. The fluidized bed is made of quartz sand by means of feeding air at a high pressure under the filling layer. The process of combustion is partly taking place in the fluidized bed, and partly – above it. The temperature of the fluidized bed is about 700-800°C and can be adjusted by air distribution.

In the nominal operating mode, the modernized KM-75-40S boiler allows burning BWW with humidity of 57%, with steam capacity equal to 66 tons per hour, without fuel oil flame stabilization. The superheated steam pressure is 4.0 MPa, its temperature being 440 °C. The boiler efficiency factor is about 85%. After the reconstruction, the hourly consumption of BWW has become twice as high, reaching 30 tons an hour.

The trials held within the second stage of the project showed that it is also possible to obtain stable and economical combustion of the BWW/WWS mixture, with the latter accounting for up to 20-25% of the weight of BWW. However WWS combustion was not practiced in 2004 yet and therefore it is not reviewed here.

WPS-3 modernization

WPS-3 modernization was performed for the purpose of improving the BWW quality in accordance with requirements set for the fuel combusted through the fluidized bed technology. The modernization was carried out in 2000, simultaneously with reconstruction of boiler St. No. 2 of TPP-3.

As a result of modernization, three independent fuel flows were replaced with a single centralized bark preparation unit equipped with a Saalasti 0912 rotor crusher and two Bark Master 1620 bark drum presses (also made by Saalasti). The equipment proved to be efficient at a number of the industry enterprises.

Modernization of WPS-3 made it possible to ensure a more homogenous breakup of BWW (pieces not larger than 75 mm) and lower their humidity down to the level of about 50%, which substantially increased the low calorific value and allowed stable combustion of BWW in boiler St. No. 2 in the fluidized bed without fuel oil flame stabilization. Besides, electric power consumption required for BWW preparation was reduced by 6-8%, due to its centralization.

On the whole, implementation of measures of the first stage enabled to make the amount of BWW burnt in boiler St. No. 2 of TPP-3 more than double, while having increased significantly the efficiency of their combustion and reduced fuel oil consumption.

Monitoring Period

The monitoring period is chosen from **1st January 2004 to 31st December 2004** (both days included).

Monitored data

Collection of all the key parameters required for greenhouse emissions to be determined, both under the project and for the baseline, is performed according to the practice established at APPM on accounting of fuel, energy, waste, and assessment of environmental impacts. Monitoring under the project requires no changes to be introduced in the existing system of accounting and collection of information. All the necessary data are determined and registered in any case.

Description of monitoring plan of all data required to calculate GHG emissions reductions is represented in Section D and Annex 3 of PDD [R1]. Table 1 and 2 below represents yearly values of project and

baseline data for 2004. It should be mentioned that it was not necessary to define some data for 2004 as WWS was not burnt and no change in biomass waste dumping occurred.³

Table 1. Values of data collected in order to monitor emissions from the project over the year $y = 2004$

ID number and symbol	Data name	Data unit	Value	Comment
1. $FC_{oil,3,PJ,y}^m$	Mass fuel oil consumption at TPP-3	t	40 927	
2. $FC_{oil,1mp,PJ,y}^m$	Mass fuel oil consumption in medium pressure boilers of TPP-1	t	13 979	
3. $NCV_{oil,y}$	Net calorific value of fuel oil	GJ/t	40.32	The weighted annual average

Table 2. Values of relevant data necessary for determining the baseline of anthropogenic emissions of greenhouse gases by sources within the project boundary over the year $y = 2004$

ID number and symbol	Data name	Data unit	Data value	Comment
4. $FC_{BWW,3ub,PJ,y}^m$	Mass BWW consumption in utilizing boilers of TPP-3	t	303 586	
5. $FC_{BWW,1mp,PJ,y}^m$	Mass BWW consumption in medium pressure boilers of TPP-1	t	178 338	
6. $BWW_{dump,PJ,y}^m$	Mass BWW removal to the landfill	t		Not necessary for 2004
7. $BWW_{side,PJ,y}^m$	Mass BWW delivery from the outside	t		Not necessary for 2004
8. $WWS_{dump,PJ,y}^m$	Wet mass WWS removal to the landfill	t		Not necessary for 2004
9. $FC_{WWS,3ub,PJ,y}^m$	Wet mass WWS consumption in utilizing boilers of TPP-3	t	0	

³ PDD shows that dumped BWW is proportional to dumped WWS to provide bearing capacity of the landfill without dependence on the project. Stipulated that WWS is not burnt volumes of dumping of both kinds of biomass waste remain the same as without the project. Due to this reason reductions of methane landfill emissions from the project equal zero in 2004.

ID number and symbol	Data name	Data unit	Data value	Comment
10. $W_{WWS,y}$	WWS humidity	%		Not necessary for 2004
11. $FC_{liq,3rb,y}^{dm}$	Dry mass black liquor consumption in recovery boilers of TPP-3	t a.d.m.	483 003	Including 5 331 t of sulfate soap
12. $FC_{oil,3rb,PJ,y}^m$	Mass fuel oil consumption in recovery boilers of TPP-3	t	40 039	
13. $NCV_{BWW,3ub,y}$	Net calorific value of BWW combusted in utilizing boilers of TPP-3	GJ/t	8.42	The weighted annual average
14. $NCV_{liq,3rb,y}$	Net calorific value of black liquor combusted in recovery boilers of TPP-3	GJ/t a.d.m.	10.47	The weighted annual average
15. $HG_{3,PJ,y}$	Total gross steam generation at TPP-3	GJ	6 768 579	
16. $HS_{3,PJ,y}$	Total useful supply of heat from TPP-3	GJ	4 971 790	
17. $HS_{3backpress,PJ,y}$	Useful supply of heat from TPP-3 with backpressure steam	GJ	4 971 790	It is equal to total useful supply because no steam supply through the PRC in 2004
18. $HG_{3rb,PJ,y}$	Gross steam generation in recovery boilers of TPP-3	GJ	5 320 442	
19. $HG_{1mp,PJ,y}$	Gross steam generation in medium pressure boilers of TPP-1	GJ	1 186 449	
20. $EF_{CO2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	91.60	Results of GHG inventory at APPM for 2004 [R3]

Calculation of emission reductions

According to formulae described in Section D [R1] calculations of project and baseline emissions have been done (see Tables 3 and 4). As shown in Section B.3 [R1] all of the leakages can be neglected. Calculation of emission reductions are presented in Table 5.

Thus, total GHG emission reductions for 2004 amounted **70 250 tCO₂e**.

Table 3. Calculation of project emissions over the year $y = 2004$

Symbol	Name	Unit	Formula or grounds	Value
PE_y	Total greenhouse gas emissions under the project	t CO ₂	$PE_y = PE_{oil,3,y} + PE_{oil,1mp,y}$	170 752
$PE_{oil,3,y}$	CO ₂ emission from burning fuel oil at TPP-3 under the project	t CO ₂	$PE_{oil,3,y} = FC_{oil,3,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	127 278
$PE_{oil,1mp,y}$	CO ₂ emission from burning fuel oil in boilers of the medium pressure station of TPP-1 under the project	t CO ₂	$PE_{oil,1mp,y} = FC_{oil,1mp,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	43 474
$FC_{oil,3,PJ,y}$	Amount of fuel oil burnt at TPP-3 under the project	GJ	$FC_{oil,3,PJ,y} = FC_{oil,3,PJ,y}^m \times NCV_{oil,y}$	1 650 177
$FC_{oil,1mp,PJ,y}$	Amount of fuel oil burnt in boilers of the medium pressure station of TPP-1 under the project	GJ	$FC_{oil,1mp,PJ,y} = FC_{oil,1mp,PJ,y}^m \times NCV_{oil,y}$	563 641
$FC_{oil,3,PJ,y}^m$	Mass of fuel oil burnt at TPP-3 under the project	t	See Table 1	40 927
$FC_{oil,1mp,PJ,y}^m$	Mass of fuel oil burnt in MP boilers of TPP-1 under the project	t	See Table 1	13 979
$NCV_{oil,y}$	Weighted average net calorific value of fuel oil	GJ/t	See Table 1	40.32
$EF_{CO_2,oil}$	Emission factor of CO ₂ from burning fuel oil	kg CO ₂ /GJ	Taken as constant according to the Inventory of GHG emissions at APPM [R3] (with the fraction of carbon oxidized taken into account)	77.13

Table 4. Calculation of baseline emissions over the year $y = 2004$

Symbol	Name	Unit	Formula or grounds	Value
BE_y	Total greenhouse gas emissions under the baseline	t CO ₂ e	$BE_y = BE_{ff,y} + \Delta BE_{dump,y}$	241 002
$BE_{ff,y}$	CO ₂ emissions from burning fossil fuel under the baseline	t CO ₂	$BE_{ff,y} = BE_{oil,3,y} + BE_{oil,1mp,y} + \Delta BE_{coal,y}$	241 002

Symbol	Name	Unit	Formula or grounds	Value
$BE_{oil,3,y}$	CO ₂ emissions from burning fuel oil at TPP-3 under the baseline	t CO ₂	$BE_{oil,3,y} = FC_{oil,3,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	210 980
$BE_{oil,1mp,y}$	CO ₂ emissions from burning fuel oil in boilers of the MP station of TPP-1 under the baseline	t CO ₂	$BE_{oil,1mp,y} = FC_{oil,1mp,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	61 412
$\Delta BE_{coal,y}$	Change in CO ₂ emissions from burning coal in boilers of the HP station of TPP-1 compared to the project	t CO ₂	$\Delta BE_{coal,y} = \Delta FC_{coal,y} \times EF_{CO_2,coal,y} \times 10^{-3}$	-31 390
$EF_{CO_2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	See Table 2	91.60
$FC_{oil,3,BL,y}$	Amount of fuel oil burnt at TPP-3 under the baseline	GJ	$FC_{oil,3,BL,y} = FC_{oil,3ub,BL,y} + FC_{oil,3rb,BL,y}$	2 735 382
$FC_{oil,3ub,BL,y}$	Amount of fuel oil burnt in utilizing boilers of TPP-3 under the baseline	GJ	$FC_{oil,3ub,BL,y} = FC_{3ub,BL,y} - FC_{BWW,3ub,BL,y}$	997 642
$FC_{oil,3rb,BL,y}$	Amount of fuel oil burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{oil,3rb,BL,y} = FC_{3rb,BL,y} - FC_{liq,3rb,y}$	1 737 740
$FC_{3ub,BL,y}$	Total amount of fuel burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{3ub,BL,y} = \frac{100 \times FC_{BWW,3ub,BL,y}}{100 - \beta_{oil,3ub,BL}}$	2 934 242
$\beta_{oil,3ub,BL}$	Share of fuel oil in total consumption of equivalent fuel in the utilizing boilers of TPP-3 under the baseline	%	According to Section B [R1] it is taken as constant	34.00
$FC_{BWW,3ub,BL,y}$	Amount of BWW burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{BWW,3ub,BL,y} = FC_{BWW,3ub,BL,y}^m \times NCV_{BWW,3ub,y}$	1 936 600
$FC_{BWW,3ub,BL,y}^m$	Mass of BWW burnt in the utilizing boilers of TPP-3 under the baseline	t	According to Section B [R1] it is taken as constant	230 000
$NCV_{BWW,3ub,y}$	Actual average weighted net calorific value of BWW at TPP-3	GJ/t	See Table 2	8.42
$FC_{3rb,BL,y}$	Total amount of fuel burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{3rb,BL,y} = \frac{100 \times HG_{3rb,BL,y}}{\eta_{3rb,y}}$	6 794 781

Symbol	Name	Unit	Formula or grounds	Value
$HG_{3rb,BL,y}$	Gross steam generation in the recovery boilers of TPP-3 under the baseline	GJ	$HG_{3rb,BL,y} = HG_{3,BL,y} - HG_{3ub,BL,y}$	5 418 827
$HG_{3,BL,y}$	Total gross steam generation at TPP-3 under the baseline	GJ	$HG_{3,BL,y} = HG_{3,PJ,y} - \frac{100 \times HS_{3bypass,PJ,y}}{(100 - \varepsilon_{3bypass})}$	6 768 579
$HG_{3,PJ,y}$	Total actual gross steam generation at TPP-3	GJ	See Table 2	6 768 579
$\varepsilon_{3bypass}$	Relative heat losses and consumption on the plant's auxiliary needs related to the steam flow passing through the PRC (by-passing the turbines)	%	According to Section B [R1] it is taken as constant	5.00
$HS_{3bypass,PJ,y}$	Actual useful steam supply from TPP-3 by-passing the turbines, via the PRC	GJ	$HS_{3bypass,PJ,y} = HS_{3,PJ,y} - HS_{3backpress,PJ,y}$	0
$HS_{3,PJ,y}$	Actual total useful heat supply from TPP-3	GJ	See Table 2	4 971 790
$HS_{3backpress,PJ,y}$	Actual useful heat supply from TPP-3 with the steam spent in the turbines	GJ	See Table 2	4 971 790
$HG_{3ub,BL,y}$	Gross steam generation in the utilizing boilers of TPP-3 under the baseline	GJ	$HG_{3ub,BL,y} = FC_{3ub,BL,y} \times \eta_{3ub,BL,y} / 100$	1 349 752
$\eta_{3ub,BL,y}$	Average efficiency factor of utilizing boilers under the baseline	%	According to Section B [R1] it is taken as constant	46.00
$\eta_{3rb,y}$	Actual average weighted efficiency factor of recovery boilers of TPP-3	%	$\eta_{3rb,y} = 100 \times HG_{3rb,PJ,y} / FC_{3rb,PJ,y}$	79.75
$HG_{3rb,PJ,y}$	Actual gross steam generation in the recovery boilers of TPP-3	GJ	See Table 2	5 320 442
$FC_{3rb,PJ,y}$	Actual total fuel consumption in the recovery boilers of TPP-3	GJ	$FC_{3rb,PJ,y} = FC_{oil,3rb,PJ,y} + FC_{liq,3rb,y}$	6 671 414
$FC_{oil,3rb,PJ,y}$	Actual consumption of fuel oil in the recovery boilers of TPP-3	GJ	$FC_{oil,3rb,PJ,y} = FC_{oil,3rb,PJ,y}^m \times NCV_{oil,y}$	1 614 372

Symbol	Name	Unit	Formula or grounds	Value
$FC_{oil,3rb,PJ,y}^m$	Actual mass consumption of fuel oil in the recovery boilers of TPP-3	t	See Table 2	40 039
$FC_{liq,3rb,y}$	Actual amount of black liquor burnt at TPP-3	GJ	$FC_{liq,3rb,y} = FC_{liq,3rb,y}^{dm} \times NCV_{liq,3rb,y}$	5 057 041
$FC_{liq,3rb,y}^{dm}$	Actual amount of absolutely dry black liquor burnt in the recovery boilers of TPP-3	t a.d.m.	See Table 2	483 003
$NCV_{liq,3rb,y}$	Actual average weighted net calorific value of black liquor at TPP-3	GJ/t a.d.m.	See Table 2	10.47
$FC_{oil,1mp,BL,y}$	Amount of fuel oil burnt in MP boilers of TPP-1 under the baseline	GJ	$FC_{oil,1mp,BL,y} = FC_{oil,1mp,PJ,y} \times \frac{FC_{BWW,1mp,BL,y}^m}{FC_{BWW,1mp,PJ,y}^m}$	796 211
$FC_{BWW,1mp,BL,y}^m$	Mass of BWW burnt in the MP boiler room of TPP-1 under the baseline	t	Taking into account explanations for 2004 in Section B [R1] : $FC_{BWW,1mp,BL,y}^m = FC_{BWW,1mp,PJ,y}^m + (FC_{BWW,3ub,PJ,y}^m - FC_{BWW,3ub,BL,y}^m)$	251 924
$FC_{BWW,3ub,PJ,y}^m$	Actual mass BWW consumption in utilizing boilers of TPP-3	t	See Table 2	303 586
$FC_{BWW,1mp,PJ,y}^m$	Actual mass of BWW burnt in the MP boiler room of TPP-1	t	See Table 2	178 338
$\Delta FC_{coal,y}$	Change in amount of coal burnt at TPP-1 compared to the project	GJ	$\Delta FC_{coal,y} = \frac{100 \times \Delta HG_{1hp,y}}{\eta_{coal}}$	-342 687
η_{coal}	Average gross coal boiler efficiency factor	%	According to Section B [R1] it is taken as constant	90.00
$\Delta HG_{1hp,y}$	Change in steam generation by HP boilers of TPP-1 compared to the project	GJ	$\Delta HG_{1hp,y} = \Delta HG'_{1hp,y} \frac{100}{100 - \varepsilon_{aux}}$	-308 418
ε_{aux}	Relative heat losses and consumption for the auxiliary needs related to additional generation of steam in HP boilers of TPP-1	%	According to Section B [R1] it is taken as constant	5.00

Symbol	Name	Unit	Formula or grounds	Value
$\Delta HG'_{1hp,y}$	Change in live steam delivery to the HP turbines of TPP-1 compared to the project	GJ	$\Delta HG'_{1hp,y} = 0.665 \Delta HS_{1hp,y}$	-292 998
$\Delta HS_{1hp,y}$	Change in steam supply from the HP station of TPP-1 compared to the project	GJ	$\Delta HS_{1hp,y} = \Delta HS_{1,y} - \Delta HS_{1mp,y}$	-440 598
$\Delta HS_{1,y}$	Additional annual steam supply for cellulose production from TPP-1, with losses in steam network taken into account, compared to the project scenario	GJ	$\Delta HS_{1,y} = \Delta HS_{3,y} \frac{100}{100 - \epsilon_{nw}}$	0
ϵ_{nw}	Relative heat losses in steam network (from TPP-1 to cellulose production)	%	According to Section B [R1] it is taken as constant	3.00
$\Delta HS_{3,y}$	Useful steam supply via PRC at TPP-3 under the project scenario	GJ	$\Delta HS_{3,y} = HS_{3bypass,PJ,y}$	0
$\Delta HS_{1mp,y}$	Change in steam supply from the MP station of TPP-1 compared to the project	GJ	$\Delta HS_{1mp,y} = HS_{1mp,BL,y} - HS_{1mp,PJ,y}$	440 598
$HS_{1mp,BL,y}$	Useful supply of thermal power from the MP station of TPP-1 under the baseline	GJ	$HS_{1mp,BL,y} = HS_{1mp,PJ,y} \times FC_{BWW,1mp,BL,y}^m / FC_{BWW,1mp,PJ,y}^m$	1 508 402
$HS_{1mp,PJ,y}$	Useful supply of thermal power from the MP station of TPP-1 under the project	GJ	$HS_{1mp,PJ,y} = HG_{1mp,PJ,y} \times (100 - \alpha) / 100$	1 067 804
α	Relative consumption of heat of live steam for the auxiliary needs and electric power generation at the MP station of TPP-1	%	According to Section B [R1] it is taken as constant	10.00
$HG_{1mp,PJ,y}$	Actual gross steam generation in boilers of the MP station of TPP-1	GJ	See Table 2	1 186 449
$\Delta BE_{dump,y}$	Additional CH ₄ emissions from the landfill compared to the project	t CO ₂ e	$\Delta BE_{dump,y} = \Delta BE_{BWW,dump,y} + \Delta BE_{WWS,dump,y}$	0

Symbol	Name	Unit	Formula or grounds	Value
$\Delta BE_{BWW,dump,y}$	Additional emissions of CH ₄ from the landfill because of BWW anaerobic decomposition, compared to the project	t CO ₂ e	Equal to zero for 2004 as BWW dumping is considered proportional to WWS dumping. WWS dumping is equal under baseline and project in 2004 (see also [R1] and text above).	0
$\Delta BE_{WWS,dump,y}$	Additional emissions of CH ₄ from the landfill because of WWS anaerobic decomposition, compared to the project	t CO ₂ e	Equal to zero for 2004 as WWS combustion had not place in 2004, thus WWS dumping is equal under baseline and project.	0

Table 5. Calculation of emission reductions over the year y = 2004

Symbol	Name	Unit	Formula or grounds	Value
ER_y	Total emission reductions	t CO₂e	$ER_y = BE_y - PE_y$ or $ER_y = ER_{CO_2,y} + ER_{CH_4,y}$	70 250
$ER_{CO_2,y}$	Emission reductions of carbon dioxide	t CO₂	$ER_{CO_2,y} = ER_{CO_2,oil,3,y} + ER_{CO_2,oil,1mp,y} + ER_{CO_2,coal,1hp,y}$	70 250
$ER_{CO_2,oil,3,y}$	Emission reductions of carbon dioxide from fuel oil combustion at TPP-3	t CO ₂	$ER_{CO_2,oil,3,y} = BE_{oil,3,y} - PE_{oil,3,y}$	83 702
$ER_{CO_2,oil,1mp,y}$	Emission reduction of carbon dioxide from fuel oil combustion at the boiler-house of medium pressure TPP-1	t CO ₂	$ER_{CO_2,oil,1mp,y} = BE_{oil,1mp,y} - PE_{oil,1mp,y}$	17 938
$ER_{CO_2,coal,1hp,y}$	Emission reduction of carbon dioxide from coal combustion at the boiler-house of high pressure TPP-1	t CO ₂	$ER_{CO_2,coal,1hp,y} = \Delta BE_{coal,y}$	-31 390
$ER_{CH_4,y}$	Emission reduction of methane	t CO₂e	$ER_{CH_4,y} = ER_{CH_4,BWW,y} + ER_{CH_4,WWS,y}$	0
$ER_{CH_4,BWW,y}$	Reduction of methane emissions from the landfill because of BWW anaerobic decomposition	t CO ₂ e	$ER_{CH_4,BWW,y} = \Delta BE_{BWW,dump,y}$	0
$ER_{CH_4,WWS,y}$	Reduction of methane emissions from the landfill because of WWS anaerobic decomposition	t CO ₂ e	$ER_{CH_4,WWS,y} = \Delta BE_{WWS,dump,y}$	0

Environmental monitoring

In process of the project implementation, analytical control over various effects on the environment is exercised in compliance with the existing regulation. In particular, control over emissions of harmful substances into the atmosphere is performed according to the “Schedule of laboratory control of standard MPE at stationary emission sources of JSC Arkhangelsk PPM”.

The data obtained by the analytical laboratory are processed and brought together in monthly and annual reports, which specify all the required itemized data, including those for the sections affected by the Project.

Table 6 represents calculated data for the changes in the amount of harmful substances thrown into the atmosphere under the project as compared to the baseline.

Table 6. Alterations in the harmful substance emissions into the atmosphere against the baseline over the year $y = 2004$, t; (+) - increase, (-) - decrease)

Harmful emissions	Fuel oil	Coal	BWW	WSS	Total
Fluidised substances	-2	150	28	0	176
Sulphur dioxide (SO ₂)	-1 440	270	0	0	-1 170
Nitrous dioxide (NO ₂)	-133	59	5	0	-70
Nitrous oxide (NO)	-22	10	1	0	-11
Carbon oxide (CO)	-436	67	74	0	-295
Total emissions	-2 033	555	108	0	-1 370

Emergencies

No emergencies occurred during the period under verification which could have given rise to emissions.

However, it should be noted that emission reductions in 2004 are less than in 2003 because the old utilizing boiler KM-75-40 (St. No. 1) at TPP-3 has been decommissioned and construction and assembly operations for the second stage of the project started in 2004.

Conclusion

The implementation of the first stage of the project “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)” allowed preventing emissions into the atmosphere in 2004:

- **greenhouse gases – by 70 250 tons CO₂e,**
- **polluting substances – by 1 370 t.**

REFERENCES

- [R1] Joint implementation project design document. “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)”. Version 1.0. 2006.
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- [R2] Decision 9/CMP.1. Guidelines for the implementation of Article 6 of the Kyoto Protocol. FCCC/KP/CMP/2005/8/Add.2. 30 March 2006
- [R3] Inventory of greenhouse gas emissions at OJSC „Arkhangelsk PPM“ for 2004. Environmental investment centre, Arkhangelsk, 2005.

MONITORING REPORT

**JOINT STOCK COMPANY
“ARKHANGELSK PULP AND PAPER MILL”**

Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (town of Novodvinsk, Russia)

PDD REFERENCE NO: 0005

Monitoring period: **1st January 2005 – 31st December 2005**

Prepared by: Environmental Investment Center (Arkhangelsk, Russia)

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Date: 26.03.2007

Introduction

The document is executed according to the developed PDD “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)” [R1]. The PDD is placed at website UNFCCC (ji.unfccc.int/JI_Projects/Verification/PDD) under reference number 0005.

The project is implemented at the territory of JSC “Arkhangelsk Pulp and Paper Mill”, town of Novodvinsk, Arkhangelsk region, Russia.

The project is aimed at increasing the share of biomass waste in the APPM fuel balance, which will allow reducing consumption of expensive and environmentally dirtier fossil fuel, as well as decrease the amount of dumped biomass waste.

With reference to the project, biomass waste is bark and wood waste (BWW) and waste water sludge (WWS). BWW includes bark, sawdust, slivers, substandard chips, as well as building waste wood, logging waste, etc. The bulk of BWW is formed at the stage of preparing pulp chips in the APPM wood-preparation shops and delivered from neighboring saw-mills, which have no their own facilities for utilization of their BWW. WWS is formed at the station of biological treatment of industrial and household waste of APPM and the town of Novodvinsk.

The project implies implementation of the following engineering solutions in two stages:

Stage I:

- Reconstruction of the obsolete and inefficient utilizing boiler KM-75-40 (St. No. 2) at TPP-3¹, with switching to BWW combustion in the fluidized bed;
- Modernization of WPS-3² with installation of advanced equipment for chopping and dewatering BWW.

Stage II:

- Replacement of an old utilizing boiler KM-75-40 (St. No. 1) at TPP-3 with a new utilizing boiler E-75-3,9-440 DFT, with biomass waste combustion in the fluidized bed;
- Assembly of a new unit for receiving and preparation BWW and WWS delivered by motor transport, to be burnt in utilizing boilers of TPP-3.

Construction and assembly operations for the first stage of the project were carried out from February to December of 2000, and for the second stage – from April of 2004 to July of 2005. According to *Decision 9/CMP.1* [R2], the project may be recognized as a joint implementation project, if its technical implementation began not earlier than in the year 2000.

Technology employed

Stage I:

Reconstruction of the KM-75-40 boiler St. No. 2

In 2000, Joint Venture Energosofin and OJSC Belenergomash performed reconstruction of the KM-75-40 boiler St. No. 2, with switching to the fluidized bed technology.

¹ TPP-3 – thermal power plant No. 3

² WPS-3 – wood-preparation shop No. 3

Burning of waste in the fluidized bed provides efficient, economical and environmentally safe combustion of high-humidity and low-calorie fuels. The fluidized bed is made of quartz sand by means of feeding air at a high pressure under the filling layer. The process of combustion is partly taking place in the fluidized bed, and partly – above it. The temperature of the fluidized bed is about 700-800°C and can be adjusted by air distribution.

In the nominal operating mode, the modernized KM-75-40S boiler allows burning BWW with humidity of 57%, with steam capacity equal to 66 tons per hour, without fuel oil flame stabilization. The superheated steam pressure is 4.0 MPa, its temperature being 440 °C. The boiler efficiency factor is about 85%. After the reconstruction, the hourly consumption of BWW has become twice as high, reaching 30 tons an hour.

The trials held within the second stage of the project showed that it is also possible to obtain stable and economical combustion of the BWW/WWS mixture, with the latter accounting for up to 20-25% of the weight of BWW.

WPS-3 modernization

WPS-3 modernization was performed for the purpose of improving the BWW quality in accordance with requirements set for the fuel combusted through the fluidized bed technology. The modernization was carried out in 2000, simultaneously with reconstruction of boiler St. No. 2 of TPP-3.

As a result of modernization, three independent fuel flows were replaced with a single centralized bark preparation unit equipped with a Saalasti 0912 rotor crusher and two Bark Master 1620 bark drum presses (also made by Saalasti). The equipment proved to be efficient at a number of the industry enterprises.

Modernization of WPS-3 made it possible to ensure a more homogenous breakup of BWW (pieces not larger than 75 mm) and lower their humidity down to the level of about 50%, which substantially increased the low calorific value and allowed stable combustion of BWW in boiler St. No. 2 in the fluidized bed without fuel oil flame stabilization. Besides, electric power consumption required for BWW preparation was reduced by 6-8%, due to its centralization.

On the whole, implementation of measures of the first stage enabled to make the amount of BWW burnt in boiler St. No. 2 of TPP-3 more than double, while having increased significantly the efficiency of their combustion and reduced fuel oil consumption.

Stage II:

Installation of a new E-75-3.9-440 DFT boiler

Inefficient operation of the KM-75-40 St. No. 1 boiler unit used for burning BWW determined the necessity to install quite a new boiler – E-75-3.9-440DFT with the fluidized bed. Works on replacement of boiler St. No. 1 were held from April 2004 to July 2005. ZAO Arkhgirobum was the project developer, with AMU Sevzapenergomontazh as the general contractor.

Boiler E-75-3.9-440DFT is a single-drum boiler with natural circulation. The boiler is equipped with the HYBEX fluidized bed grate developed and patented by Kvaerner. The rated steam capacity is 75 t/hr without fuel oil flame stabilization. The pressure of superheated steam is 4.0 MPa, its temperature being 440 °C. The furnace efficiency factor is about 92%.

The main fuel was constituted by a mixture of bark, waste wood and waste water sludge. Operating the boiler allows increasing the WWS delivery to 10 t/hr, with the boiler steam capacity reduced, accordingly. The fuel must come into the boiler well-mixed, homogenous, with the average humidity of the BWW/WWS mixture not exceeding 63%. No dimension of the BWW fragments should be more than 100 mm. Fuel oil M100 is used as starting fuel.

Low content of oxygen in smoke fumes at combustion in the fluidized bed and the absence of unburnt particles is achieved owing to efficient mixing in the fluidized bed, and air distribution among the blasting zones, which ensures the boiler's high efficiency factor.

The tests of the boiler, which took place in 2005, showed that it is possible to achieve stable and economical combustion of the BWW/WWS mixture, with the latter being 20-25% of the BWW weight.

Assembly of a new unit for receiving and preparation of motor delivered BWW and WWS

To provide the utilizing boilers of TPP-3 with sufficient amount of biofuel, a unit for receiving and preparation of BWW delivered by motor transport, was assembled at WPS-3, with a section for receiving WWS from the mill's treatment facilities. The design of the receiving unit was developed as an addition to the project of installation of boiler unit E-75-3.9-440DFT.

The flow chart of the unit for receiving and processing of delivered waste includes:

- unit for receiving BWW from motor transport, with an unloading platform;
- unit for crushing large BWW;
- sorting unit;
- unit for receiving WWS;
- track of feeding waste to the utilizing boiler room of TPP-3.

The unit for receiving BWW comprises a 50 m³ hopper equipped with two worm dischargers supplied by Raumaster Oy, with capacity up to 250 packed m³/hr, and provides for receiving BWW from chip trucks.

The crushing unit is equipped with a hydraulic Crush Master RWC-2-600 rotor crusher with capacity of 5 to 50 packed m³/hr. Large waste is fed to the crusher with a manipulator, and the screenings are transferred by a belt conveyor. The crushing unit equipment is supplied by Raumaster Oy.

Delivery of bark from the receiving unit, and delivery of ground wood from the crushing unit to sorting is to be carried out with a 1000 mm belt conveyor. To remove metal objects out of the waste wood flow, a PS-120M iron separator is to be installed.

The sorting unit is equipped with a disk sorter supplied by LLC Soyuzlesmontazh (Vologda).

The processing chart of the unit for receiving WWS looks as follows. WWS is delivered from filter-presses of the biological treatment station by dump-trucks. WWS consumption is 4 to 20 wet t/hr. The sludge is unloaded into the receiving hopper, its lower part equipped with four dosing worms. At the output of the dosing worms, there is a slanting worm conveyor for delivering sludge to belt conveyor with a weigher for ensuring the BWW/WWS ratio within the range from 8/1 to 4/1, respectively. The worms of the receiving hopper are equipped with geared motors enabling variation of rotating speed, thus adjusting the amount of the fed WWS.

The BWW/WWS mixture comes to the buffer storage with self-propelled worm unloaders, and then goes through the belt weigher and is distributed to receiving hoppers of the TPP-3 utilizing boilers.

The designed capacity of the BWW-feeding truck at TPP-3 was increased up to 750 thousand dense m³/year, including up to 450 thousand dense m³ of motor delivered BWW (here, the delivered waste also include the waste delivered by motor transport within the mill – from WPS-2 and WPS-4). Besides, it has become possible to utilize about 100 thousand tons of wet WWS per year.

Implementation of the second stage measures made it possible to increase radically the amount of burnt BWW at TPP-3, to increase steam output, to ensure receiving and preparation for combustion of a higher BWW amount of heterogenous breakup, to ensure receiving and combustion of WWS. All that has eventually allowed for fossil fuel consumption, amount of dumped waste and GHG emissions to be reduced.

Monitoring period

The monitoring period is chosen from **1st January 2005 to 31st December 2005** (both days included).

Monitored data

Collection of all the key parameters required for greenhouse emissions to be determined, both under the project and for the baseline, is performed according to the practice established at APPM on accounting of fuel, energy, waste, and assessment of environmental impacts. Monitoring under the project requires no changes to be introduced in the existing system of accounting and collection of information. All the necessary data are determined and registered in any case.

Description of monitoring plan of all data required to calculate GHG emissions reductions is represented in Section D and Annex 3 of PDD [R1]. Table 1 and 2 below represents yearly values of project and baseline data for 2005.

Table 1. Values of data collected in order to monitor emissions from the project over the year $y = 2005$

ID number and symbol	Data name	Data unit	Value	Comment
1. $FC_{oil,3,PJ,y}^m$	Mass fuel oil consumption at TPP-3	t	29 983	
2. $FC_{oil,1mp,PJ,y}^m$	Mass fuel oil consumption in medium pressure boilers of TPP-1	t	13 132	
3. $NCV_{oil,y}$	Net calorific value of fuel oil	GJ/t	40.28	The weighted annual average

Table 2. Values of relevant data necessary for determining the baseline of anthropogenic emissions of greenhouse gases by sources within the project boundary over the year $y = 2005$

ID number and symbol	Data name	Data unit	Data value	Comment
4. $FC_{BWW,3ub,PJ,y}^m$	Mass BWW consumption in utilizing boilers of TPP-3	t	282 560	
5. $FC_{BWW,1mp,PJ,y}^m$	Mass BWW consumption in medium pressure boilers of TPP-1	t	190 669	
6. $BWW_{dump,PJ,y}^m$	Mass BWW removal to the landfill	t	174 868	
7. $BWW_{side,PJ,y}^m$	Mass BWW delivery from the outside	t		Not necessary for 2005

ID number and symbol	Data name	Data unit	Data value	Comment
8. $WWS_{dump,PJ,y}^m$	Wet mass WWS removal to the landfill	t	236 409	
9. $FC_{WWS,3ub,PJ,y}^m$	Wet mass WWS consumption in utilizing boilers of TPP-3	t	23 504	
10. $W_{WWS,y}$	WWS humidity	%	76.34	The weighted annual average
11. $FC_{liq,3rb,y}^{dm}$	Dry mass black liquor consumption in recovery boilers of TPP-3	t a.d.m.	492 087	
12. $FC_{oil,3rb,PJ,y}^m$	Mass fuel oil consumption in recovery boilers of TPP-3	t	29 833	
13. $NCV_{BWV,3ub,y}$	Net calorific value of BWV combusted in utilizing boilers of TPP-3	GJ/t	8.83	The weighted annual average
14. $NCV_{liq,3rb,y}$	Net calorific value of black liquor combusted in recovery boilers of TPP-3	GJ/t a.d.m.	10.28	The weighted annual average
15. $HG_{3,PJ,y}$	Total gross steam generation at TPP-3	GJ	6 767 272	
16. $HS_{3,PJ,y}$	Total useful supply of heat from TPP-3	GJ	5 097 036	
17. $HS_{3backpress,PJ,y}$	Useful supply of heat from TPP-3 with backpressure steam	GJ	5 097 036	It is equal to total useful supply because no steam supply through the PRC in 2005
18. $HG_{3rb,PJ,y}$	Gross steam generation in recovery boilers of TPP-3	GJ	5 246 738	
19. $HG_{1mp,PJ,y}$	Gross steam generation in medium pressure boilers of TPP-1	GJ	1 210 047	
20. $EF_{CO2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	91.78	Results of GHG inventory at APPM for 2005 [R3]

Calculation of emission reductions

According to formulae described in Section D [R1] and with help of the tool [R4] calculations of project and baseline emissions have been done (see Tables 3...6). As shown in Section B.3 [R1] all of the leakages can be neglected.

Calculation of emission reductions are presented in Table 7.

Thus, total GHG emission reductions for 2005 amounted **84 514 tCO₂e**.

Table 3. Calculation of project emissions over the year $y = 2005$

Symbol	Name	Unit	Formula or grounds	Value
PE_y	Total greenhouse gas emissions under the project	t CO ₂	$PE_y = PE_{oil,3,y} + PE_{oil,1mp,y}$	133 948
$PE_{oil,3,y}$	CO ₂ emission from burning fuel oil at TPP-3 under the project	t CO ₂	$PE_{oil,3,y} = FC_{oil,3,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	93 151
$PE_{oil,1mp,y}$	CO ₂ emission from burning fuel oil in boilers of the medium pressure station of TPP-1 under the project	t CO ₂	$PE_{oil,1mp,y} = FC_{oil,1mp,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	40 797
$FC_{oil,3,PJ,y}$	Amount of fuel oil burnt at TPP-3 under the project	GJ	$FC_{oil,3,PJ,y} = FC_{oil,3,PJ,y}^m \times NCV_{oil,y}$	1 207 715
$FC_{oil,1mp,PJ,y}$	Amount of fuel oil burnt in boilers of the medium pressure station of TPP-1 under the project	GJ	$FC_{oil,1mp,PJ,y} = FC_{oil,1mp,PJ,y}^m \times NCV_{oil,y}$	528 941
$FC_{oil,3,PJ,y}^m$	Mass of fuel oil burnt at TPP-3 under the project	t	See Table 1	29 983
$FC_{oil,1mp,PJ,y}^m$	Mass of fuel oil burnt in MP boilers of TPP-1 under the project	t	See Table 1	13 132
$NCV_{oil,y}$	Weighted average net calorific value of fuel oil	GJ/t	See Table 1	40.28
$EF_{CO_2,oil}$	Emission factor of CO ₂ from burning fuel oil	kg CO ₂ /GJ	Taken as constant according to the Inventory of GHG emissions at APPM [R3] (with the fraction of carbon oxidized taken into account)	77.13

Table 4. Calculation of baseline emissions over the year $y = 2005$

Symbol	Name	Unit	Formula or grounds	Value
BE_y	Total greenhouse gas emissions under the baseline	t CO ₂ e	$BE_y = BE_{ff,y} + \Delta BE_{dump,y}$	218 462
$BE_{ff,y}$	CO ₂ emissions from burning fossil fuel under the baseline	t CO ₂	$BE_{ff,y} = BE_{oil,3,y} + BE_{oil,1mp,y} + \Delta BE_{coal,y}$	217 031
$BE_{oil,3,y}$	CO ₂ emissions from burning fuel oil at TPP-3 under the baseline	t CO ₂	$BE_{oil,3,y} = FC_{oil,3,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	183 049
$BE_{oil,1mp,y}$	CO ₂ emissions from burning fuel oil in boilers of the MP station of TPP-1 under the baseline	t CO ₂	$BE_{oil,1mp,y} = FC_{oil,1mp,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	48 323
$\Delta BE_{coal,y}$	Change in CO ₂ emissions from burning coal in boilers of the HP station of TPP-1 compared to the project	t CO ₂	$\Delta BE_{coal,y} = \Delta FC_{coal,y} \times EF_{CO_2,coal,y} \times 10^{-3}$	-14 341
$EF_{CO_2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	See Table 2	91.78
$FC_{oil,3,BL,y}$	Amount of fuel oil burnt at TPP-3 under the baseline	GJ	$FC_{oil,3,BL,y} = FC_{oil,3ub,BL,y} + FC_{oil,3rb,BL,y}$	2 373 249
$FC_{oil,3ub,BL,y}$	Amount of fuel oil burnt in utilizing boilers of TPP-3 under the baseline	GJ	$FC_{oil,3ub,BL,y} = FC_{3ub,BL,y} - FC_{BWW,3ub,BL,y}$	1 046 221
$FC_{oil,3rb,BL,y}$	Amount of fuel oil burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{oil,3rb,BL,y} = FC_{3rb,BL,y} - FC_{liq,3rb,y}$	1 327 027
$FC_{3ub,BL,y}$	Total amount of fuel burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{3ub,BL,y} = \frac{100 \times FC_{BWW,3ub,BL,y}}{100 - \beta_{oil,3ub,BL}}$	3 077 121
$\beta_{oil,3ub,BL}$	Share of fuel oil in total consumption of equivalent fuel in the utilizing boilers of TPP-3 under the baseline	%	According to Section B [R1] it is taken as constant	34.00
$FC_{BWW,3ub,BL,y}$	Amount of BWW burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{BWW,3ub,BL,y} = FC_{BWW,3ub,BL,y}^m \times NCV_{BWW,3ub,y}$	2 030 900
$FC_{BWW,3ub,BL,y}^m$	Mass of BWW burnt in the utilizing boilers of TPP-3 under the baseline	t	According to Section B [R1] it is taken as constant	230 000

Symbol	Name	Unit	Formula or grounds	Value
$NCV_{BWW,3ub,y}$	Actual average weighted net calorific value of BWW at TPP-3	GJ/t	See Table 2	8.83
$FC_{3rb,BL,y}$	Total amount of fuel burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{3rb,BL,y} = \frac{100 \times HG_{3rb,BL,y}}{\eta_{3rb,y}}$	6 385 682
$HG_{3rb,BL,y}$	Gross steam generation in the recovery boilers of TPP-3 under the baseline	GJ	$HG_{3rb,BL,y} = HG_{3,BL,y} - HG_{3ub,BL,y}$	5 351 796
$HG_{3,BL,y}$	Total gross steam generation at TPP-3 under the baseline	GJ	$HG_{3,BL,y} = HG_{3,PJ,y} - \frac{100 \times HS_{3bypass,PJ,y}}{(100 - \varepsilon_{3bypass})}$	6 767 272
$HG_{3,PJ,y}$	Total actual gross steam generation at TPP-3	GJ	See Table 2	6 767 272
$\varepsilon_{3bypass}$	Relative heat losses and consumption on the plant's auxiliary needs related to the steam flow passing through the PRC (by-passing the turbines)	%	According to Section B [R1] it is taken as constant	5.00
$HS_{3bypass,PJ,y}$	Actual useful steam supply from TPP-3 by-passing the turbines, via the PRC	GJ	$HS_{3bypass,PJ,y} = HS_{3,PJ,y} - HS_{3backpress,PJ,y}$	0
$HS_{3,PJ,y}$	Actual total useful heat supply from TPP-3	GJ	See Table 2	5 097 036
$HS_{3backpress,PJ,y}$	Actual useful heat supply from TPP-3 with the steam spent in the turbines	GJ	See Table 2	5 097 036
$HG_{3ub,BL,y}$	Gross steam generation in the utilizing boilers of TPP-3 under the baseline	GJ	$HG_{3ub,BL,y} = FC_{3ub,BL,y} \times \eta_{3ub,BL,y} / 100$	1 415 476
$\eta_{3ub,BL,y}$	Average efficiency factor of utilizing boilers under the baseline	%	According to Section B [R1] it is taken as constant	46.00
$\eta_{3rb,y}$	Actual average weighted efficiency factor of recovery boilers of TPP-3	%	$\eta_{3rb,y} = 100 \times HG_{3rb,PJ,y} / FC_{3rb,PJ,y}$	83.81
$HG_{3rb,PJ,y}$	Actual gross steam generation in the recovery boilers of TPP-3	GJ	See Table 2	5 246 738

Symbol	Name	Unit	Formula or grounds	Value
$FC_{3rb,PJ,y}$	Actual total fuel consumption in the recovery boilers of TPP-3	GJ	$FC_{3rb,PJ,y} = FC_{oil,3rb,PJ,y} + FC_{liq,3rb,y}$	6 260 328
$FC_{oil,3rb,PJ,y}$	Actual consumption of fuel oil in the recovery boilers of TPP-3	GJ	$FC_{oil,3rb,PJ,y} = FC_{oil,3rb,PJ,y}^m \times NCV_{oil,y}$	1 201 673
$FC_{oil,3rb,PJ,y}^m$	Actual mass consumption of fuel oil in the recovery boilers of TPP-3	t	See Table 2	29 833
$FC_{liq,3rb,y}$	Actual amount of black liquor burnt at TPP-3	GJ	$FC_{liq,3rb,y} = FC_{liq,3rb,y}^{dm} \times NCV_{liq,3rb,y}$	5 058 654
$FC_{liq,3rb,y}^{dm}$	Actual amount of absolutely dry black liquor burnt in the recovery boilers of TPP-3	t a.d.m.	See Table 2	492 087
$NCV_{liq,3rb,y}$	Actual average weighted net calorific value of black liquor at TPP-3	GJ/t a.d.m.	See Table 2	10.28
$FC_{oil,1mp,BL,y}$	Amount of fuel oil burnt in MP boilers of TPP-1 under the baseline	GJ	$FC_{oil,1mp,BL,y} = FC_{oil,1mp,PJ,y} \times \frac{FC_{BWW,1mp,BL,y}^m}{FC_{BWW,1mp,PJ,y}^m}$	626 518
$FC_{BWW,1mp,BL,y}^m$	Mass of BWW burnt in the MP boiler room of TPP-1 under the baseline	t	Taking into account explanations for 2005 in Section B [R1] : $FC_{BWW,1mp,BL,y}^m = FC_{BWW,1mp,PJ,y}^m + (FC_{BWW,3ub,PJ,y}^m - FC_{BWW,3ub,BL,y}^m) + (BWW_{dump,PJ,y}^m - BWW_{dump,BL,y}^m)$	225 843
$FC_{BWW,3ub,PJ,y}^m$	Actual mass of BWW consumption in utilizing boilers of TPP-3	t	See Table 2	282 560
$FC_{BWW,1mp,PJ,y}^m$	Actual mass of BWW burnt in the MP boiler room of TPP-1	t	See Table 2	190 669
$BWW_{dump,PJ,y}^m$	Actual mass of BWW dumped to the landfill	t	See Table 2	174 868
$BWW_{dump,BL,y}^m$	Mass of BWW dumped to the landfill under the baseline	t	$BWW_{dump,BL,y}^m = BWW_{dump,PJ,y}^m \times \frac{WWS_{dump,BL,y}^{dm}}{WWS_{dump,PJ,y}^{dm}}$	192 253

Symbol	Name	Unit	Formula or grounds	Value
$WWS_{dump,BL,y}^{dm}$	Amount of absolutely dry WWS dumped to the landfill under the baseline	t a.d.m.	$WWS_{dump,BL,y}^{dm} = WWS_{dump,PJ,y}^{dm} + FC_{WWS,3ub,PJ,y}^{dm}$	61 496
$WWS_{dump,PJ,y}^{dm}$	Actual amount of absolutely dry WWS dumped to the landfill	t a.d.m.	$WWS_{dump,PJ,y}^{dm} = WWS_{dump,PJ,y}^m \times (100 - W_{WWS,y}) / 100$	55 934
$FC_{WWS,3ub,PJ,y}^{dm}$	Actual amount of absolutely dry WWS burnt in the utilizing boilers of TPP-3	t a.d.m.	$FC_{WWS,3ub,PJ,y}^{dm} = FC_{WWS,3ub,PJ,y}^m \times (100 - W_{WWS,y}) / 100$	5 561
$WWS_{dump,PJ,y}^m$	Actual mass of wet WWS dumped to the landfill	t	See Table 2	236 409
$FC_{WWS,3ub,PJ,y}^m$	Actual mass of wet WWS burnt in the utilizing boilers of TPP-3	t	See Table 2	23 504
$W_{WWS,y}$	Average weighted humidity of formed WWS	%	See Table 2	76.34
$\Delta FC_{coal,y}$	Change in amount of coal burnt at TPP-1 compared to the project	GJ	$\Delta FC_{coal,y} = \frac{100 \times \Delta HG_{1hp,y}}{\eta_{coal}}$	-156 257
η_{coal}	Average gross coal boiler efficiency factor	%	According to Section B [R1] it is taken as constant	90.00
$\Delta HG_{1hp,y}$	Change in steam generation by HP boilers of TPP-1 compared to the project	GJ	$\Delta HG_{1hp,y} = \Delta HG'_{1hp,y} \frac{100}{100 - \epsilon_{aux}}$	-140 631
ϵ_{aux}	Relative heat losses and consumption for the auxiliary needs related to additional generation of steam in HP boilers of TPP-1	%	According to Section B [R1] it is taken as constant	5.00
$\Delta HG'_{1hp,y}$	Change in live steam delivery to the HP turbines of TPP-1 compared to the project	GJ	$\Delta HG'_{1hp,y} = 0.665 \Delta HS_{1hp,y}$	-133 600
$\Delta HS_{1hp,y}$	Change in steam supply from the HP station of TPP-1 compared to the project	GJ	$\Delta HS_{1hp,y} = \Delta HS_{1,y} - \Delta HS_{1mp,y}$	-200 902

Symbol	Name	Unit	Formula or grounds	Value
$\Delta HS_{1,y}$	Additional annual steam supply for cellulose production from TPP-1, with losses in steam network taken into account, compared to the project scenario	GJ	$\Delta HS_{1,y} = \Delta HS_{3,y} \frac{100}{100 - \epsilon_{nw}}$	0
ϵ_{nw}	Relative heat losses in steam network (from TPP-1 to cellulose production)	%	According to Section B [R1] it is taken as constant	3.00
$\Delta HS_{3,y}$	Useful steam supply via PRC at TPP-3 under the project scenario	GJ	$\Delta HS_{3,y} = HS_{3bypass,PJ,y}$	0
$\Delta HS_{1mp,y}$	Change in steam supply from the MP station of TPP-1 compared to the project	GJ	$\Delta HS_{1mp,y} = HS_{1mp,BL,y} - HS_{1mp,PJ,y}$	200 902
$HS_{1mp,BL,y}$	Useful supply of thermal power from the MP station of TPP-1 under the baseline	GJ	$HS_{1mp,BL,y} = HS_{1mp,PJ,y} \times FC_{BWW,1mp,BL,y}^m / FC_{BWW,1mp,PJ,y}^m$	1 289 945
$HS_{1mp,PJ,y}$	Useful supply of thermal power from the MP station of TPP-1 under the project	GJ	$HS_{1mp,PJ,y} = HG_{1mp,PJ,y} \times (100 - \alpha) / 100$	1 089 042
α	Relative consumption of heat of live steam for the auxiliary needs and electric power generation at the MP station of TPP-1	%	According to Section B [R1] it is taken as constant	10.00
$HG_{1mp,PJ,y}$	Actual gross steam generation in boilers of the MP station of TPP-1	GJ	See Table 2	1 210 047
$\Delta BE_{dump,y}$	Additional CH ₄ emissions from the landfill compared to the project	t CO ₂ e	$\Delta BE_{dump,y} = \Delta BE_{BWW,dump,y} + \Delta BE_{WWS,dump,y}$	1 432
$\Delta BE_{BWW,dump,y}$	Additional emissions of CH ₄ from the landfill because of BWW anaerobic decomposition, compared to the project	t CO ₂ e	Numerical values have been determined with the “Calculation of CO ₂ -equivalent emission reduction from BWW prevented from stockpiling or taken from stockpiles” model developed by BTG biomass technology group B.V. [R4]. See Tables 5 and 6. In this model variable parameters for year y are indicated in the next two lines.	965
$\Delta BE_{WWS,dump,y}$	Additional emissions of CH ₄ from the landfill because of WWS anaerobic decomposition, compared to the project	t CO ₂ e		467

Symbol	Name	Unit	Formula or grounds	Value
$\Delta BWW_{dump,y}^m$	Additional amount of dumped BWW under the baseline compared to the project	t	$\Delta BWW_{dump,y}^m = BWW_{dump,BL,y}^m - BWW_{dump,PJ,y}^m$	17 386
$\Delta WWS_{dump,y}^{dm}$	Additional amount of dumped WWS under the baseline compared to the project	t a.d.m.	$\Delta WWS_{dump,y}^{dm} = WWS_{dump,BL,y}^{dm} - WWS_{dump,PJ,y}^{dm}$	5 561

Table 5. Calculations of reductions of methane emissions from landfill because of BWW anaerobic decay

Calculation of CO₂-equivalent emission reduction from BWW prevented from stockpiling or taken from stockpiles

General input data		
Conversion factor organic carbon to biogas (a)	1,87 m ³ biogas/kg carbon	
GWP CH ₄	21	
Density methane	0,654 kg/m ³	
Methane concentration biogas	50%	
Half-life biomass (tau)	15 year	
Decomposition constant (k)	0,046 year ⁻¹	
Generation factor (zeta)	0,77	
Methane oxidation factor	0,10	
Percentage of the stockpile under aerobic conditions	20%	

BWW - bark wood waste

LEGEND
db = dry basis
wb = wet basis
yellow cells = unprotected cells
red marks = comment field included

Biomass specific input data	Biomass from stockpile	Fresh
Organic carbon content (db)		50,0% db
Moisture content		55% wb
Organic carbon content (wb)	0,0%	22,5% wb
Lignin fraction of C		0,25

Year	Fresh biomass prevented from stockpiling or taken from stockpile			Year								
	Biomass from stockpile (ton _w)	Age of biomass (years)	Fresh (ton _w)	2004 ton CO2-eq	2005	2006	2007	2008	2009	2010	2011	2012
2004			0	0	0	0	0	0	0	0	0	0
2005			17 386	965	922	880	840	802	766	731	698	
2006				0	0	0	0	0	0	0	0	
2007				0	0	0	0	0	0	0	0	
2008				0	0	0	0	0	0	0	0	
2009				0	0	0	0	0	0	0	0	
2010				0	0	0	0	0	0	0	0	
2011				0	0	0	0	0	0	0	0	
2012				0	0	0	0	0	0	0	0	
2013												
2014												
2015												
2016												
2017												
2018												
2019												
Total	017 386			0	965	922	880	840	802	766	731	698
	Total emission prevention			0	965	1 887	2 767	3 607	4 409	5 175	5 907	6 605
	Cumulative total emission prevention			0	965	1 887	2 767	3 607	4 409	5 175	5 907	6 605

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This spreadsheet model is based on the report: "Methane and Nitrous Oxide Emissions from Biomass Waste Stockpiles", Worldbank PCFplus research, August 2002

Table 6. Calculations of reductions of methane emissions from landfill because of WWS anaerobic decay

Calculation of CO₂-equivalent emission reduction from WWS prevented from stockpiling or taken from stockpiles

General input data

Conversion factor organic carbon to biogas (a)	1,87 m ³ biogas/kg carbon
GWP CH ₄	21
Density methane	0,654 kg/m ³
Methane concentration biogas	50%
Half-life biomass (tau)	15 year
Decomposition constant (k)	0,046 year ⁻¹
Generation factor (zeta)	0,77
Methane oxidation factor	0,10
Percentage of the stockpile under aerobic conditions	20%

WWS - waste water sludge

LEGEND

db = dry basis
wb = wet basis
yellow cells = unprotected cells
red marks = comment field included

Biomass specific input data	Biomass from stockpile	Fresh
Organic carbon content (db)		34,0% db
Moisture content		0% wb
Organic carbon content (wb)	0,0%	34,0% wb
Lignin fraction of C		0,25

Year	Fresh biomass prevented from stockpiling or taken from stockpile			Year									
	Biomass from stockpile (ton _w)	Age of biomass (years)	Fresh (ton _w)	2004	2005	2006	2007	2008	2009	2010	2011	2012	
2004			0	0	0	0	0	0	0	0	0	0	
2005			5 561	0	467	445	425	406	388	370	354	338	
2006					0		0	0	0	0	0	0	
2007							0		0	0	0	0	
2008									0	0	0	0	
2009										0	0	0	
2010											0	0	
2011												0	
2012													0
2013													
2014													
2015													
2016													
2017													
2018													
2019													
Total			0 5 561										
	Total emission prevention			0	467	445	425	406	388	370	354	338	
	Cumulative total emission prevention			0	467	912	1 337	1 743	2 131	2 501	2 855	3 193	

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Table 7. Calculation of emission reductions over the year $y = 2005$

Symbol	Name	Unit	Formula or grounds	Value
ER_y	Total emission reductions	t CO₂e	$ER_y = BE_y - PE_y$ or $ER_y = ER_{CO_2,y} + ER_{CH_4,y}$	84 514
$ER_{CO_2,y}$	Emission reductions of carbon dioxide	t CO₂	$ER_{CO_2,y} = ER_{CO_2,oil,3,y} + ER_{CO_2,oil,1mp,y} + ER_{CO_2,coal,1hp,y}$	83 082
$ER_{CO_2,oil,3,y}$	Emission reductions of carbon dioxide from fuel oil combustion at TPP-3	t CO ₂	$ER_{CO_2,oil,3,y} = BE_{oil,3,y} - PE_{oil,3,y}$	89 898
$ER_{CO_2,oil,1mp,y}$	Emission reduction of carbon dioxide from fuel oil combustion at the boiler-house of medium pressure TPP-1	t CO ₂	$ER_{CO_2,oil,1mp,y} = BE_{oil,1mp,y} - PE_{oil,1mp,y}$	7 526
$ER_{CO_2,coal,1hp,y}$	Emission reduction of carbon dioxide from coal combustion at the boiler-house of high pressure TPP-1	t CO ₂	$ER_{CO_2,coal,1hp,y} = \Delta BE_{coal,y}$	-14 341
$ER_{CH_4,y}$	Emission reduction of methane	t CO₂e	$ER_{CH_4,y} = ER_{CH_4,BWW,y} + ER_{CH_4,WWS,y}$	1 432
$ER_{CH_4,BWW,y}$	Reduction of methane emissions from the landfill because of BWW anaerobic decomposition	t CO ₂ e	$ER_{CH_4,BWW,y} = \Delta BE_{BWW,dump,y}$	965
$ER_{CH_4,WWS,y}$	Reduction of methane emissions from the landfill because of WWS anaerobic decomposition	t CO ₂ e	$ER_{CH_4,WWS,y} = \Delta BE_{WWS,dump,y}$	467

Environmental monitoring

In process of the project implementation, analytical control over various effects on the environment is exercised in compliance with the existing regulation. In particular, control over emissions of harmful substances into the atmosphere is performed according to the “Schedule of laboratory control of standard MPE at stationary emission sources of JSC Arkhangelsk PPM”.

The data obtained by the analytical laboratory are processed and brought together in monthly and annual reports, which specify all the required itemized data, including those for the sections affected by the Project.

Table 8 represents calculated data for the changes in the amount of harmful substances thrown into the atmosphere under the project as compared to the baseline.

Table 8. Alterations in the harmful substance emissions into the atmosphere against the baseline over the year $y = 2005$, t; (+) - increase, (–) - decrease)

Harmful emissions	Fuel oil	Coal	BWW	WSS	Total
Fluidised substances	-2	76	44	53	171
Sulphur dioxide (SO ₂)	-1 419	136	0	140	-1 143
Nitrous dioxide (NO ₂)	-132	30	7	2	-93
Nitrous oxide (NO)	-21	5	1	0	-15
Carbon oxide (CO)	-430	34	115	50	-231
Total emissions	-2 004	280	168	245	-1 311

Emergencies

No emergencies occurred during the period under verification which could have given rise to emissions.

Conclusion

The implementation of the project “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)” allowed preventing emissions into the atmosphere in 2005:

- **greenhouse gases – by 84 514 tons CO₂e,**
- polluting substances – by 1 311 t.

REFERENCES

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- [R2] Decision 9/CMP.1. Guidelines for the implementation of Article 6 of the Kyoto Protocol. FCCC/KP/CMP/2005/8/Add.2. 30 March 2006.
- [R3] Inventory of greenhouse gas emissions at OJSC “Arkhangelsk PPM” for 2005. APPM, Novodvinsk, 2006.
- [R4] Methane and Nitrous Oxide Emissions from Biomass Waste Stockpiles, Worldbank PCFplus research, August 2002

MONITORING REPORT

**JOINT STOCK COMPANY
“ARKHANGELSK PULP AND PAPER MILL”**

Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (town of Novodvinsk, Russia)

PDD REFERENCE NO: 0005

Monitoring period: **1st January 2006 – 31st December 2006**

Prepared by: Environmental Investment Center (Arkhangelsk, Russia)

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Date: 26.03.2007

Introduction

The document is executed according to the developed PDD “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)” [R1]. The PDD is placed at website UNFCCC (ji.unfccc.int/JI_Projects/Verification/PDD) under reference number 0005.

The project is implemented at the territory of JSC “Arkhangelsk Pulp and Paper Mill”, town of Novodvinsk, Arkhangelsk region, Russia.

The project is aimed at increasing the share of biomass waste in the APPM fuel balance, which will allow reducing consumption of expensive and environmentally dirtier fossil fuel, as well as decrease the amount of dumped biomass waste.

With reference to the project, biomass waste is bark and wood waste (BWW) and waste water sludge (WWS). BWW includes bark, sawdust, slivers, substandard chips, as well as building waste wood, logging waste, etc. The bulk of BWW is formed at the stage of preparing pulp chips in the APPM wood-preparation shops and delivered from neighboring saw-mills, which have no their own facilities for utilization of their BWW. WWS is formed at the station of biological treatment of industrial and household waste of APPM and the town of Novodvinsk.

The project implies implementation of the following engineering solutions in two stages:

Stage I:

- Reconstruction of the obsolete and inefficient utilizing boiler KM-75-40 (St. No. 2) at TPP-3¹, with switching to BWW combustion in the fluidized bed;
- Modernization of WPS-3² with installation of advanced equipment for chopping and dewatering BWW.

Stage II:

- Replacement of an old utilizing boiler KM-75-40 (St. No. 1) at TPP-3 with a new utilizing boiler E-75-3,9-440 DFT, with biomass waste combustion in the fluidized bed;
- Assembly of a new unit for receiving and preparation BWW and WWS delivered by motor transport, to be burnt in utilizing boilers of TPP-3.

Construction and assembly operations for the first stage of the project were carried out from February to December of 2000, and for the second stage – from April of 2004 to July of 2005. According to *Decision 9/CMP.1* [R2], the project may be recognized as a joint implementation project, if its technical implementation began not earlier than in the year 2000.

Technology employed

Stage I:

Reconstruction of the KM-75-40 boiler St. No. 2

In 2000, Joint Venture Energosofin and OJSC Belenergomash performed reconstruction of the KM-75-40 boiler St. No. 2, with switching to the fluidized bed technology.

¹ TPP-3 – thermal power plant No. 3

² WPS-3 – wood-preparation shop No. 3

Burning of waste in the fluidized bed provides efficient, economical and environmentally safe combustion of high-humidity and low-calorie fuels. The fluidized bed is made of quartz sand by means of feeding air at a high pressure under the filling layer. The process of combustion is partly taking place in the fluidized bed, and partly – above it. The temperature of the fluidized bed is about 700-800°C and can be adjusted by air distribution.

In the nominal operating mode, the modernized KM-75-40S boiler allows burning BWW with humidity of 57%, with steam capacity equal to 66 tons per hour, without fuel oil flame stabilization. The superheated steam pressure is 4.0 MPa, its temperature being 440 °C. The boiler efficiency factor is about 85%. After the reconstruction, the hourly consumption of BWW has become twice as high, reaching 30 tons an hour.

The trials held within the second stage of the project showed that it is also possible to obtain stable and economical combustion of the BWW/WWS mixture, with the latter accounting for up to 20-25% of the weight of BWW.

WPS-3 modernization

WPS-3 modernization was performed for the purpose of improving the BWW quality in accordance with requirements set for the fuel combusted through the fluidized bed technology. The modernization was carried out in 2000, simultaneously with reconstruction of boiler St. No. 2 of TPP-3.

As a result of modernization, three independent fuel flows were replaced with a single centralized bark preparation unit equipped with a Saalasti 0912 rotor crusher and two Bark Master 1620 bark drum presses (also made by Saalasti). The equipment proved to be efficient at a number of the industry enterprises.

Modernization of WPS-3 made it possible to ensure a more homogenous breakup of BWW (pieces not larger than 75 mm) and lower their humidity down to the level of about 50%, which substantially increased the low calorific value and allowed stable combustion of BWW in boiler St. No. 2 in the fluidized bed without fuel oil flame stabilization. Besides, electric power consumption required for BWW preparation was reduced by 6-8%, due to its centralization.

On the whole, implementation of measures of the first stage enabled to make the amount of BWW burnt in boiler St. No. 2 of TPP-3 more than double, while having increased significantly the efficiency of their combustion and reduced fuel oil consumption.

Stage II:

Installation of a new E-75-3.9-440 DFT boiler

Inefficient operation of the KM-75-40 St. No. 1 boiler unit used for burning BWW determined the necessity to install quite a new boiler – E-75-3.9-440DFT with the fluidized bed. Works on replacement of boiler St. No. 1 were held from April 2004 to July 2005. ZAO Arkhgirobum was the project developer, with AMU Sevzapenergomontazh as the general contractor.

Boiler E-75-3.9-440DFT is a single-drum boiler with natural circulation. The boiler is equipped with the HYBEX fluidized bed grate developed and patented by Kvaerner. The rated steam capacity is 75 t/hr without fuel oil flame stabilization. The pressure of superheated steam is 4.0 MPa, its temperature being 440 °C. The furnace efficiency factor is about 92%.

The main fuel was constituted by a mixture of bark, waste wood and waste water sludge. Operating the boiler allows increasing the WWS delivery to 10 t/hr, with the boiler steam capacity reduced, accordingly. The fuel must come into the boiler well-mixed, homogenous, with the average humidity of the BWW/WWS mixture not exceeding 63%. No dimension of the BWW fragments should be more than 100 mm. Fuel oil M100 is used as starting fuel.

Low content of oxygen in smoke fumes at combustion in the fluidized bed and the absence of unburnt particles is achieved owing to efficient mixing in the fluidized bed, and air distribution among the blasting zones, which ensures the boiler's high efficiency factor.

The tests of the boiler, which took place in 2005, showed that it is possible to achieve stable and economical combustion of the BWW/WWS mixture, with the latter being 20-25% of the BWW weight.

Assembly of a new unit for receiving and preparation of motor delivered BWW and WWS

To provide the utilizing boilers of TPP-3 with sufficient amount of biofuel, a unit for receiving and preparation of BWW delivered by motor transport, was assembled at WPS-3, with a section for receiving WWS from the mill's treatment facilities. The design of the receiving unit was developed as an addition to the project of installation of boiler unit E-75-3.9-440DFT.

The flow chart of the unit for receiving and processing of delivered waste includes:

- unit for receiving BWW from motor transport, with an unloading platform;
- unit for crushing large BWW;
- sorting unit;
- unit for receiving WWS;
- track of feeding waste to the utilizing boiler room of TPP-3.

The unit for receiving BWW comprises a 50 m³ hopper equipped with two worm dischargers supplied by Raumaster Oy, with capacity up to 250 packed m³/hr, and provides for receiving BWW from chip trucks.

The crushing unit is equipped with a hydraulic Crush Master RWC-2-600 rotor crusher with capacity of 5 to 50 packed m³/hr. Large waste is fed to the crusher with a manipulator, and the screenings are transferred by a belt conveyor. The crushing unit equipment is supplied by Raumaster Oy.

Delivery of bark from the receiving unit, and delivery of ground wood from the crushing unit to sorting is to be carried out with a 1000 mm belt conveyor. To remove metal objects out of the waste wood flow, a PS-120M iron separator is to be installed.

The sorting unit is equipped with a disk sorter supplied by LLC Soyuzlesmontazh (Vologda).

The processing chart of the unit for receiving WWS looks as follows. WWS is delivered from filter-presses of the biological treatment station by dump-trucks. WWS consumption is 4 to 20 wet t/hr. The sludge is unloaded into the receiving hopper, its lower part equipped with four dosing worms. At the output of the dosing worms, there is a slanting worm conveyor for delivering sludge to belt conveyor with a weigher for ensuring the BWW/WWS ratio within the range from 8/1 to 4/1, respectively. The worms of the receiving hopper are equipped with geared motors enabling variation of rotating speed, thus adjusting the amount of the fed WWS.

The BWW/WWS mixture comes to the buffer storage with self-propelled worm unloaders, and then goes through the belt weigher and is distributed to receiving hoppers of the TPP-3 utilizing boilers.

The designed capacity of the BWW-feeding truck at TPP-3 was increased up to 750 thousand dense m³/year, including up to 450 thousand dense m³ of motor delivered BWW (here, the delivered waste also include the waste delivered by motor transport within the mill – from WPS-2 and WPS-4). Besides, it has become possible to utilize about 100 thousand tons of wet WWS per year.

Implementation of the second stage measures made it possible to increase radically the amount of burnt BWW at TPP-3, to increase steam output, to ensure receiving and preparation for combustion of a higher BWW amount of heterogenous breakup, to ensure receiving and combustion of WWS. All that has eventually allowed for fossil fuel consumption, amount of dumped waste and GHG emissions to be reduced.

Monitoring period

The monitoring period is chosen from **1st January 2006 to 31st December 2006** (both days included).

Monitored data

Collection of all the key parameters required for greenhouse emissions to be determined, both under the project and for the baseline, is performed according to the practice established at APPM on accounting of fuel, energy, waste, and assessment of environmental impacts. Monitoring under the project requires no changes to be introduced in the existing system of accounting and collection of information. All the necessary data are determined and registered in any case.

Description of monitoring plan of all data required to calculate GHG emissions reductions is represented in Section D and Annex 3 of PDD [R1]. Table 1 and 2 below represents yearly values of project and baseline data for 2006.

Table 1. Values of data collected in order to monitor emissions from the project over the year $\gamma = 2006$

ID number and symbol	Data name	Data unit	Value	Comment
1. $FC_{oil,3,PJ,\gamma}^m$	Mass fuel oil consumption at TPP-3	t	13 885	
2. $FC_{oil,1mp,PJ,\gamma}^m$	Mass fuel oil consumption in medium pressure boilers of TPP-1	t	8 272	
3. $NCV_{oil,\gamma}$	Net calorific value of fuel oil	GJ/t	40.31	The weighted annual average

Table 2. Values of relevant data necessary for determining the baseline of anthropogenic emissions of greenhouse gases by sources within the project boundary over the year $\gamma = 2006$

ID number and symbol	Data name	Data unit	Data value	Comment
4. $FC_{BWW,3ub,PJ,\gamma}^m$	Mass BWW consumption in utilizing boilers of TPP-3	t	355 776	
5. $FC_{BWW,1mp,PJ,\gamma}^m$	Mass BWW consumption in medium pressure boilers of TPP-1	t	119 351	
6. $BWW_{dump,PJ,\gamma}^m$	Mass BWW removal to the landfill	t	129 655	
7. $BWW_{side,PJ,\gamma}^m$	Mass BWW delivery from the outside	t	107 770	

ID number and symbol	Data name	Data unit	Data value	Comment
8. $WWS_{dump,PJ,y}^m$	Wet mass WWS removal to the landfill	t	175 955	
9. $FC_{WWS,3ub,PJ,y}^m$	Wet mass WWS consumption in utilizing boilers of TPP-3	t	89 479	
10. $W_{WWS,y}$	WWS humidity	%	76.74	The weighted annual average
11. $FC_{liq,3rb,y}^{dm}$	Dry mass black liquor consumption in recovery boilers of TPP-3	t a.d.m.	539 603	
12. $FC_{oil,3rb,PJ,y}^m$	Mass fuel oil consumption in recovery boilers of TPP-3	t	13 735	
13. $NCV_{BWV,3ub,y}$	Net calorific value of BWV combusted in utilizing boilers of TPP-3	GJ/t	8.34	The weighted annual average
14. $NCV_{liq,3rb,y}$	Net calorific value of black liquor combusted in recovery boilers of TPP-3	GJ/t a.d.m.	10.72	The weighted annual average
15. $HG_{3,PJ,y}$	Total gross steam generation at TPP-3	GJ	7 443 741	
16. $HS_{3,PJ,y}$	Total useful supply of heat from TPP-3	GJ	5 808 324	
17. $HS_{3backpress,PJ,y}$	Useful supply of heat from TPP-3 with backpressure steam	GJ	5 808 324	It is equal to total useful supply because no steam supply through the PRC in 2006
18. $HG_{3rb,PJ,y}$	Gross steam generation in recovery boilers of TPP-3	GJ	5 126 010	
19. $HG_{1mp,PJ,y}$	Gross steam generation in medium pressure boilers of TPP-1	GJ	735 777	
20. $EF_{CO2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	91.62	Average value for 2003-2005

Calculation of emission reductions

According to formulae described in Section D [R1] and with help of the tool [R4] calculations of project and baseline emissions have been done (see Tables 3...6). As shown in Section B.3 [R1] all of the leakages can be neglected.

Calculation of emission reductions are presented in Table 7.

Thus, total GHG emission reductions for 2006 amounted **165 292 tCO₂e**.

Table 3. Calculation of project emissions over the year $y = 2006$

Symbol	Name	Unit	Formula or grounds	Value
PE_y	Total greenhouse gas emissions under the project	t CO ₂	$PE_y = PE_{oil,3,y} + PE_{oil,1mp,y}$	68 889
$PE_{oil,3,y}$	CO ₂ emission from burning fuel oil at TPP-3 under the project	t CO ₂	$PE_{oil,3,y} = FC_{oil,3,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	43 170
$PE_{oil,1mp,y}$	CO ₂ emission from burning fuel oil in boilers of the medium pressure station of TPP-1 under the project	t CO ₂	$PE_{oil,1mp,y} = FC_{oil,1mp,PJ,y} \times EF_{CO_2,oil} \times 10^{-3}$	25 719
$FC_{oil,3,PJ,y}$	Amount of fuel oil burnt at TPP-3 under the project	GJ	$FC_{oil,3,PJ,y} = FC_{oil,3,PJ,y}^m \times NCV_{oil,y}$	559 704
$FC_{oil,1mp,PJ,y}$	Amount of fuel oil burnt in boilers of the medium pressure station of TPP-1 under the project	GJ	$FC_{oil,1mp,PJ,y} = FC_{oil,1mp,PJ,y}^m \times NCV_{oil,y}$	333 444
$FC_{oil,3,PJ,y}^m$	Mass of fuel oil burnt at TPP-3 under the project	t	See Table 1	13 885
$FC_{oil,1mp,PJ,y}^m$	Mass of fuel oil burnt in MP boilers of TPP-1 under the project	t	See Table 1	8 272
$NCV_{oil,y}$	Weighted average net calorific value of fuel oil	GJ/t	See Table 1	40.31
$EF_{CO_2,oil}$	Emission factor of CO ₂ from burning fuel oil	kg CO ₂ /GJ	Taken as constant according to the Inventory of GHG emissions at APPM [R3] (with the fraction of carbon oxidized taken into account)	77.13

Table 4. Calculation of baseline emissions over the year $y = 2006$

Symbol	Name	Unit	Formula or grounds	Value
BE_y	Total greenhouse gas emissions under the baseline	t CO ₂ e	$BE_y = BE_{ff,y} + \Delta BE_{dump,y}$	234 180
$BE_{ff,y}$	CO ₂ emissions from burning fossil fuel under the baseline	t CO ₂	$BE_{ff,y} = BE_{oil,3,y} + BE_{oil,1mp,y} + \Delta BE_{coal,y}$	227 407
$BE_{oil,3,y}$	CO ₂ emissions from burning fuel oil at TPP-3 under the baseline	t CO ₂	$BE_{oil,3,y} = FC_{oil,3,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	212 453
$BE_{oil,1mp,y}$	CO ₂ emissions from burning fuel oil in boilers of the MP station of TPP-1 under the baseline	t CO ₂	$BE_{oil,1mp,y} = FC_{oil,1mp,BL,y} \times EF_{CO_2,oil} \times 10^{-3}$	38 614
$\Delta BE_{coal,y}$	Change in CO ₂ emissions from burning coal in boilers of the HP station of TPP-1 compared to the project	t CO ₂	$\Delta BE_{coal,y} = \Delta FC_{coal,y} \times EF_{CO_2,coal,y} \times 10^{-3}$	-23 660
$EF_{CO_2,coal,y}$	Emission factor of CO ₂ for coal	kg CO ₂ /GJ	See Table 2	91.62
$FC_{oil,3,BL,y}$	Amount of fuel oil burnt at TPP-3 under the baseline	GJ	$FC_{oil,3,BL,y} = FC_{oil,3ub,BL,y} + FC_{oil,3rb,BL,y}$	2 754 480
$FC_{oil,3ub,BL,y}$	Amount of fuel oil burnt in utilizing boilers of TPP-3 under the baseline	GJ	$FC_{oil,3ub,BL,y} = FC_{3ub,BL,y} - FC_{BWW,3ub,BL,y}$	988 288
$FC_{oil,3rb,BL,y}$	Amount of fuel oil burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{oil,3rb,BL,y} = FC_{3rb,BL,y} - FC_{liq,3rb,y}$	1 766 192
$FC_{3ub,BL,y}$	Total amount of fuel burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{3ub,BL,y} = \frac{100 \times FC_{BWW,3ub,BL,y}}{100 - \beta_{oil,3ub,BL}}$	2 906 729
$\beta_{oil,3ub,BL}$	Share of fuel oil in total consumption of equivalent fuel in the utilizing boilers of TPP-3 under the baseline	%	According to Section B [R1] it is taken as constant	34.00
$FC_{BWW,3ub,BL,y}$	Amount of BWW burnt in the utilizing boilers of TPP-3 under the baseline	GJ	$FC_{BWW,3ub,BL,y} = FC_{BWW,3ub,BL,y}^m \times NCV_{BWW,3ub,y}$	1 918 441
$FC_{BWW,3ub,BL,y}^m$	Mass of BWW burnt in the utilizing boilers of TPP-3 under the baseline	t	According to Section B [R1] it is taken as constant	230 000

Symbol	Name	Unit	Formula or grounds	Value
$NCV_{BWW,3ub,y}$	Actual average weighted net calorific value of BWW at TPP-3	GJ/t	See Table 2	8.34
$FC_{3rb,BL,y}$	Total amount of fuel burnt in recovery boilers of TPP-3 under the baseline	GJ	$FC_{3rb,BL,y} = \frac{100 \times HG_{3rb,BL,y}}{\eta_{3rb,y}}$	7 550 737
$HG_{3rb,BL,y}$	Gross steam generation in the recovery boilers of TPP-3 under the baseline	GJ	$HG_{3rb,BL,y} = HG_{3,BL,y} - HG_{3ub,BL,y}$	6 106 645
$HG_{3,BL,y}$	Total gross steam generation at TPP-3 under the baseline	GJ	$HG_{3,BL,y} = HG_{3,PJ,y} - \frac{100 \times HS_{3bypass,PJ,y}}{(100 - \varepsilon_{3bypass})}$	7 443 741
$HG_{3,PJ,y}$	Total actual gross steam generation at TPP-3	GJ	See Table 2	7 443 741
$\varepsilon_{3bypass}$	Relative heat losses and consumption on the plant's auxiliary needs related to the steam flow passing through the PRC (by-passing the turbines)	%	According to Section B [R1] it is taken as constant	5.00
$HS_{3bypass,PJ,y}$	Actual useful steam supply from TPP-3 by-passing the turbines, via the PRC	GJ	$HS_{3bypass,PJ,y} = HS_{3,PJ,y} - HS_{3backpress,PJ,y}$	0
$HS_{3,PJ,y}$	Actual total useful heat supply from TPP-3	GJ	See Table 2	5 808 324
$HS_{3backpress,PJ,y}$	Actual useful heat supply from TPP-3 with the steam spent in the turbines	GJ	See Table 2	5 808 324
$HG_{3ub,BL,y}$	Gross steam generation in the utilizing boilers of TPP-3 under the baseline	GJ	$HG_{3ub,BL,y} = FC_{3ub,BL,y} \times \eta_{3ub,BL,y} / 100$	1 337 095
$\eta_{3ub,BL,y}$	Average efficiency factor of utilizing boilers under the baseline	%	According to Section B [R1] it is taken as constant	46.00
$\eta_{3rb,y}$	Actual average weighted efficiency factor of recovery boilers of TPP-3	%	$\eta_{3rb,y} = 100 \times HG_{3rb,PJ,y} / FC_{3rb,PJ,y}$	80.87
$HG_{3rb,PJ,y}$	Actual gross steam generation in the recovery boilers of TPP-3	GJ	See Table 2	5 126 010

Symbol	Name	Unit	Formula or grounds	Value
$FC_{3rb,PJ,y}$	Actual total fuel consumption in the recovery boilers of TPP-3	GJ	$FC_{3rb,PJ,y} = FC_{oil,3rb,PJ,y} + FC_{liq,3rb,y}$	6 338 202
$FC_{oil,3rb,PJ,y}$	Actual consumption of fuel oil in the recovery boilers of TPP-3	GJ	$FC_{oil,3rb,PJ,y} = FC_{oil,3rb,PJ,y}^m \times NCV_{oil,y}$	553 658
$FC_{oil,3rb,PJ,y}^m$	Actual mass consumption of fuel oil in the recovery boilers of TPP-3	t	See Table 2	13 735
$FC_{liq,3rb,y}$	Actual amount of black liquor burnt at TPP-3	GJ	$FC_{liq,3rb,y} = FC_{liq,3rb,y}^{dm} \times NCV_{liq,3rb,y}$	5 784 544
$FC_{liq,3rb,y}^{dm}$	Actual amount of absolutely dry black liquor burnt in the recovery boilers of TPP-3	t a.d.m.	See Table 2	539 603
$NCV_{liq,3rb,y}$	Actual average weighted net calorific value of black liquor at TPP-3	GJ/t a.d.m.	See Table 2	10.72
$FC_{oil,1mp,BL,y}$	Amount of fuel oil burnt in MP boilers of TPP-1 under the baseline	GJ	$FC_{oil,1mp,BL,y} = FC_{oil,1mp,PJ,y} \times \frac{FC_{BWW,1mp,BL,y}^m}{FC_{BWW,1mp,PJ,y}^m}$	500 632
$FC_{BWW,1mp,BL,y}^m$	Mass of BWW burnt in the MP boiler room of TPP-1 under the baseline	t	$FC_{BWW,1mp,BL,y}^m = FC_{BWW,1mp,PJ,y}^m + (FC_{BWW,3ub,PJ,y}^m - FC_{BWW,3ub,BL,y}^m) + (BWW_{dump,PJ,y}^m - BWW_{dump,BL,y}^m) - (BWW_{side,PJ,y}^m - BWW_{side,BL,y}^m)$	179 193
$FC_{BWW,3ub,PJ,y}^m$	Actual mass of BWW consumption in utilizing boilers of TPP-3	t	See Table 2	355 776
$FC_{BWW,1mp,PJ,y}^m$	Actual mass of BWW burnt in the MP boiler room of TPP-1	t	See Table 2	119 351
$BWW_{dump,PJ,y}^m$	Actual mass of BWW dumped to the landfill	t	See Table 2	129 655
$BWW_{dump,BL,y}^m$	Mass of BWW dumped to the landfill under the baseline	t	$BWW_{dump,BL,y}^m = BWW_{dump,PJ,y}^m \times \frac{WWS_{dump,BL,y}^{dm}}{WWS_{dump,PJ,y}^{dm}}$	195 589

Symbol	Name	Unit	Formula or grounds	Value
$WWS_{dump,BL,y}^{dm}$	Amount of absolutely dry WWS dumped to the landfill under the baseline	t a.d.m.	$WWS_{dump,BL,y}^{dm} = WWS_{dump,PJ,y}^{dm} + FC_{WWS,3ub,PJ,y}^{dm}$	61 740
$WWS_{dump,PJ,y}^{dm}$	Actual amount of absolutely dry WWS dumped to the landfill	t a.d.m.	$WWS_{dump,PJ,y}^{dm} = WWS_{dump,PJ,y}^m \times (100 - W_{WWS,y}) / 100$	40 927
$FC_{WWS,3ub,PJ,y}^{dm}$	Actual amount of absolutely dry WWS burnt in the utilizing boilers of TPP-3	t a.d.m.	$FC_{WWS,3ub,PJ,y}^{dm} = FC_{WWS,3ub,PJ,y}^m \times (100 - W_{WWS,y}) / 100$	20 813
$WWS_{dump,PJ,y}^m$	Actual mass of wet WWS dumped to the landfill	t	See Table 2	175 955
$FC_{WWS,3ub,PJ,y}^m$	Actual mass of wet WWS burnt in the utilizing boilers of TPP-3	t	See Table 2	89 479
$W_{WWS,y}$	Average weighted humidity of formed WWS	%	See Table 2	76.74
$BWW_{side,PJ,y}^m$	Actual mass of BWW delivered from outside	t	See Table 2	107 770
$BWW_{side,BL,y}^m$	Mass of BWW delivered from outside under the baseline	t	According to Section B [R1], it is assumed equal to 120 000 t per year from 2006, but not more than $BWW_{side,PJ,y}^m$	107 770
$\Delta FC_{coal,y}$	Change in amount of coal burnt at TPP-1 compared to the project	GJ	$\Delta FC_{coal,y} = \frac{100 \times \Delta HG_{1hp,y}}{\eta_{coal}}$	-258 241
η_{coal}	Average gross coal boiler efficiency factor	%	According to Section B [R1] it is taken as constant	90.00
$\Delta HG_{1hp,y}$	Change in steam generation by HP boilers of TPP-1 compared to the project	GJ	$\Delta HG_{1hp,y} = \Delta HG'_{1hp,y} \frac{100}{100 - \epsilon_{aux}}$	-232 417
ϵ_{aux}	Relative heat losses and consumption for the auxiliary needs related to additional generation of steam in HP boilers of TPP-1	%	According to Section B [R1] it is taken as constant	5.00
$\Delta HG'_{1hp,y}$	Change in live steam delivery to the HP turbines of TPP-1 compared to the project	GJ	$\Delta HG'_{1hp,y} = 0.665 \Delta HS_{1hp,y}$	-220 796

Symbol	Name	Unit	Formula or grounds	Value
$\Delta HS_{1hp,y}$	Change in steam supply from the HP station of TPP-1 compared to the project	GJ	$\Delta HS_{1hp,y} = \Delta HS_{1,y} - \Delta HS_{1mp,y}$	-332 024
$\Delta HS_{1,y}$	Additional annual steam supply for cellulose production from TPP-1, with losses in steam network taken into account, compared to the project scenario	GJ	$\Delta HS_{1,y} = \Delta HS_{3,y} \frac{100}{100 - \epsilon_{nw}}$	0
ϵ_{nw}	Relative heat losses in steam network (from TPP-1 to cellulose production)	%	According to Section B [R1] it is taken as constant	3.00
$\Delta HS_{3,y}$	Useful steam supply via PRC at TPP-3 under the project scenario	GJ	$\Delta HS_{3,y} = HS_{3bypass,PJ,y}$	0
$\Delta HS_{1mp,y}$	Change in steam supply from the MP station of TPP-1 compared to the project	GJ	$\Delta HS_{1mp,y} = HS_{1mp,BL,y} - HS_{1mp,PJ,y}$	332 024
$HS_{1mp,BL,y}$	Useful supply of thermal power from the MP station of TPP-1 under the baseline	GJ	$HS_{1mp,BL,y} = HS_{1mp,PJ,y} \times FC_{BWW,1mp,BL,y}^m / FC_{BWW,1mp,PJ,y}^m$	994 224
$HS_{1mp,PJ,y}$	Useful supply of thermal power from the MP station of TPP-1 under the project	GJ	$HS_{1mp,PJ,y} = HG_{1mp,PJ,y} \times (100 - \alpha) / 100$	662 200
α	Relative consumption of heat of live steam for the auxiliary needs and electric power generation at the MP station of TPP-1	%	According to Section B [R1] it is taken as constant	10.00
$HG_{1mp,PJ,y}$	Actual gross steam generation in boilers of the MP station of TPP-1	GJ	See Table 2	735 777
$\Delta BE_{dump,y}$	Additional CH ₄ emissions from the landfill compared to the project	t CO ₂ e	$\Delta BE_{dump,y} = \Delta BE_{BWW,dump,y} + \Delta BE_{WWS,dump,y}$	6 773

Symbol	Name	Unit	Formula or grounds	Value
$\Delta BE_{BWW,dump,y}$	Additional emissions of CH ₄ from the landfill because of BWW anaerobic decomposition, compared to the project	t CO ₂ e	Numerical values have been determined with the “Calculation of CO ₂ -equivalent emission reduction from BWW prevented from stockpiling or taken from stockpiles” model developed by BTG biomass technology group B.V. [R4]. See Tables 5 and 6. In this model variable parameters for year y are indicated in the next two lines.	4 582
$\Delta BE_{WWS,dump,y}$	Additional emissions of CH ₄ from the landfill because of WWS anaerobic decomposition, compared to the project	t CO ₂ e		2 191
$\Delta BWW_{dump,y}^m$	Additional amount of dumped BWW under the baseline compared to the project	t	$\Delta BWW_{dump,y}^m = BWW_{dump,BL,y}^m - BWW_{dump,PJ,y}^m$	65 934
$\Delta WWS_{dump,y}^{dm}$	Additional amount of dumped WWS under the baseline compared to the project	t a.d.m.	$\Delta WWS_{dump,y}^{dm} = WWS_{dump,BL,y}^{dm} - WWS_{dump,PJ,y}^{dm}$	20 813

Table 5. Calculations of reductions of methane emissions from landfill because of BWW anaerobic decay

Calculation of CO₂-equivalent emission reduction from BWW prevented from stockpiling or taken from stockpiles

General input data	
Conversion factor organic carbon to biogas (a)	1,87 m ³ biogas/kg carbon
GWP CH ₄	21
Density methane	0,654 kg/m ³
Methane concentration biogas	50%
Half-life biomass (tau)	15 year
Decomposition constant (k)	0,046 year ⁻¹
Generation factor (zeta)	0,77
Methane oxidation factor	0,10
Percentage of the stockpile under aerobic conditions	20%

BWW - bark wood waste

LEGEND
db = dry basis
wb = wet basis
yellow cells = unprotected cells
red marks = comment field included

Biomass specific input data	Biomass from stockpile	Fresh
Organic carbon content (db)		50,0% db
Moisture content		55% wb
Organic carbon content (wb)	0,0%	22,5% wb
Lignin fraction of C		0,25

Year	Fresh biomass prevented from stockpiling or taken from stockpile			Year								
	Biomass from stockpile (ton _w)	Age of biomass (years)	Fresh (ton _w)	2004 ton CO2-eq	2005	2006	2007	2008	2009	2010	2011	2012
2004			0	0	0	0	0	0	0	0	0	0
2005			17 386	965	922	880	840	802	766	731	698	
2006			65 934			3 660	3 495	3 337	3 186	3 043	2 905	2 774
2007							0	0	0	0	0	0
2008								0	0	0	0	0
2009									0	0	0	0
2010										0	0	0
2011											0	0
2012												0
2013												
2014												
2015												
2016												
2017												
2018												
2019												
Total	083 320											
	Total emission prevention			0	965	4 582	4 375	4 177	3 989	3 809	3 637	3 472
	Cumulative total emission prevention			0	965	5 547	9 922	14 099	18 088	21 897	25 534	29 006

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This spreadsheet model is based on the report: "Methane and Nitrous Oxide Emissions from Biomass Waste Stockpiles", Worldbank PCFplus research, August 2002

Table 6. Calculations of reductions of methane emissions from landfill because of WWS anaerobic decay

Calculation of CO₂-equivalent emission reduction from WWS prevented from stockpiling or taken from stockpiles

General input data

Conversion factor organic carbon to biogas (a)	1,87 m ³ biogas/kg carbon
GWP CH ₄	21
Density methane	0,654 kg/m ³
Methane concentration biogas	50%
Half-life biomass (tau)	15 year
Decomposition constant (k)	0,046 year ⁻¹
Generation factor (zeta)	0,77
Methane oxidation factor	0,10
Percentage of the stockpile under aerobic conditions	20%

WWS - waste water sludge

LEGEND

db = dry basis
wb = wet basis
yellow cells = unprotected cells
red marks = comment field included

Biomass specific input data	Biomass from stockpile	Fresh
Organic carbon content (db)		34,0% db
Moisture content		0% wb
Organic carbon content (wb)	0,0%	34,0% wb
Lignin fraction of C		0,25

Year	Fresh biomass prevented from stockpiling or taken from stockpile			Year								
	Biomass from stockpile (ton _w)	Age of biomass (years)	Fresh (ton _w)	2004 ton CO2-eq	2005	2006	2007	2008	2009	2010	2011	2012
2004			0	0	0	0	0	0	0	0	0	0
2005			5 561	467	445	425	406	388	370	354	338	
2006			20 813		1 746	1 667	1 592	1 520	1 451	1 386	1 323	
2007						0	0	0	0	0	0	
2008							0		0	0	0	
2009									0	0	0	
2010										0	0	
2011											0	
2012												0
2013												
2014												
2015												
2016												
2017												
2018												
2019												
Total	026 374											
	Total emission prevention			0	467	2 191	2 092	1 998	1 908	1 822	1 739	1 661
	Cumulative total emission prevention			0	467	2 658	4 750	6 748	8 656	10 478	12 217	13 878

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Table 7. Calculation of emission reductions over the year $y = 2006$

Symbol	Name	Unit	Formula or grounds	Value
ER_y	Total emission reductions	t CO₂e	$ER_y = BE_y - PE_y$ or $ER_y = ER_{CO_2,y} + ER_{CH_4,y}$	165 292
$ER_{CO_2,y}$	Emission reductions of carbon dioxide	t CO₂	$ER_{CO_2,y} = ER_{CO_2,oil,3,y} + ER_{CO_2,oil,1mp,y} + ER_{CO_2,coal,1hp,y}$	158 518
$ER_{CO_2,oil,3,y}$	Emission reductions of carbon dioxide from fuel oil combustion at TPP-3	t CO ₂	$ER_{CO_2,oil,3,y} = BE_{oil,3,y} - PE_{oil,3,y}$	169 283
$ER_{CO_2,oil,1mp,y}$	Emission reduction of carbon dioxide from fuel oil combustion at the boiler-house of medium pressure TPP-1	t CO ₂	$ER_{CO_2,oil,1mp,y} = BE_{oil,1mp,y} - PE_{oil,1mp,y}$	12 895
$ER_{CO_2,coal,1hp,y}$	Emission reduction of carbon dioxide from coal combustion at the boiler-house of high pressure TPP-1	t CO ₂	$ER_{CO_2,coal,1hp,y} = \Delta BE_{coal,y}$	-23 660
$ER_{CH_4,y}$	Emission reduction of methane	t CO₂e	$ER_{CH_4,y} = ER_{CH_4,BWW,y} + ER_{CH_4,WWS,y}$	6 773
$ER_{CH_4,BWW,y}$	Reduction of methane emissions from the landfill because of BWW anaerobic decomposition	t CO ₂ e	$ER_{CH_4,BWW,y} = \Delta BE_{BWW,dump,y}$	4 582
$ER_{CH_4,WWS,y}$	Reduction of methane emissions from the landfill because of WWS anaerobic decomposition	t CO ₂ e	$ER_{CH_4,WWS,y} = \Delta BE_{WWS,dump,y}$	2 191

Environmental monitoring

In process of the project implementation, analytical control over various effects on the environment is exercised in compliance with the existing regulation. In particular, control over emissions of harmful substances into the atmosphere is performed according to the “Schedule of laboratory control of standard MPE at stationary emission sources of JSC Arkhangelsk PPM”.

The data obtained by the analytical laboratory are processed and brought together in monthly and annual reports, which specify all the required itemized data, including those for the sections affected by the Project.

Table 8 represents calculated data for the changes in the amount of harmful substances thrown into the atmosphere under the project as compared to the baseline.

Table 8. Alterations in the harmful substance emissions into the atmosphere against the baseline over the year $y = 2006$, t; (+) - increase, (-) - decrease)

Harmful emissions	Fuel oil	Coal	BWW	WSS	Total
Fluidised substances	-5	240	69	187	491
Sulphur dioxide (SO ₂)	-2 869	431	0	494	-1 944
Nitrous dioxide (NO ₂)	-266	94	11	6	-155
Nitrous oxide (NO)	-43	15	2	1	-25
Carbon oxide (CO)	-869	106	179	176	-407
Total emissions	-4 051	886	261	865	-2 040

Emergencies

No emergencies occurred during the period under verification which could have given rise to emissions.

Conclusion

The implementation of the project “Waste Biomass Utilization at Arkhangelsk Pulp and Paper Mill (APPM)” allowed preventing emissions into the atmosphere in 2006:

- **greenhouse gases – by 165 292 tons CO₂e,**
- polluting substances – by 2 040 t.

REFERENCES

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