REPUBLIC OF MOLDOVA

APA CANAL CHISINAU

CHISINAU WATER SUPPLY & SEWAGE TREATMENT - FEASIBILITY STUDY

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Potential for Carbon Trade Report - DRAFT

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LIST OF ABBREVIATIONS AND ACRONYMS

ACC	Apa Canal Chisinau
CAPEX	Capital Expenses
CDM	Clean Development Mechanism
CHP	Combined Heat and Power
DNA	Designated National Authority
GHG	Greenhouse gas
O&M	Operation and Maintenance
OPEX	Operating Expenses
PDD	Project Design Document
PIN	Project Identification Note
PIP	Priority Investment Program
PS	Pumping station
ROI	Return On Investment
WTP	Water Treatment Plant
WWTP	Wastewater treatment plant

TABLE OF CONTENTS

1. BACKGROUND 1
1.1. TERMS OF REFERENCE 1
1.2. INTRODUCTION 1
1.3. KYOTO PROTOCOL AND CARBON CREDITS 1
1.3.1. General context 1
1.3.1.1. Kyoto Protocol 1
1.3.1.2. Project mechanisms 2
1.4. CARBON FOOTPRINT OF WATER AND WASTEWATER SERVICES 2
1.5. CURRENT SITUATION IN ACC 4
1.6. CDM OPPORTUNITY 5

2. WATER TREATMENT PLANT 8
2.1. CONSUMPTION OF CHEMICALS 8
2.2. CONSUMPTION OF ENERGY 8
2.3. CHLORINATION 8
2.4. OTHER IMPROVEMENT WORKS 9

3. DRINKING WATER NETWORK 10
3.1. GENERAL 10
3.2. ADAPTED HYDRO POWER GENERATING DEVICES 10
3.3. POTENTIAL FOR HYDRO POWER GENERATION 12
3.4. ENERGY EFFICIENCY INCREASE 13
3.5. STRUCTURAL CHANGES 14

4. SEWERAGE NETWORK 16
4.1. CURRENT SITUATION 16
4.1.1. Energy consumption 16
4.1.2. Fuel consumption of vehicles 16
4.2. IMPROVEMENT OF EXISTING PUMPING STATIONS 17
4.3. STRUCTURAL MODIFICATIONS OF THE NETWORK 17
4.4. POTENTIAL FOR HYDRO POWER GENERATION 17
4.5. HEAT PUMPS 18
4.6. VEHICLES 19

5. WASTEWATER TREATMENT PLANT 20
5.1. ENERGY CONSUMPTION 20
5.2. CONSUMPTION OF CHEMICALS 23

6. CONCLUSION 24

7. EXAMPLES IN EASTERN EUROPE 27
7.1. GENERAL 27
7.2. SOFIA, BULGARIA 27
7.2.1. General information 27
7.2.2. History of the JI project 28
7.2.3. Communication about the project 30

7.3. BUDAPEST, HUNGARY 33
7.4. PILSEN, CZECH REPUBLIC 34

8. SELECTED REFERENCES 36

LIST OF FIGURES & TABLES

Figure 1 Evidence of informal incentive to energy reduction at Chisinau WWTP 4
Figure 2 Section view of a centrifugal pump 11
Figure 3 Installation of several pump-turbines in parallel when high flow rate fluctuations are expected.. 11
Figure 4 Electricity consumption at the pumping stations of the sewerage network and at the WWTPs. 16
Figure 5 Sketch of heat pump installed in a wastewater network 18
Figure 6 Monthly wastewater volumes and electricity consumption at Chisinau WWTP 20
Figure 7 Monthly wastewater volumes and electricity consumption at Colonita WWTP 21
Figure 8 Monthly wastewater volumes and electricity consumption at Vadul lui voda WWTP 21
Figure 9 Annual CO2 emissions (in tCO2eq) at Kubratovo WWTP.. 29
Figure 10 Evolution of costs and revenues of the project 30
Figure 11 Structure of cash flows... 30
Figure 12 Aerial view of South-Pest WWTP 33
Figure 13 Biogas production at Pilsen WWTP.. 34
Figure 14 Electricity production at Pilsen WWTP 35

Table 1 Main contributors to GHG emissions for water and wastewater services...............................3
Table 2 Electricity tariff in Moldova as of November 2011...5
Table 3 Emission factor for electricity in Moldova 5
Table 4 CDM projects in Moldova as of June 2006 (source: Survey on CDM Project Developments in Caucasus & Moldova, Fichtner, 2006)...6
Table 5 Registered CDM project in Moldova as of March 2011 (source: http://cdm.unfccc.int/) 6
Table 6 DNA of Moldova – Contact details 6
Table 7 Estimation of CO2 emissions of the two options for chlorination at Chisinau WTP.................9
Table 8 Main hypotheses for ROI calculations.. 12
Table 9 Identification of relevant locations where turbines could be installed 12
Table 10 Estimation of revenues brought by electricity generation and selling at four locations 13
Table 11 Energy savings for locations where ROI is below 10 years 14
Table 12 Summary of energy savings and associated CO2 emission reduction.............................. 14
Table 13 Energy consumption for pumping in MWh/year 17
Table 14 Energy ratio of WWTPs... 22
Table 15 Anticipated situation for Chisinau WWTP after implementation of the PIP 22
Table 16 CO2 emissions due to chemical consumption in the future situation (Option 2) 23

Table 17 PIP actions and their carbon footprint impact 24
Table 18 Other relevant actions to improve the carbon footprint 26
Table 19 General data for Kubratovo WWTP (in 2010) 27
Table 20 Sludge treatment and disposal at Budapest WWTPs (after D. Nick, 2010) 33

1. BACKGROUND

1.1. TERMS OF REFERENCE

Phase B.6 Institutional and Economic Operation

Potential for Carbon Trade Identify expected emission reductions from the proposed investments compared with the baseline scenario and quantify roughly the related CO2 equivalent (COre) emission reductions	B.6.	SEURECA	Carbon Credit Specialist

1.2. INTRODUCTION

This report does not intend to cover the carbon footprint of ACC in details or the various existing methodologies for GHG emissions accounting, but rather aims at providing the basis for understanding and addressing the main factors that affect the current carbon footprint of ACC and the impact of the recommendations that have been made in the course of the feasibility study for the following infrastructures:

- Drinking water plant
- Drinking water network
- Wastewater network
- Wastewater treatment plant

The carbon footprint of the very organization of ACC (real estate strategy, utility management, transportation of goods and personnel, office works, etc.) and the impact of the associated recommendations will not be addressed in this report although they may not be insignificant compared to the ones of the above mentioned infrastructures.

1.3. KYOTO PROTOCOL AND CARBON CREDITS

1.3.1. GENERAL CONTEXT

1.3.1.1. Kyoto Protocol

By embracing the United Nations Framework Convention on Climate Change (UNFCCC, Rio, 1992), which was ratified by 189 countries (as of May 24, 2004), 40 industrialised nations made a commitment to bring their 2000 Greenhouse Gases (GHG) emissions back to 1990 levels. They succeeded in reaching their objective in 2000, mainly due to the de-industrialisation of former USSR countries from years 1990 to 2000.

The Kyoto Protocol (1997), ratified by 162 countries (as of February 2006), puts the UNFCCC commitments into action, primarily by setting specific national GHG reduction targets for 38 countries, listed in a document called Annex B. (The United States and Australia are part of Annex B; however they did not ratify the Protocol and are therefore not bound by the above-mentioned commitments). The GHG reduction commitments of Annex B countries came into force on February 16, 2005, the date that Russia ratified the Kyoto Protocol. It is said that the annex B countries (except USA and Australia) are ‘under constraint’.

The Kyoto Protocol provided three tools, called “flexibility mechanisms”, which aim to limit the economic impact of the fight against climate change. The mechanisms were defined in the Kyoto Protocol and made operational by the Marrakech Accords and the decisions taken in Montreal in 2005. The mechanisms are: a) Emissions Trading (ET), b) Clean Development Mechanism (CDM) and c) Joint Implementation (JI).

1.3.1.2. Project mechanisms

The so-called CDM (Clean Development Mechanism) and JI (Joint Implementation) are the project mechanisms implemented to allow businesses making “clean” investments (i.e. reducing the greenhouse gases (GHG) emissions of a facility) outside their own country, and to realise a financial gain in carbon credits.

The “Clean Development Mechanism” allows nations under constraint (for example France) or their businesses to obtain carbon credits by investing in projects that reduce or avoid emissions in nations that have ratified the Kyoto Protocol but are not under constraint, and do not have quantitative targets for the reduction of GHG emissions (among them, Moldova).

“Joint Implementation” refers to projects implemented by a nation under constraint in another nation under constraint (Ukraine and Russia are priority).

It must be underlined here that the cost of setting up such a project is high and the carbon credits do not provide a high profitability. In fact, profitable projects are not eligible to carbon credits. The carbon credits must only help the implementation of the project.

The procedure for presenting a project is long and complex; it involves the participation of several actors, both national and inter-governmental.

1.4. Carbon footprint of water and wastewater services

The evaluation of the carbon footprint of water and wastewater services is currently following the worldwide trend of GHG emissions accounting in any industrial activity. Although the contributions of these services to the global GHG emissions is very low compared to other services - in France for instance water and wastewater services account for less than 1% of the total GHG emissions, whereas transportation accounts for 27% - accounting methodologies have been adapted to suit their specificities.

When dealing with carbon footprint evaluation, it is worth keeping in mind the following statements:

- Emission factors give the equivalent amount of CO2 that is emitted through one process unit or by the production of one given goods. The “emission factors” shall be estimated locally. The emission factor of 1 kg of NaClO will not be the same in Germany and in Moldova. The emission factor of electricity is of prime importance since electricity generally accounts for a large part of GHG emissions in water and wastewater services. This factor is largely dependent on the way electricity is produced in the country (91 gCO2/kWh in France, 521 gCO2/kWh in Moldova because the sources of energy production are not the same).

- The results of carbon accounting are highly uncertainty (up to 40 %) due to the lack of precision in the description of the processes and in the emission factors and in the various assumptions that are made during the study.

- The definition of the various scopes is not homogeneous among the various studies addressing carbon footprint and benchmark between water and wastewater services of different cities is therefore not meaningful.

- Carbon footprint studies should be used as tools for identifying the main contributors to GHG emissions within the entity at stake and for targeting priority improvements to reduce them, rather than as absolute indicators. The re-evaluation of the carbon footprint should be done regularly to monitor the improvements made year after year.

The accounting of GHG emissions is generally distributed into several categories to allow for a better identification of the major contributors to GHG emissions.

Distribution by activity

GHG emissions of water and wastewater services - as for other industrial sectors - are usually grouped into different categories that represent the various activities of the company: operation and works or operation and asset management (maintenance) for instance.

Distribution by scope

Most national and international bodies in charge of definition the rules for carbon accounting (ADEME in France and GHG Protocol in the USA for instance) recommend a fragmentation that includes the three scopes presented below. However the precise boundaries of these scopes are sometimes unclear and may not be the same from one study to another.

- Scope 1: direct emissions generated by processes or pieces of equipment owned or controlled by the entity
- Scope 2: indirect emissions associated to the import and/or export of electricity or heat
- Scope 3: emissions generated by the activity of the entity but coming from a site or from operations that are not under the control of the entity at stake

This distribution, when applied to water and wastewater services allows to identify the main sources of GHG emissions for each scope, as presented in Table 1. The intrinsic GHG emissions of a WWTP (CH4 and CO2 emissions) are not included in the table since they are generally excluded from the various GHG accounting methodologies due to the fact that these emissions would be the same as the ones generated if wastewater was discharged to the environment without any treatment.

Table 1 Main contributors to GHG emissions for water and wastewater services

Activity	Scope 1	Scope 2	Scope 3
Water	Fuel consumption for vehicles Landfilling of wastes (solid waste and sludge)	Electricity consumption	Purchase of chemicals, pipes, connections, filling material Maintenance activities
Wastewater	Fuel consumption for vehicles Landfilling of wastes (solid waste and sludge) Uncontrolled anaerobic digestion of sludge, methanisation of liquid effluents	Electricity consumption	Purchase of chemicals, pipes, connections, filling material Maintenance activities

Within existing carbon accounting systems it is also common practice to include the “avoided emissions” that account for the emissions that are avoided through various mechanisms implemented in the entity. The most common example comes from the implementation of a waste-to-energy plant that allows to recover some energy that would otherwise have been produced with fossil fuel.

1.5. CURRENT SITUATION IN ACC

The development stage of Moldova has not yet provided opportunities to switch from heavy polluting industrial facilities and services towards greener technologies that would significantly impact the GHG emissions of the country. However efforts have been made to provide adequate conditions for the development of “green” projects (see Section 1.6), especially with regards to the definition of an appropriate legal framework.

As for any other Moldovan company, ACC is too much concerned by financial issues to devote a lot of resources to specifically address GHG emissions in its strategic planning.

Awareness of ACC management towards climate change issues and potential GHG emission reductions achievable within ACC activities seems low, and no evidence of projects targeting GHG emissions has been found during the investigations performed in the course of the feasibility study.

However the three “Rs” principle (reuse, reduce, recycle) is well-known under an informal but nonetheless quite efficient way in all Moldovan population. This is mainly true as far as electricity is concerned (Figure 1) due to the high relative cost of electricity in Moldova (Table 2). Incidentally these efforts related to energy savings directly contribute to reducing the carbon footprint of ACC since electrical consumption usually represents the main part of GHG emissions in water and wastewater services, all the more when fossil fuel is the main source of electricity production, which is the case in Moldova.

The emission factor for electricity in Moldova has been assumed to be 521 gCO2/kWh in all calculations presented in this report (Table 3).

Figure 1 Evidence of informal incentive to energy reduction at Chisinau WWTP

Table 2 Electricity tariff in Moldova as of November 2011

Electricity supplier	Rate from 19/01/2010 MDL/kWh	New rate from 15/04/2011 MDL/kWh
RED Union Fenosa		
- For consumers connected to high voltage networks (35 - 110 kV)	0.95	1.07
- For consumers connected to medium voltage networks (6 - 10 kV)	1.33	1.34
- For consumers connected to low voltage networks (up to 0.4 kV)	1.33	1.48
RED Nord		
- For consumers connected to medium voltage networks (6 - 10 kV)	1.43	1.45
- For consumers connected to low voltage networks (up to 0.4 kV)	1.43	1.57
RED Nord- Vest		
- For consumers connected to high voltage networks (35 - 110 kV)	1.43	1.20
- For consumers connected to medium voltage networks (6 - 10 kV)	1.43	1.45
- For consumers connected to low voltage networks (up to 0.4 kV)	1.43	1.57

Table 3 Emission factor for electricity in Moldova

	Source: CO_2 Emissions from Fuel Combustion (2009 Edition), IEA, Paris. CO2 emissions per kWh from electricity and heat generation																Source : US Energy Information Administration, 2007; in EBRD report " Electricity Emission Factors Review, November 2009 »				
Year	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
gCO2/kWh	704	614	578	514	710	730	685	631	739	767	738	755	515	519	476	507	521	521	521	521	521

1.6. CDM OPPORTUNITY

The Republic of Moldova signed the United Nation Framework Convention on Climate Change (UNFCCC) on June 12th 1992 and it was ratified by the Parliament on March 16th 1995. The "Second National Communication of the Republic of Moldova under the United Nations Framework Convention on Climate Change, Chisinau, 2009" provides valuable information about relevant issues related to climate change in Moldova, especially with GHG emissions.

The Kyoto Protocol was signed in 1997 under the UNFCCC. Under this international treaty, developed countries (also called Annex-I countries) committed to reduce their global greenhouse gas emissions by 5% compared to the level of 1990 over the period 2008-2012. *Clean Development Mechanism* and *Joint Implementation* allow Annex-I countries to invest in projects located outside their boarders and to use the associated greenhouse gas emission reductions, materialized by "Carbon Credits", for their compliance to the Kyoto Protocol.

The "Post-2012" is the main challenge of Climate Change policies negotiators. However, carbon finance has proven to be a powerful tool to incentivize the development of virtuous technologies, and will remain at the heart of future mitigation policies.

Moldova is not part of the Annex I Parties of the United Nations Framework Convention on Climate Change and can therefore develop Clean Development Mechanism (CDM) projects with countries belonging to Annex I.

Table 4 presents the list of the CDM projects that were on-going in 2006. From this list, it appears that one project was already targeting Chisinau WWTP. It was developed by COWI A/S (Denmark) and intended to capture methane gas and generate electricity. This project led to the parallel development of a methodology that did not exist at that time. The methodology NM0038 was then created and further integrated into AM0013 and finally into the ACM0014, which is the latest version to be used.

The approved consolidated baseline and monitoring methodology ACM0014 targets the "mitigation of greenhouse gas emissions from treatment of industrial wastewater". This consolidated baseline and monitoring methodology is based on elements from various approved baseline and monitoring methodologies and proposed new methodologies. Among them, one can find the NM0038-rev "Methane Gas Capture and Electricity Production at Chisinau Wastewater Treatment Plant project, Moldova prepared by COWI A/S, Denmark".

Table 4 CDM projects in Moldova as of June 2006 (source: Survey on CDM Project Developments in Caucasus & Moldova, Fichtner, 2006)

Project	Location	CDM Methodology	Status
Methane Capture and Biogas-to-Energy Project for Poultry Farms	Floreni, nn (Chisinau region), Pirlita	AM0016+ AMS-I.D	PDD
Leak Reduction from Natural Gas Pipeline Compressor and Gate Stations	Moldova country-wide	NM0091	PDD meth review
Landfill Gas Capture and flaring at Chisinau Landfill	Chisinau Region	AM0011	PDD DOE validation
Methane Gas Capture and Electricity Production at Chisinau Wastewater Treatment Plant	Chisinau	NM0038	PDD meth review
Moldova Soil Conservation Project	Molodva country-wide	new metholdology	PDD meth review
Moldova Biomass Heating in Rural Communities Project	Molodva country-wide	AMS-I.C. AMS-II.E AMS-III.B	registered
Hydropower rehabilitation	Dubasari	AMS-I.D	Activity started
Moldova Biofuel Project	Molodva country-wide	new metholdology	???

The main objectives of NM0038 were described as follows. "The project activity consists of the treatment of primary sludge in digester(s) and the treatment of secondary sludge and the sludge residue from the digester(s) in dewatering facilities. Produced gas from the digesters shall according to the methodology be burned. The energy in the gas can be converted into electricity and heat, in combustion plants. Further the project activity consists of spreading the dewatered sludge i.e. on fields or in forests in order to prevent further anaerobic degradation."

Table 5 Registered CDM project in Moldova as of March 2011 (source: http://cdm.unfccc.int/)

Registered	Title	Methodology
20/01/2006	Moldova Biomass Heating in Rural Communities	AMS-I.C. ver. 6 AMS-II.E. ver. 6 AMS-III.B. ver. 6
29/01/2006	Moldova Energy Conservation and Greenhouse Gases Emissions Reduction	AMS-II.E. ver. 6 AMS-III.B. ver. 6
30/01/2009	Moldova Soil Conservation Project	AR-AM0002 ver. 1

However, the CDM project targeting Chisinau WWTP has not been registered yet (Table 5), which seems to indicate that the project was abandoned considering the elapsed time since the start up of the project (2005).

The Designated National Authority (DNA) is the body granted responsibility by a Party to authorise and approve participation in CDM projects. The Republic of Moldova has created a DNA, which is part of the Ministry of Environment and Natural Resources (Table 6).

Table 6 DNA of Moldova – Contact details

Name	H.E. Mr. Ghoerghe Salaru
E-mail	clima@mediu.gov.md ghsalaru@gmail.com
Organization	Ministry of Environment and Natural Resources

	9 Cosmonautilor Str. Chisinau, Republic of Moldova
Phone	(373-22) 20-4507 / (373-22) 23-2247
Fax	(373-22) 22-6858/ (373-22) 23-2247

The opportunity of setting up a CDM project at Chisinau WWTP has been further investigated. These investigations have provided the following elements:

- All administrative procedures for CDM development are already in place in Moldova as shown by the three registered projects listed in Table 5.
- The Moldovan DNA was contacted about the CDM project targeting Chisinau WWTP. It was not aware of this project.
- The legal and technical frameworks for selling “green” electricity and connecting the green energy source to the grid are not in place in Moldova.

Based on the previous elements, the development of a new CDM project at Chisinau WWTP is not expected to be more successful than the first one if selling “green” energy is part of the project.

However CDM projects could be developed at Chisinau WWTP and at other locations providing they do not include selling “green” electricity.

Additionally, assessing the relevance of developing a CDM project should also take into consideration the following uncertainties:

- The future of Moldova with regards to EU integration (EU countries belong to the Annex I, which means that CDM project should be changed into a Joint Implementation (JI) project if Moldova enters the EU).
- The future management of the carbon market after 2012. It is very likely that similar mechanisms will replace CDM and JI projects but the organization of the market and of the trading schemes could be modified.

2. WATER TREATMENT PLANT

2.1. CONSUMPTION OF CHEMICALS

The overhauling works that could be implemented at Chisinau Water treatment Plant (WTP) would lead to a global reduction of the injected amounts of chemicals. These chemicals include the following:

- Coagulant: aluminium sulphate or aluminium hydroxide chloride
- Flocculant: polyacrylamide
- Disinfection: gas chlorine, to be replaced within the emergency investment program by sodium hydroxide

The overhauling of the coagulation/flocculation/settling would reduce the need of pre-chlorination, while the renovation of the chemical storage preparation and dosing plant associated with the upgrade of the automation system would allow for a better management of chemical injection control, which is likely to result in a global reduction of chemical consumption.

The reduction of chemicals consumption directly leads to the reduction of the carbon footprint of this activity, although the quantification of this reduction is difficult to precisely assess due to the lack of adequate operational data.

2.2. CONSUMPTION OF ENERGY

Similarly to the expected benefits of a global upgrade of Chisinau WWTP in terms of chemicals savings, it is expected that improvement works will also lead to a reduction of the energy consumption through the implementation of the following works:

- full renovation of the electrical plant (planned for the long-term)
- overall improvement of O&M procedures; for instance less water would be used for backwashing the filters (redesign of the filters and revision of the backwash procedure)

Since the carbon footprint of energy is directly proportional to the electricity consumed by the facility, a reduction in energy consumption of x % will lead to the reduction in carbon footprint due to energy consumption of x %.

2.3. CHLORINATION

A step further in the analysis of CO2 emissions generated by the various treatment options that can be implemented at Chisinau WTP is exemplified by the following discussion related to chlorination.

Two options have previously been identified to generate the hypochlorite required for disinfection purposes. A CAPEX/OPEX comparison has been done to help ACC in their decision (see the report “Proposals for the disinfection of potable water”). It is worth looking at the consequences of these two options in terms of CO2 emissions, within the limits set by the available data. A tentative evaluation of CO2 emissions of these two options has been made (Table 7) which shows the great influence of the transportation of chemicals in the final result. A distance of 50 km between the production facility and Chisinau WTP was assumed for the purpose of this evaluation, while an emission factor for transportation was taken equal to 0.270 kgCO2/(t.km) according to Ademe (Bilan

Carbone v6) for 11-19 t trucks. These assumptions should ideally be revised to take into account the local context of Moldova.

Table 7 Estimation of CO2 emissions of the two options for chlorination at Chisinau WTP

Item	Quantity		Emission factor		kgCO2 equivalent
Option 1 Electrochlorination (180,000 m3/d - 3.1 mgCl2/L average)					**604 295**
Energy	913 467	kWh/year	521	gCO2/kWh	475 916
Salt (NaCl)	693	t/year	0,170	kgCO2/kg(Ecoinvent)	117 810
Other chemicals (HCl)	1,00	t/year	1,200	kgCO2/kg pureHCl (Arkema)	1 200
Transportation of chemicals	34 700	t.km/year	0,270	kgCO2/(t.km)	9 369
Option 2 Hypochlorite bulk supply (180,000 m3/d - 3.1 mgCl2/L average)					**457 787**
Energy	5 560	kWh/year	521	gCO2/kWh	2 897
NaClO 14.6 % purety	1 180	t/year	0,372	kg/kg of product (Arkema)	438 960
Transportation of chemicals	59 000	t.km/year	0,270	kgCO2/(t.km)	15 930

Based on these results (to be considered with care due to the above mentioned assumptions), it appears that the CO2 emissions of Option 1 are 30 % higher than the ones of Option 2, whereas the OPEX of Option 1 was estimated lower than the one of Option 2 (198,215 vs. 313,851 EUR/year). This calculation shows that the transportation of NaClO in Option 2 does not compensate the large energy requirements of Option 1 (in terms of CO2 emission).

The above example illustrates the fact that when a choice between various investment options is to be made, the evaluation of the carbon footprint of these options can be done to provide another point of view in addition to the traditional CAPEX/OPEX figures.

ACC has chosen to implement Option 2 as a short-term measure at Chisinau WTP and other chlorination points along the drinking water network and Option 1 as a long-term improvement option (included in the PIP) at Chisinau WTP.

2.4. OTHER IMPROVEMENT WORKS

The improvement of the O&M procedures for backwashing the filters and the upgrade of the very design of the filters would allow to significantly reduce the water losses, which in turn would lead to chemicals and energy savings since these “reclaimed” water losses will allow for the reduction of the raw water flow rate to be pumped to the plant and to the flow rate to be chemically treated in the coagulation/flocculation/settling stage. Reducing water losses will therefore reduce the global carbon footprint of Chisinau WTP.

Additionally, fixing the roof of the sand filters would allow for some energy savings that cannot be quantified with the currently available data.

3. DRINKING WATER NETWORK

3.1. GENERAL

The current design of the drinking water network and the associated operational procedures lead to the dissipation of hydraulic energy. This mainly comes from the forced reduction of head losses at various locations along the network. This subject was already investigated in 1996 by the Energy Institute of the Academy of Sciences of Moldova which developed a project entitled “Improvement of Chisinau Energy Efficiency Of Water Supply Networks by Means of Hydraulic Turbines Application”. The goal of this project was to introduce Small Hydropower Plants (SHPP), working on the basis of hydraulic turbines with a total electrical capacity of 1,700 kW. It was mentioned in the final report that 15 million kWh of electricity might be saved with the implementation of the SHPP.

This project was not implemented and the local conditions have changed a lot since 1996. Water flow rates have significantly decreased, operating costs and electricity tariffs have changed. A new estimation has been done in the course of the present study and concluded that approximately 9,720 kWh/d of hydraulic energy was dissipated along the drinking water network (Table 9).

Without modifying the design and the operations of the drinking water network, it is worth looking at the best way of collecting this wasted energy though the implementation of adequate energy production systems.

In addition, several recommendations made in the course of this feasibility study will impact the GHG emissions of the operation of the drinking water network. The following measures will reduce these emissions, although the precise quantification cannot be done at this stage:

- Reducing the pressure of the drinking water network is expected to make water losses decrease by 10 %, which would save around 2,000 MWh/year when considering only the pumping stations of the drinking water network.
- The implementation of an effective leak reduction program would also reduce water losses.

The reduction of water losses has a two-folded effect on GHG emissions:

- Less energy is used by reducing the flow rate to be pumped (from the Nistru River, via Chisinau WTP and down to the distribution network)
- Less energy and chemicals are used to treat the raw water at Chisinau WTP

Finally, the improvement of O&M practices is also expected to reduce GHG emissions by using more efficient engines and trucks for repair works and by decreasing the frequency of repair works (fuel savings).

3.2. ADAPTED HYDRO POWER GENERATING DEVICES

Hydro power generation generally comes from the implementation of specific turbines (Pelton, Francis or Kaplan turbines are the most used worldwide) that are not adapted to situations where available hydro power is below 100 kW, since they would require a long ROI (Return On Investment) period in that case. When the available hydro power is below 100 kW and above 10 kW, it is worth investigating the possibility to use reversible pumping devices that can be used as turbines and that feature the following advantages:

- Pumps are much cheaper than specific turbines
- They are well adapted to small power generation

- They are easy and cheap to maintain
- They are easy to install on existing networks
- They are “standard” devices already known by the operating personnel
- Their overall efficiency (electrical and mechanical) is good enough (~70% when working at their optimum)
- They can be coupled to existing neighboring pumps – working as pumps and not as turbines – to supply their power requirements.
- They can be installed in parallel when high fluctuations of the water flow rate are expected (Figure 3).
- They are generally already complying with Health requirements for the equipment pieces in direct contact with drinking water.

The working principle of these pumps is very simple (Figure 2) since they allow the fluid to flow backward through the pump body thus rotating the shaft in reverse. The electrical motor of the pump is then transformed into an electrical generator.

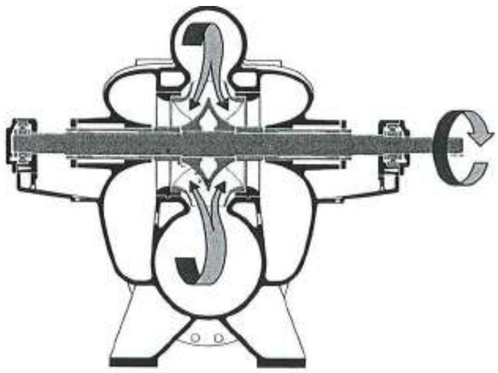

Figure 2 Section view of a centrifugal pump

Figure 3 Installation of several pump-turbines in parallel when high flow rate fluctuations are expected.

3.3. POTENTIAL FOR HYDRO POWER GENERATION

The potential for hydro power generation along the Chisinau drinking water network has been assessed based on the head loss reduction and associated averaged flow rate at various locations as presented in Table 9.

The ROI for each location has been estimated on the basis of the realistic hypotheses summarized in Table 8. Selling price of electricity has been taken equal to the current purchase price of electricity (0.088 €/kWh corresponds to 1.45 MDL/kWh with an exchange rate of 16.5 MDL/€) although in most countries "green" energy is very often purchased at a higher price than the usual market price.

It is worth reminding here that producing and selling electricity is subject to the approval of the authorities and to the technical feasibility of the connection to the grid. There is no guarantee that these two conditions can be fulfilled in a near future in Moldova, which makes the practical implementation of the following evaluation highly uncertain.

The most direct way of utilizing this energy potential would consist in coupling pump-turbines to electrical devices on the same site to avoid any electricity transit through the national grid and associated administrative procedures.

Table 8 Main hypotheses for ROI calculations

Hypotheses		
Approval of Health authorities	-	OK
Total yield (mechanical & electrical)	-	72%
Electricity selling price	€/kWh	0.088
OPEX of one pump-turbine	€/year	5,000

Table 9 Identification of relevant locations where turbines could be installed

Location	Dissipated energy kWh/d	Available power kW	CAPEX €	Available energy kWh/year	Potential revenues €/year	ROI year
Downstream Ciocana reservoirs	223	9	29,563	58,505	5,141	209.2
Upstream Codru reservoir	1,006	42	80,794	264,317	23,228	4.4
Upstream Gribov reservoirs	31	1	17,031	8,159	717	no financial gain
Upstream Telecentru reservoirs	241	10	30,786	63,418	5,573	53.7
Downstream Ialoveni PS	121	5	22,886	31,682	2,784	no financial gain
Downstream Codru PS	387	16	40,307	101,666	8,934	10.2
Upstream Airport reservoirs	38	2	17,505	10,064	884	no financial gain
Upstream Sîngera reservoirs	5	0	15,297	1,195	105	no financial gain
Upstream Balisevschi reservoirs	482	20	46,525	126,647	11,130	7.6
Upstream Independenta reservoirs	225	9	29,706	59,078	5,192	154.9
Upstream Valea Dicescu reservoirs	765	32	65,047	201,057	17,669	5.1
Upstream Buiucani reservoirs	348	15	37,782	91,521	8,043	12.4
Upstream Ciocana reservoirs	3,422	143	238,872	899,366	79,035	3.2
On the outlet Otel of the WTP	1,854	77	136,305	487,322	42,825	3.6
Downstream Gribov PS	67	3	19,415	17,736	1,559	no financial gain
Upstream Cartusa reservoirs	10	0	15,638	2,562	225	no financial gain
Upstream Schinoasa reservoir	131	5	23,552	34,358	3,019	no financial gain
Upstream Stauceni Reservoir	42	2	17,761	11,093	975	no financial gain
Outlet to Cosernita in SAN	9	0	15,594	2,386	210	no financial gain
Outlet to Vadul Lui Voda in SAN	314	13	35,512	82,401	7,241	15.8
Total	**9,720**	**405**	**935,879**	**2,554,532**	**224,489**	

This evaluation shows that only four locations display a ROI shorter than 5 years or so, for a total amount of power of 294 kW out of a total identified available power of 405 kW. These four facilities could generate 1.9 million kWh/year, which would bring revenues estimated at 142,757 €/year after the ROI periods when considering a total OPEX of 20,000 €/year for all four facilities (Table 10).

Table 10 Estimation of revenues brought by electricity generation and selling at four locations

Location	Dissipated energy kWh/d	Available power kW	CAPEX €	Available energy kWh/year	Potential revenues €/year	Revenues after ROI period €/year
Upstream Codru reservoir	1,006	42	80,794	264,317	23,228	18,228
Upstream Valea Dicescu reservoirs	765	32	65,047	201,057	17,669	12,669
Upstream Ciocana reservoirs	3,422	143	238,872	899,366	79,035	74,035
On the outlet Otel of the WTP	1,854	77	136,305	487,322	42,825	37,825
Total	**7,047**	**294**	**521,019**	**1,852,061**	**162,757**	**142,757**

The use of hydro power generated by pump-turbines would save the amount of fossil fuel which would be consumed for the production of 1,852,061 kWh/year and consequently it would reduce by 965 tCO2/year the CO2 emissions in Moldova.

3.4. ENERGY EFFICIENCY INCREASE

Another way of reducing the global energy consumption – and the carbon footprint at the same time – simply consists in improving the current energy efficiency through repair or renewal of existing pumps.

The detailed evaluation of energy savings through replacement of pumps can be found in the report entitled “Investment Program - Water Supply Network". Table 11 displays the group of pumping stations where a ROI has been estimated to be below 10 years; the pumping stations identified as the ones to be included in the emergency investment plan are highlighted in red.

In Table 12, energy savings and associated reduction of CO2 emissions are presented for the renewal of all pumping stations identified in Table 11 and only for those included in the PIP (in red).

These tables show that the implementation of the emergency plan (PIP) will allow to reduce by approximately 3 % the total energy consumption for pumping, which is roughly half the total potential of energy savings. These energy savings will account for the reduction of approximately 1,200 tCO2/year of the CO2 emissions associated with energy production in Moldova.

Table 11 Energy savings for locations where ROI is below 10 years

	Energy savings kWh/year	Financial savings €/year	CAPEX €	ROI year
Ghidighici PS	78,395	6,354	11,515	1.8
Ghidighici wells	72,137	5,847	10,909	1.9
Balsevsc PS	75,420	6,097	12,727	2.1
Ialoveni PS	316,316	25,836	23,030	0.9
Ialoveni wells	251,478	20,540	20,000	1.0
Buiucani Z3 PS	84,171	6,808	8,485	1.2
Buiucani Z4 PS	531,451	42,986	30,909	0.7
Independenta Z3 PS	287,315	23,255	21,818	0.9
Independenta Z4 PS	353,649	28,624	29,091	1.0
Botanica PS	10,659	859	8,485	9.9
Telecentru Z4 PS	28,991	2,344	9,091	3.9
Telecentru Z4a PS	148,904	12,039	22,424	1.9
Schinoasa PS	94,481	7,630	9,697	1.3
Tohatin PS to Tohatin	18,861	1,603	8,485	5.3
Tohatin PS to Colonita	53,650	4,560	10,909	2.4
Aeroport PS	21,312	1,799	8,485	4.7
Codru PS	251,036	20,303	26,667	1.3
Treapta II a raw water	1,021,343	83,023	447,273	5.4
Treapta II a treated water	464,269	37,740	29,697	0.8
Total	**4,163,838**	**338,248**	**749,697**	
Total (emergency plan)	2,277,929	184,697	537,576	

Table 12 Summary of energy savings and associated CO2 emission reduction

Total energy consumption in 2010	kWh/year	65,148,588
Potential annual savings	kWh/year	4,163,838
		6%
	tCO2/year	2,169
Annual savings (emergency plan)	kWh/year	2,277,929
		3%
	tCO2/year	1,187

3.5. STRUCTURAL CHANGES

The estimations presented in the above paragraphs are based on a "business as usual" scenario when the design and the operation of the drinking water network is not modified compared to the current situation. However, significant modifications are recommended in the near future to optimize this network (see the report entitled "Investment Program - Water Supply Network"). These modifications affect the previous calculations especially through the following facts:

- The shutdown of the Statia de Apa Nistru (SAN) water treatment plant lead to the shutdown of the treated water pumping stations Treapta II and IIa
- Shutdown of Codru PS
- The expected production from Ialoveni well field under normal condition will concern the supply of the Zone 4a - Schinoasa. The existing pumping station of Telecentru supplying this Zone will be impacted
- The expected production from Ialoveni well field under normal condition and for the emergency plan will impact the design of the pumps of the production system of Ialoveni.

- The pipe at the outlet of the WTP will need to be changed so that it is pressure resistance enough. The CAPEX of implementing a pump-turbine station at the outlet of the WTP will then significantly increase compared to the previous calculations where it was accounting only for the pump-turbines and direct ancillaries.

4. SEWERAGE NETWORK

4.1. CURRENT SITUATION

No chemical is currently injected into the wastewater network by ACC. The GHG emissions of the operation of the wastewater network mainly come only from the energy consumed for pumping where the network is pressurized and to a lesser extent from the fuel consumption of the vehicles used by operational teams.

4.1.1. ENERGY CONSUMPTION

The energy data recorded by ACC allows to depict the global situation in terms of energy consumption of the wastewater pumping and treatment system.

The average monthly energy consumption for the whole wastewater pumping and treatment system in Chisinau (including Colonita WWTP and Vadul lui voda WWTP) amounts to 1,600 MWh in the period 2007-2010 (Figure 4). The wastewater treatment at Chisinau WWTP accounts for 60% of this figure, while pumping along the wastewater network accounts for 40% - the energy consumed at Vadul lui voda and Colonita WWTPs being neglictible.

It is worth mentioning here that the fraction of energy used for wastewater pumping at Chisinau WWTP (443 MWh/month) accounts for slightly more than 70% of the total energy used for wastewater pumping.

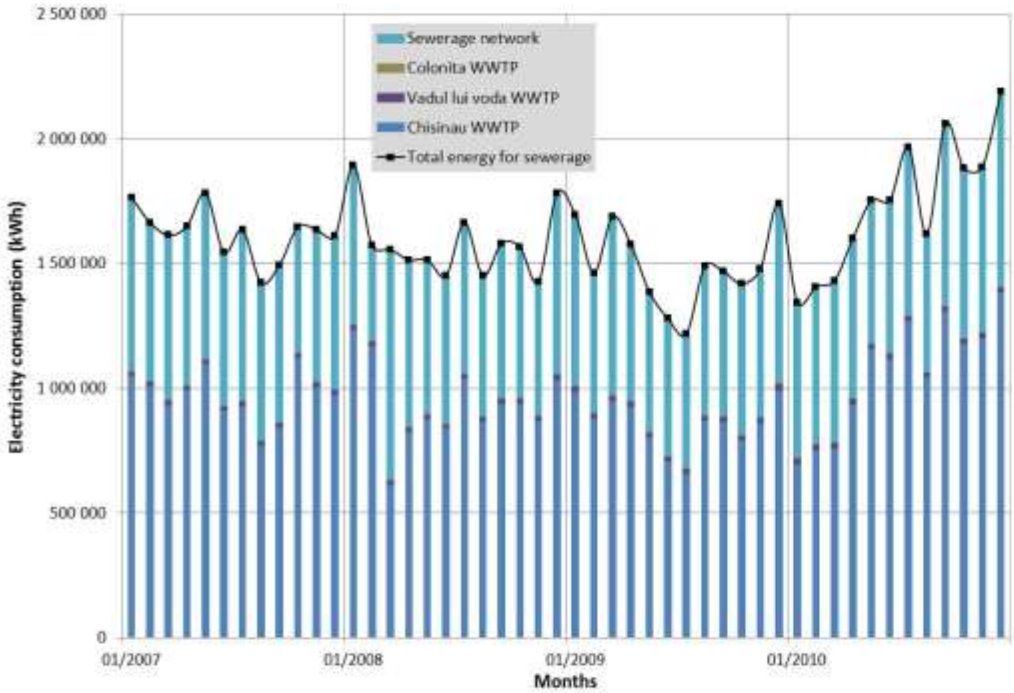

Figure 4 Electricity consumption at the pumping stations of the sewerage network and at the WWTPs.

4.1.2. FUEL CONSUMPTION OF VEHICLES

Estimating the fuel consumption of the operational teams in charge of maintaining the wastewater network is difficult due to the absence of adequate records within ACC.

However it is obvious that the fleet of vehicles currently used by ACC is very old and the fuel consumption of some of the trucks was reported to be as high as 100 L per 100 km, which can be significantly reduced by purchasing new trucks.

It is estimated that about 1,250 tCO2/year can be saved by renewing the fleet of vehicles dedicated to the operation of the wastewater water network (see section 4.6).

4.2. IMPROVEMENT OF EXISTING PUMPING STATIONS

The report entitled "Wastewater collection system" displays the major recommendations with regards to how and where energy savings can be done along the sewerage network. This audit highlighted the fact that huge energy savings (Table 13) can be done through the implementation of the following recommendations:

- Replacement of the pumps that display the main energy savings potential
- Reduce of artificial head losses that have been introduced by throttled valves

These modifications would allow to save approximately 3,451,000 kWh/year i.e. the equivalent of 1,800 tCO_2/year.

Table 13 Energy consumption for pumping in MWh/year

	WWTP PS	Other PS	Total
Average (period 2007-2010)	5,314	2,156	7,470
Future (preliminary estimates)	2,100	1,919	4,019

This improvement is addressed in the recommendation "Rehabilitation of PS" included in the PIP.

4.3. STRUCTURAL MODIFICATIONS OF THE NETWORK

There is no plan for reducing the length of existing pressurized wastewater network (i.e. change into gravity pipes). No energy savings is expected from this side.

On the contrary, the future connection of suburban areas (Zones W, N and E) to the existing wastewater network would increase the length of the network and some of the new pipes would be pressurized, thus increasing the pumping requirements and the consumption of energy.

4.4. POTENTIAL FOR HYDRO POWER GENERATION

Similarly to what could be implemented on the drinking water network, it is worth looking at the potential for hydro power generation along the wastewater network although the implementation of turbines in this case is subject to specific protections. In case a significant water level drop along a gravity pipe and a sufficiently high wastewater flow rate in the same pipe are identified, then the implementation of a turbine can prove to be cost-efficient and a good way to generate "green" energy that can be sold or directly used on-site.

There is no significant potential of hydro-power generation on the wastewater network of ACC. The height of the water fall at the outlet of Chisinau WWTP is less than 5 m, which is the approximate lower limit below which it is not cost efficient to install a turbine.

4.5. HEAT PUMPS

In 2007, more than 500 projects where heat pumps were installed on wastewater networks were in operation worldwide. This installation of such a technology is presented in Figure 5.

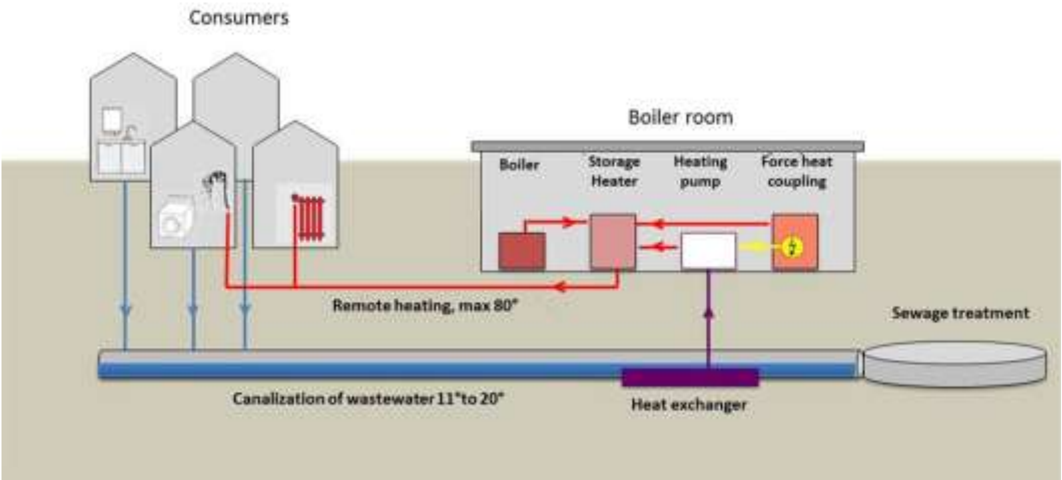

Figure 5 Sketch of heat pump installed in a wastewater network

Heat pumps allows to extract some heat from the wastewater (or another heat source such as soil or air or another fluid) to feed domestic or industrial heating systems or hot water networks. The thermal power that can be recovered from the wastewater network is given by the following formula:

P (kW) = 1.16 x Q (m3/h) x ΔT (K)

Where :

- P: power
- Q: wastewater flow rate
- ΔT: temperature difference in the wastewater (inlet – outlet of the heat pump)

Example of recovered thermal power:

- Q = 500 L/s = 1,800 m3/h
- ΔT = 1 °C = 1 °K
- P = 2,088 kW

The criteria that must be fulfilled to start further investigations in evaluating the potential heat recovery from the wastewater network are as follows:

- Potential consumers shall be present near the wastewater network. The customers' requirements in terms of heating capacity and characteristics shall be adapted to what a heat pup can deliver. For instance, the more constant the heat demand, the better. The installation of a heat pump to partially meet the heat demand of a swimming pool would be an ideal case.
- A minimum wastewater flow rate of 15 L/s shall be available in the sewer and the flow rate shall be as constant as possible.
- A minimum of 150 kW shall be available as recoverable power.
- It is also important not to impede the performances of the downstream WWTP by lowering too much the temperature of the wastewater.

At first, the situation in Chisinau appears to be quite favorable to the installation of heat pumps along the wastewater networks for the following reasons:

- The hot water network extends over the whole city.
- The wastewater flow rate is higher than 15 L/s in about 80 km of wastewater pipes. The pipes in central Chisinau convey a wastewater flow rate of 500 up to 3,000 L/s close to Chisinau WWTP.
- The renewal of 15 km of wastewater pipes is included in the Priority Investment Program (PIP).

The installation of heat pumps at Chisinau would reduce the fossil fuel consumption required to heat the water of the hot water network and would therefore reduce the carbon footprint of this activity.

A more detailed assessment should be done in order to precisely assess the potential of this technology in Chisinau, although it is not considered as a priority work and is therefore not included in the PIP.

4.6. VEHICLES

The ACC fleet of trucks and other vehicles used for the operation of the wastewater network is very old and so are the trucks used by other local companies for septic tank drainage.

Because of the lack of precise information about the number and characteristics of the trucks and the distance traveled each year, the benefits that can derive from the renewal of the fleet can only be roughly assessed as follows.

Assumptions:

- The fleet is composed of 20 trucks of 19 t each.
- Each of them travels 100 km/d, 5d/week, 50 weeks/year.
- The total distance traveled by all trucks is then 9,500,000 t.km/year.

Such a fleet would emit about 2,565 tCO2/year when the standard French emission factor is taken into account for this kind of trucks (0.270 kgCO2/(t.km), source: ADEME BC v6).

Assuming that the current fuel consumption of ACC vehicles is about 1.5 the one of the average EU fleet, the renewal ACC fleet by more recent vehicles could reduce the carbon footprint of this activity by about 1,250 tCO2/year.

This improvement is addressed in the recommendation “Equipment for operating the wastewater network” included in the PIP.

5. WASTEWATER TREATMENT PLANT

5.1. ENERGY CONSUMPTION

The energy consumption of Chisinau WWTP excluding raw water pumping was 11,487 MWh/year in the period 2007-2010 (Figure 6).

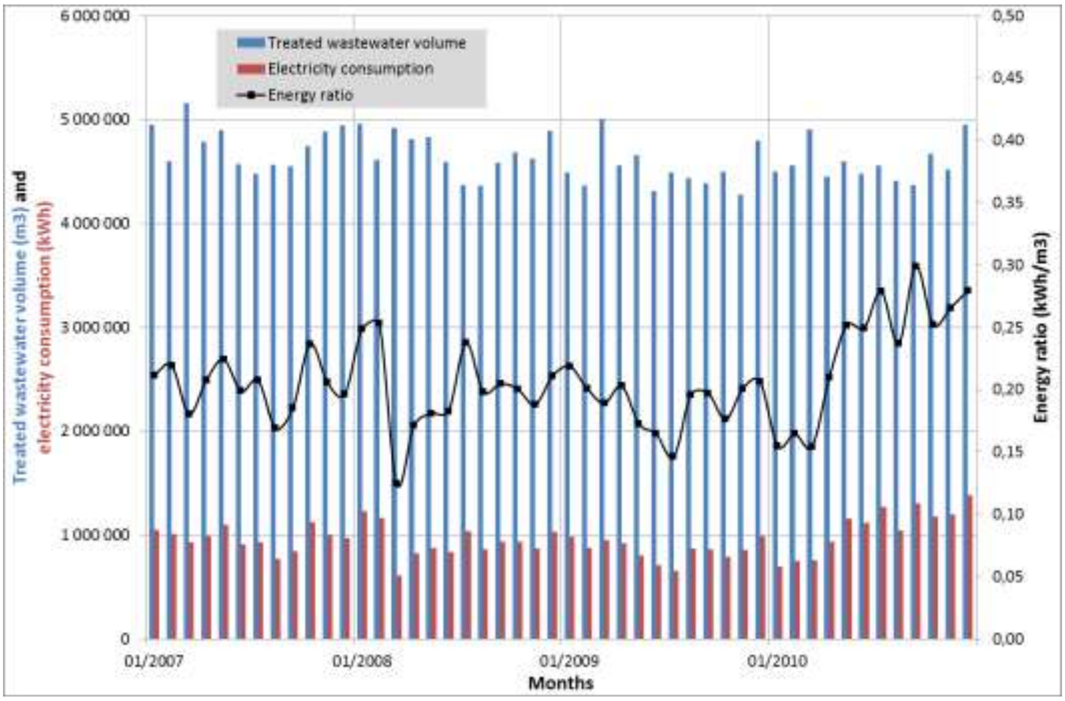

Figure 6 Monthly wastewater volumes and electricity consumption at Chisinau WWTP

For comparison purposes the same graphs are provided below for Colonita WWTP (Figure 7) and Vadul lui voda WWTP (Figure 8) although the capacity of these two plants is less than 1 % of the one of Chisinau WWTP.

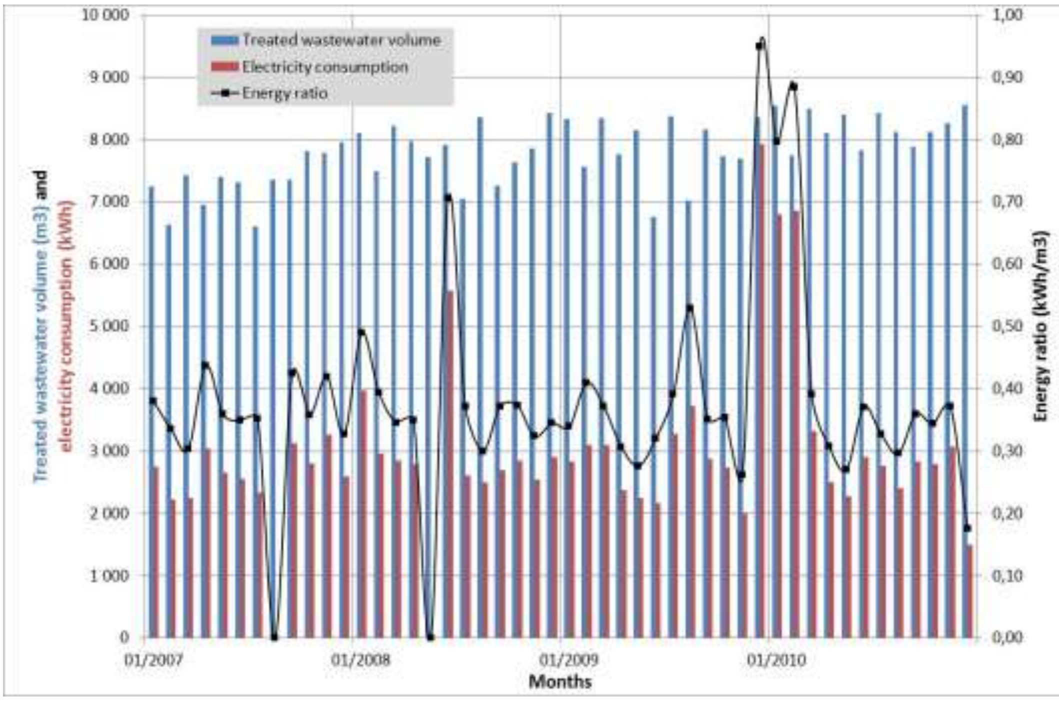

Figure 7 Monthly wastewater volumes and electricity consumption at Colonita WWTP

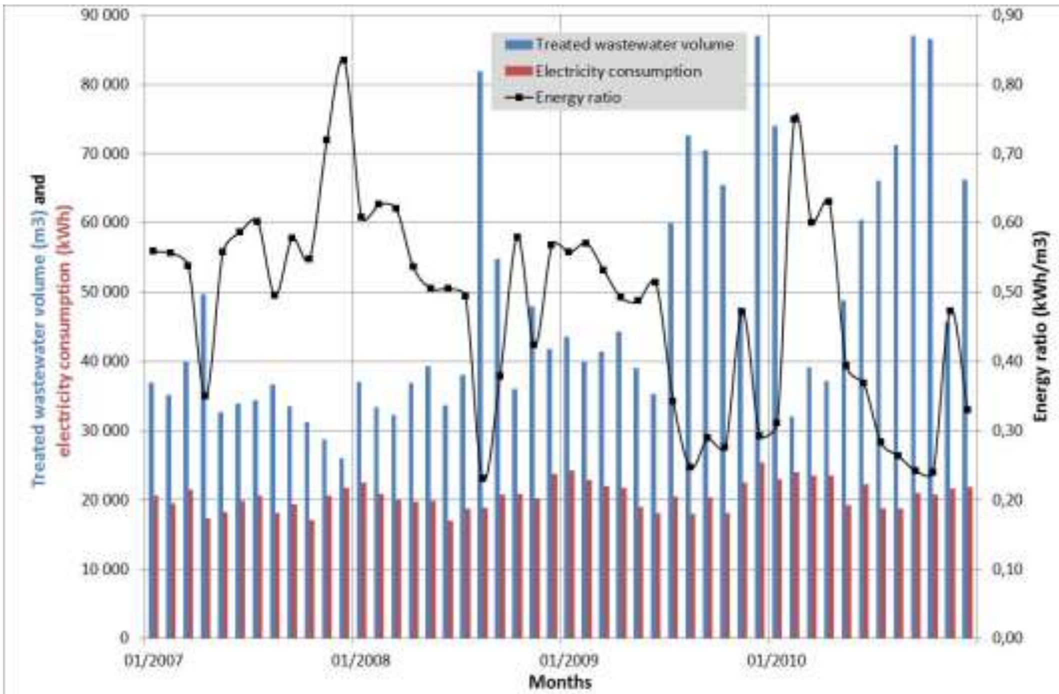

Figure 8 Monthly wastewater volumes and electricity consumption at Vadul lui voda WWTP

The calculation of the energy ratio expressed in kWh per m3 of raw wastewater indicates that all three WWTPs have a low energy consumption (Table 14). This calculation does not take into consideration the performances of the treatment – which do not comply with EU standards - and should therefore not be directly compared to standard values. However they show that there is no significant energy loss in these plants although the high variations of the energy ratio in time (especially visible for Colonita and Vadul lui voda WWTPs, which can be explained by the small capacity of these plants) clearly shows that the process operation is not very stable. The low values of the energy ratio are likely due to the very limited number of engines on site and on the relatively poor performances in terms of COD and BOD removal rather than to the optimization of the process control.

Table 14 Energy ratio of WWTPs

	Energy ratio (kWh/m3)
Chisinau WWTP	0.21
Colonita WWTP	*0.38*
Vadul lui voda WWTP	*0.48*

On one hand the optimization of the process performances recommended by the PIP are expected to require more energy, on the other hand the energy performances are expected to increase due to the renewal of air blowers and the implementation of an aeration control (also included in the PIP). A conservative estimate indicates that the global energy consumption of the wastewater treatment line will not change with the implementation of the PIP.

The sludge treatment line - which will be significantly modified by the PIP - is expected to consume more energy than today, but will also produce energy.

The implementation of anaerobic sludge digestion in Chisinau WWTP would allow to produce biogas that could be used to recover energy as heat and electricity. The current sludge production (~46 tDS/d) would allow to generate about 12,000 m3/d of biogas, which in turn would produce 27,000 kWh/d of electricity and approximately the same energy as heat.

Table 15 Anticipated situation for Chisinau WWTP after implementation of the PIP

WWTP capacity	150,000 m3/d
Average BOD concentration at the inlet	200 mg/L
Average BOD concentration at the outlet	25 mg/L
Production of biogas	4,380,000 m3/year
Electricity produced	9,855 MWh/year
Electrical coverage of the WWTP	54%
Thermal coverage of the WWTP	100%

The benefits of anaerobic digestion compared to the current situation can be derived from the comparison of the baseline scenario (current situation with Geotubes followed by sludge landfilling) with the scenario of the recommended sludge treatment options including thickening, anaerobic digestion, dewatering and landfilling.

A qualitative comparison shows that the implementation of anaerobic digestion decrease the CO2 emission in two ways compared to the baseline scenario:

- Direct GHG emissions of landfilled sludge after digestion and dewatering are lower than the ones of the sludge landfilled after the geotubes (VSS content is lower).
- Biogas generated by anaerobic digestion is converted into “green” energy which can be used instead of conventional electricity and heat produced with fossil fuel, thus avoiding the amount of GHG emissions that would be generated by a conventional power plant to produce the same energy recovered through anaerobic digestion.

A quantitative comparison can be found in “Methane Gas Capture and Electricity Production at Chisinau Wastewater Treatment Plant project, Moldova prepared by COWI A/S, Denmark”. This study showed that the emission reduction was in the order of magnitude of 70,000 tCO2/year in 2004 (the baseline scenario included sludge pits and not the current Geotubes).

5.2. CONSUMPTION OF CHEMICALS

The only chemical used at Chisinau WWTP today is the polymer injected prior to the Geotubes. The amount of polymer consumed per day is about 80 kg, which gives about 65 kgCO2/d.

The new wastewater and sludge treatment line recommended in the future configuration of Chisinau WWTP (option 2) will necessitate the use of various chemicals, which will increase the CO2 emissions originating from chemical consumption up to around 8 tCO2/d (Table 15).

Table 16 CO2 emissions due to chemical consumption in the future situation (Option 2)

	Consumption	Emission factor	CO2 emission
	kg/d	kgCO2/kg pure product	kgCO2/d
Methanol	1,499	0.512	767
FeCl3 (41%)	8,672	0.81	7,024
Polymer	310	0.81	251
Total			8,042

However, the modification of the wastewater and sludge treatment line recommended in the PIP will only require the utilization of polymer in the quantity indicated in Table 15, which will increase the CO2 emissions from 65 kgCO2/d up to 251 kgCO2/d, i.e. an increase of 68 tCO2/year, which can be neglected compared to the other emission reductions inferred by the implementation of the PIP.

6. CONCLUSION

The various actions recommended in the PIP are listed in Table 17 together with their impact in terms of CO2 emissions. Almost all actions induce a reduction of CO2 emissions, mainly through energy savings (18,400 MWh/year). If all of them (excluding WW-T-01 / WW-P-01) are implemented, the reduction in CO2 emissions would amount to approximately 7,000 tCO2/year although a high uncertainty (~30%) is attached to this figure.

The only action that would increase the CO2 emission is the one related to the “Treatment of the water produced from Ialoveni wellfield”.

The major impact comes from the recommended works at Chisinau WWTP (WW-T-01 / WW-P-01), especially the implementation of anaerobic sludge digestion, which alone would reduce GHG emissions by 5,000 tCO2/year through “green” energy production and save approximately 70,000 tCO2/year as estimated by COWI in 2004.

Based on the above figures, it seems relevant to further investigate the possibility to use carbon finance mechanisms (CDM or others) to help implementing anaerobic digestion at Chisinau WWTP if funds are missing. The action plan for such a task should include the following:

- Discuss with COWI and the Moldovan DNA to clarify the reasons why the first CDM project targeting Chisinau WWTP failed (the true reason has not been found in the course of this preliminary study).
- Find a project developer
- Study in depth the PDD established by COWI and update this document with the current baseline scenario (Geotubes) and future situation (PIP actions only or final recommended situation for Chisinau WWTP?) and assess if a CDM project would be technically feasible (additionality principle is met?) and financially relevant considering a carbon price to be estimated (6 EUR/t?).

The outcome of such a project development is today highly uncertain due to the international context and especially to the evolution of the international rules of CCM project and of the carbon price itself.

Table 17 PIP actions and their carbon footprint impact

Description	Code	Carbon footprint reduction	Quantification in kWh/year	Quantification in tCO2/year
Urgent rehabilitation work including electro-chlorination plant	DW-T-01	Yes, through various improvement measures (chemicals and energy consumption savings, reduction of water losses) but not significant	- ε	- ε
Treatment of the water produced from Ialoveni wellfield	DW-T-03	No, additional treatment will increase the carbon footprint	+ ε	+ ε
Rehabilitation of 190 km of water pipes and 3,270 block	DW-N-05 / DW-N-	Yes, through the reduction of water losses and of repair	- 775,000	- 400

Description	Code	Carbon footprint reduction	Quantification in kWh/year	Quantification in tCO2/year
service connections+ hydraulic fittings	02 DW-N-04 / DW-N-01	works (with more efficient trucks and engines) and decommissioning of Codru PS		
Rehabilitation of reservoirs	DW-N-15 / DW-N-14	No	0	0
Pressure reduction on the network	DW-N-04 / DW-N-12	Yes, through the reduction of water losses and the optimization of pumping energy	- 2,000,000	- 1,000
Adaptation of the water distribution system to the new production scheme: By-pass of SAN facilities, New PS from Zone 2 to Tohatin, New PS from Tohatin tanks to VdV Ghidighici dilution	DW-N-13	Yes, through the decommissioning of SAN (the energy needed to pump the water from STA is slightly less than the one needed to pump from SAN) but not significant	- ε	- ε
Rehabilitation of the existing PS	DW-P-01	Yes, through energy savings	- 2,277,929	- 1,200
Equipment for operating the drinking water network	DW-OM-03 /DW-OM-04 DW-OM-01 /DW-OM-05 / DW-OM-02	Yes, through the reduction of fuel consumption of the vehicles	0	- 1,250
Emergency plan (rehabilitation of the wells + treatment facilities + adaptation of distribution system)	DW-O-05 / DW-O-06 / DW-O-04	No	0	0
First phase of upgrading the WWTP for Chisinau (New pre-treatment, light rehabilitation of primary settling, biological tanks and secondary clarification, separated thickening for biological excess sludge, anaerobic	WW-T-01 / WW-P-01	Yes, mainly through energy production by sludge anaerobic digestion and avoided emissions	- 9,855,000	- 5,130 -70,000 (estimated in 2004 by COWI)

Description	Code	Carbon footprint reduction	Quantification in kWh/year	Quantification in tCO2/year
digestion with energy generation, sludge dewatering)				
Renewal of sewers (15 km)	WW-N-02 / WW-N-01	No, unless heat pumps are installed	0	0
Rehabilitation of PS	WW-P-02 / WW-P-03	Yes, through pumping energy savings	- 3,451,000	- 1,800
Equipment for operating the wastewater network	WW-OM-01	Yes, through the reduction of fuel consumption of the vehicles	0	- 1,250
Purchase of MIS equipment	O-OM-01	No	0	0
Replacement of the electrical lines in STA, SAN, SESE, SSP	O-OM-03	No	0	0
SCADA: Upgrading or renewal of the equipment for drinking & wastewater PS + Data Storage + Implement a unique tool for data processing	O-OM-02	No	0	0
Total				

It is worth further investigating two other actions with ACC representatives to evaluate in more details the possibility to develop realistic projects that would value the renewable energy sources currently owned by ACC (Table 18).

Table 18 Other relevant actions to improve the carbon footprint

Description	Carbon footprint reduction	Quantification
Installation of pump turbines along the drinking water network	Yes, through the production of renewable energy (up to 1,852,061 kWh/year)	965 tCO2/year
Installation of heat pumps along the wastewater network	Yes, through the production of green energy	Detailed investigations are needed to assess the compatibility of such projects with local conditions

7. EXAMPLES IN EASTERN EUROPE

7.1. GENERAL

The following three examples describe the anaerobic digestion projects that were implemented in Sofia (Bulgaria), Budapest (Hungary) and Pilsen (Czech Republic).

While the project in Sofia took advantage of the financial benefit brought by the development of a JI project – the same JI project would probably not be accepted today – the other two were implemented without carbon finance activity, probably because the additionality principle was not met. This means that they were financially viable without resorting to any carbon finance mechanism.

7.2. SOFIA, BULGARIA

A Joint Implementation (JI) project called “Methane gas capture and electricity production at Kubratovo Wastewater Treatment, Sofia Bulgaria”, has been recently developed to implement a CHP plant at Kubratovo WWTP, which is the most technology advanced WWTP in Bulgaria.

7.2.1. GENERAL INFORMATION

General data

Table 19 General data for Kubratovo WWTP (in 2010)

Population connected to the sewerage system	75%
WWTP capacity	400,000 m3/d
Average BOD concentration at the inlet	103 mg/L
Average BOD concentration at the outlet	15 mg/L
Production of biogas	8,174,954 m3
Methane fraction	62%
Electricity produced	15,288 MWh
Electrical coverage of the WWTP	90%
Thermal coverage of the WWTP	100%

Due to the exceptional topographic situation of Sofia, all the collected wastewater flows by gravity to the same outlet and can be treated in one wastewater treatment plant, located in the Kubratovo village – 20km away from Sofia, next to the River Iskar.

The volume of treated wastewater is expected to increase, with a growing share of population being connected to the network. In the same way, the average DBO of incoming wastewater (average) is expected to go up as the standards of life of Sofia inhabitants rises.

Wastewater treatment process

Pre-treatment: screening, grit and grease removal

Primary treatment: primary settling tanks

Secondary treatment: aeration tanks, N& P removal

Sludge treatment process

Mesophilic anaerobic digesters (4 x 7,000 m^3 each), fed with primary and secondary sludge

Mechanical dewatering of digested sludge

Residual sludge valorization through agricultural use

Energy

3 Combined Heat and Power co-generators (capacity: 1,063 kW electric / 1,088 kW thermal each)

Fed with biogas from the 4 digesters: 22,000 m^3/d

The electricity production covers 90% of the needs of the WWTP.

Heat production covers both process and heating needs.

7.2.2. HISTORY OF THE JI PROJECT

The Sofia wastewater treatment plant was commissioned in 1984, with an original Russian design and equipment. At the time, it was fully owned and managed by the Water Company of Sofia, which itself belonged to the Municipality of Sofia. The plant encountered operational issues in the operation since the very beginning, especially on the sludge digesters. These were definitely stopped in 1992, and from then on, the sludge was directed to drying beds, before being landfilled.

This resulted in methane emissions, odor nuisances, and more generally in a poor environmental performance of the sludge treatment process. Several plans were made in order to recover from this situation, first by the Water Company of Sofia and then by Sofiyska Voda. None of these attempts was successful, mainly due to the lack of financing.

The idea of developing a Joint Implementation project to refurbish the sludge treatment process emerged in 2004. At this time, “early-movers” were expecting that the Kyoto Protocol would come into force in a close future, and started looking at the associated carbon finance opportunities.

The additional revenues from selling the Carbon Credits (AAUs and ERUs) made the refurbishment project viable. The four digesters are back in operation, and the biogas is fed in a new Combined Heat Power (CHP) unit. The CHP unit provides electricity and thermal energy for on-site use, and the electricity surplus is sold to the national grid. The residual sludge is dewatered and used as agricultural fertilizer.

The project is registered under the Bulgarian Track 1 of Joint Implementation mechanism.

It will deliver an average of 100,000 $TeqCO_2$ emission reductions per year over the 2007-2012 period.

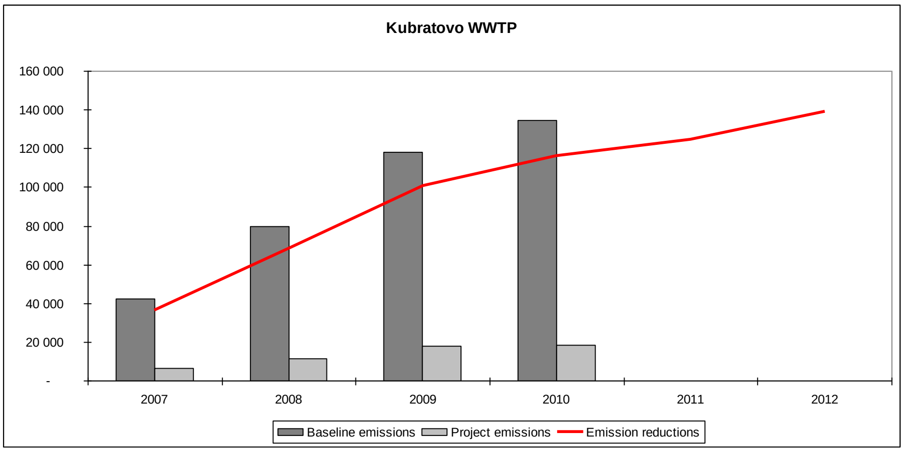

Figure 9 Annual CO2 emissions (in tCO2eq) at Kubratovo WWTP

The environmental co-benefits of this project are the following:

- Reduction of direct methane emissions from sludge drying beds and landfills (Figure 9)
- Reduction of CO2 emissions due to electricity and heat production from fossil fuel
- Reduction of odours
- Valorisation of sludge residual as agricultural fertilizer

The financial benefits of this project resulted in the 50% coverage of the project costs by carbon finance revenues (Figure 10 and Figure 11); the project costs included the following elements:

- Rehabilitation of the 4 digesters
- Provision of a new raw sludge pumping station
- Biogas withdrawal system
- Provision of a new sludge recirculation unit
- Provision of biogas utilization and mixing system
- Refurbishment of gas holder
- Refurbishment of heating and boiler system
- Provision of CHP gas engines

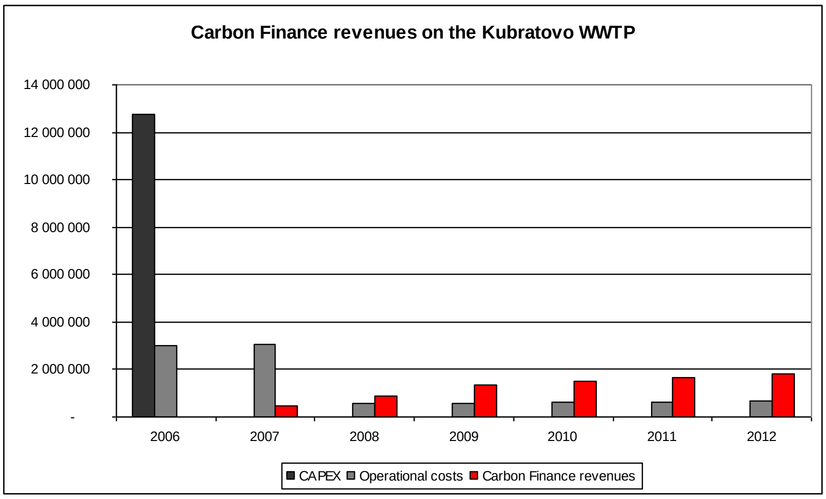

Figure 10 Evolution of costs and revenues of the project

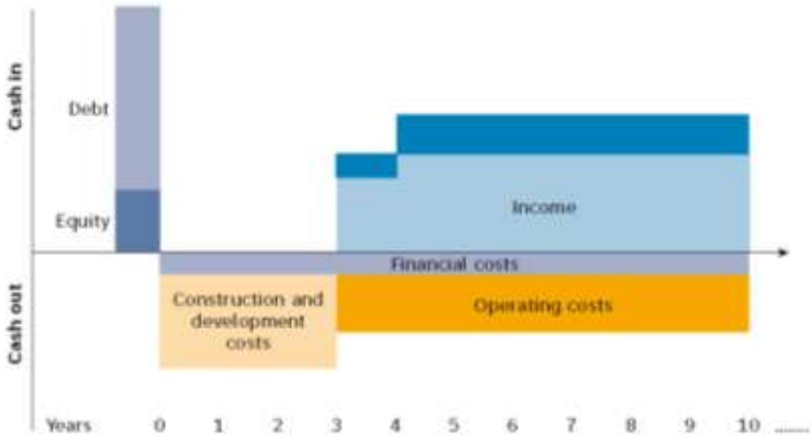

Figure 11 Structure of cash flows

7.2.3. COMMUNICATION ABOUT THE PROJECT

Sofiyska Voda took advantage of this project to communicate about the environmental benefit of implementing CHP plants as presented in the following document.

Sofiyska Voda

Installation for combined production of heat and electrical energy

The cogeneration system has been constructed in Sofia Wastewater Treatment Plant (WWTP) for producing electrical and heat energy from biogas.

The investment of Sofiyska Voda AD for ensuring the installation amounts to BGN 5 million and includes the design, purchase, delivery and installation of the co-generators. The project was commenced in 2008, and was the second stage of the project for the modernization of the sludge and gas line in the WWTP (amounting to more than BGN 10M, completed in 2007).

Technical description of the project

The cogeneration (Combined Heat and Power – CHP) is a technology for combined production of heat and electrical energy as an independent source. It uses biogas obtained in the sludge treatment process.

Three JENBACHER co-generators have been installed in the WWTP Kubratovo with an option for the installation of a further unit in the future. The total power of the three co-generators is a little over six megawatts which is sufficient to meet the needs of the plant.

At the treatment plant biogas is produced in the process of sludge digestion. Up to now it has been burnt without being utilized. It contains about 68% methane, 30% carbon dioxide and 2% other gases. The highest energy consumption for Sofiyska Voda AD is at the Wastewater Treatment Plant and the energy produced from CHP's will provide more than is necessary at Kubratovo.

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Sofiyska Voda

Capacity and operating mode of the facility

- Each engine has a daily biogas consumption of 8 000 m^3/day.
- The operating mode of the engines is two working and one standby with the possibility for simultaneous operation of all machines.

Amount of the biogas

The Sofia WWTP produces 20 000 – 25 000 m^3/day, which is enough to ensure the operation of 2 or three engines.

Utilization of the generated energy

The energy generated from each engine equal to 1063 KW/h power energy and 1088 KW/h heat energy is to be used at the plant.

Benefits of the co-generation installation

The co-generation transforms about 82% of the energy contents of the fuels into useful energy which is about twice that compared to the conventional plants. This means higher efficiency at lower price and less pollution. Putting the CHP plant into operation has an ecological, economic and social effect:

- Considerable fuel and energy cost reduction;
- Utilization of the waste product – biogas released in the sludge treatment process;
- Limiting the release of methane and carbon dioxide in the atmosphere which contributes to the improvement of the condition of the environment;
- The benefits from the harmful emissions reduction are not only for Sofia citizens, they also have national and global impact;
- It contributes to the execution of the obligation of the country regarding the reduction of the harmful emissions in the atmosphere in accordance with the Kyoto Protocol.

This project is also a part of the company's activities under the carbon emission reduction in compliance with the Emission Reduction Purchase Agreement between Sofiyska Voda AD, the EBRD Carbon Fund and the Dutch Government.

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7.3. BUDAPEST, HUNGARY

The case study of Budapest is a good example of the recent development of a wastewater and sludge treatment and disposal strategy by the local authorities of a large city. Table 20 displays the options that have been chosen to treat and dispose of the sludge of the three WWTPs in Budapest. It appears that sludge digestion has been widely implemented to benefit from electricity and heat recovery via biogas utilization, while the options for final sludge disposal are not yet satisfactory since a large amount of sludge is still currently being landfilled. The latter subject is still being discussed and local authorities are investigating the possibilities to overcome usual barriers to the other disposal options (mainly related to public acceptance of agricultural use or incineration). A presentation of the global picture of sludge management in Budapest can be found here:
http://www.acrplus.org/upload/documents/events/SEVILLE%202010/DNick_Budapest_2nd_Experts_Seminar_2010-06-16.pdf

Table 20 Sludge treatment and disposal at Budapest WWTPs (after D. Nick, 2010)

	South Pest WWTP	North-Pest WWTP	Central WWTP
Today			
Sludge treatment	Co-digestion	Dewatering and liming	Digestion (thermophilic)
Sludge disposal	Agricultural use	Landfill	Landfill
Future			
Sludge treatment	Digestion (+ electro-osmosis dewatering)	Digestion	Digestion + composting
Sludge disposal	Agricultural use	Landfill	?

Co-digestion has been implemented at South-Pest WWTP to treat together organic solid and liquid waste and sludge generated by the WWTP itself. This experience is briefly presented in the following text extracting from the website of Budapest Sewage Works Ltd (http://www.fcsm.hu/en/content/index.php/84).

Figure 12 Aerial view of South-Pest WWTP

"Electric energy from wastewater sludge and foodstuff waste

The pollution of our living waters causes a considerable environmental problem all around the world. The main sources of pollution are the industry, agriculture and population. For the purpose of protecting our living waters, the primarily applied technology is wastewater treatment, whose main goal is to prevent the arrival of polluting matters in the environment. Wastewater treatment is a high energy need process, however, through the practical utilization of organic matters harmful for the environment, a very important produce, renewable energy can be produced. The method through

which waste is removed, degraded and then reused and finally produce renewable energy is nothing else but anaerobe treatment. Biogas can be produced from the joint anaerobe fermentation of the high organic matter content sludge produced as a product of wastewater treatment and of the matters originating from urban and industrial organic waste, whose utilization considerably contribute to the lowering of the costs of wastewater treatment processes. The role of this efficient, cost saving and environment friendly technology has increased, since the removal of harmful matters at low costs becomes an ever more important issue in the programs of the governments of the various countries.
At the South-Pest Wastewater Treatment Plant, for the purpose of producing biogas, solid and liquid organic waste is managed together with sludge originating from wastewater treatment. As a first step, we execute the degrading of organic matters in thermophilic anaerobic digesters (operating temperature 55°C, useful volume: 2,000 m3), then in mesophilic anaerobic digesters (operating temperature 35°C, useful volume: 3x2,600 m3), which is a quite complicated process based on the symbiotic relation of numerous strains. Hydrolytic bacteria degrade the big molecule organic compounds with their extracellular enzymes, as a result of which short carbon chain fatty acids, carbon dioxide and hydrogen gas are produced. After that, a second group of bacteria transforms the short carbon chain fatty acids into organic acids, mainly into acetous acid. Further carbon dioxide and hydrogen gas is produced during this process. Finally methanogenes produce biogas from acetous acid and hydrogen, the methane content of which exceeds 60%. At the South-Pest Wastewater Treatment Plant, the energy content of the biogas produced as described above is transformed into electric energy by two gas engine-generators (their electric performance is 494 kW and 836 kW respectively). The produced electric energy covers 90% of the plants electric needs and 100% of its thermal needs."

7.4. PILSEN, CZECH REPUBLIC

Anaerobic sludge digestion has been implemented in many WWTPs in Czech republic. As illustration, Figure 13 and Figure 14 display the production of biogas and the associated energy production in Pilsen WWTP where the digestion process was upgraded to a fully thermophilic process in 2005.

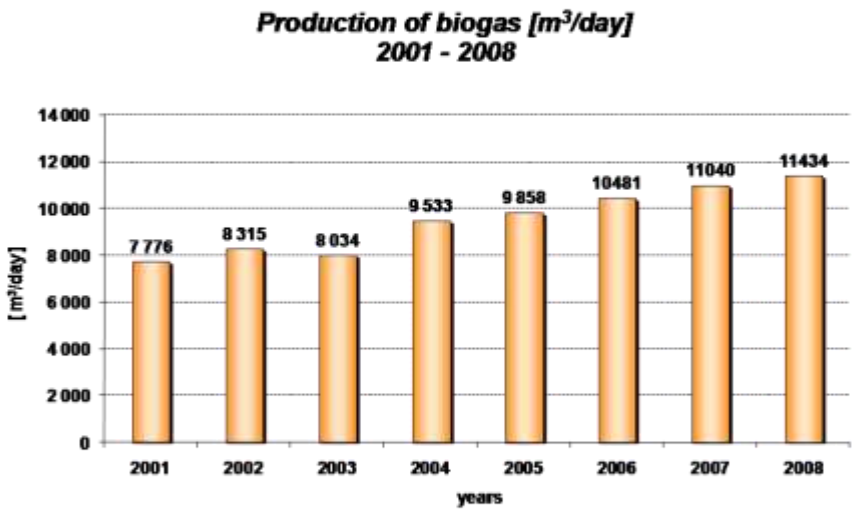

Figure 13 Biogas production at Pilsen WWTP

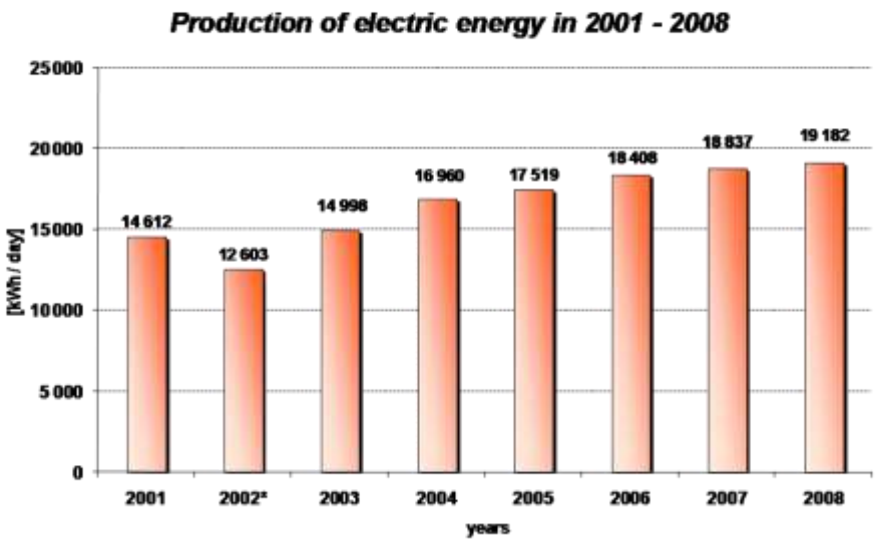

Figure 14 Electricity production at Pilsen WWTP

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