Project: BiG>East

(EIE/07/214)

Biogas Show Cases in the target region of Bulgaria

Deliverable D 6.4

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02 April 2009

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Table of Contents

Executive summary

The aim of the Show Cases is to show the way on how to realize a biogas plant and to prepare the ground for the implementation of pilot projects. This document will be used as a communication tool to motivate and convince decision makers (financers, politicians, utilities, NGOs, project developers, SMEs) to support new biogas production facilities.

Show Cases 1 and 2 demonstrates that there should be preferential prices for electricity from biogas in order to stimulate developments of the sector and corresponding ecological and social benefits. Feed in tariffs for electrical energy produced from biogas should be at least 0,12 €/kWh. Alternative mechanisms for biogas projects support like income from carbon emission reduction, better conditions for bank loans could be provided.

Biogas Show Case 1 considers pig-reproduction farm – JSC Kalchevo.
The potential biomass for biogas production is 36500 m^3/year liquid pig manure and 3000 t/year silage (maize or sunflower). Average produced biogas per year is 1000000 m^3. Electrical output would be about 250÷300 kW. Potential heat produced is about 300 kW of which about 60 % could be utilized considering current heat consumers. Biogas plant could be based on vertical complete mix digester.
Economic calculations are performed for low to medium standard plant (3100 €/kW). It is showed that at current feed-in tariffs of 0,07 €/kWh_{el} biogas project could not be profitable. Investment costs are 850000 € that is equivalent to 104000 €/year for 15 years at 8% bank interest rate. Calculated yield from electricity sale is 158500 €/year at 0,07 €/kWh_{el}. Yield from heat sale is 26000 €/year at 0,015 €/kWh_{th}. General business cost (maintenance, personnel) are 81500 €/year. Biomass cost is 95000 €/year (28 €/t). Therefore Internal Return Rate and Total Earnings are negative. Different strategies to improve the economy of the project are discussed.

Biogas Show Case 2 considers Mekom JSC, Silistra, Sitovo pig farm.
The potential biomass for biogas production is 43000 m^3/year liquid pig manure and 5500 t/year slaughter wastes. Average produced biogas per year is 1550000 m^3. Electrical output would be about 350÷450 kW. Potential heat produced is about 450 kW.
Biogas plant could be based on vertical complete mix digester. Appropriate sanitation and conditioning of slaughter wastes is important in order to comply with the regulations.
Economic calculations are performed for high standard plant (4500 €/kW). Hypothetical feed-in tariff of 0,09 €/kWh_{el} is used. Investment cost is 1800000 € that is equivalent to 215000 €/year for 15 years at 8% bank interest rate. Calculated yield from electricity sale is 296500 €/year at 0,09 €/kWh_{el}. Yield from heat sale is 38500 €/year at 0,015 €/kWh_{th}. General business costs (maintenance, personnel) are 136800 €/year. Biomass costs are not considered. Internal Return Rate is 5,2 %. Total Earnings are negative -33550 €/year. Losses could be reduced if careful planning of the biogas plant is performed.

Organisational structure for both Show Cases is simple –operator and feedstock suppliers are the same company (or are owned by one company as in Show Case 2).

Main risks for the potential biogas plants analysed are technological and regulatory.

1. Biogas Show Case: Pig-reproduction farm – JSC Kal-chevo

1.1. Basic plant design

The main biogas sources available at the farm are liquid pig manure and sunflower silage:

- 36500 m^3 liquid pig manure per year with total solids content of 3÷6%
- 3000 t/year sunflower (harvested area ~200 ha)

This feedstock determines the process technology, basic plant design and dimensions. Electrical output would be 250 to 300 kW (275 kW for the calculations).
Agricultural biogas plant operates with four process stages (figure 1.1):

1. Transport, delivery, storage and pre-treatment of feedstock
2. Biogas production (Anaerobic Digestion)
3. Storage of digestate, eventual conditioning and utilization in CHP
4. Storage of biogas, conditioning and utilisation

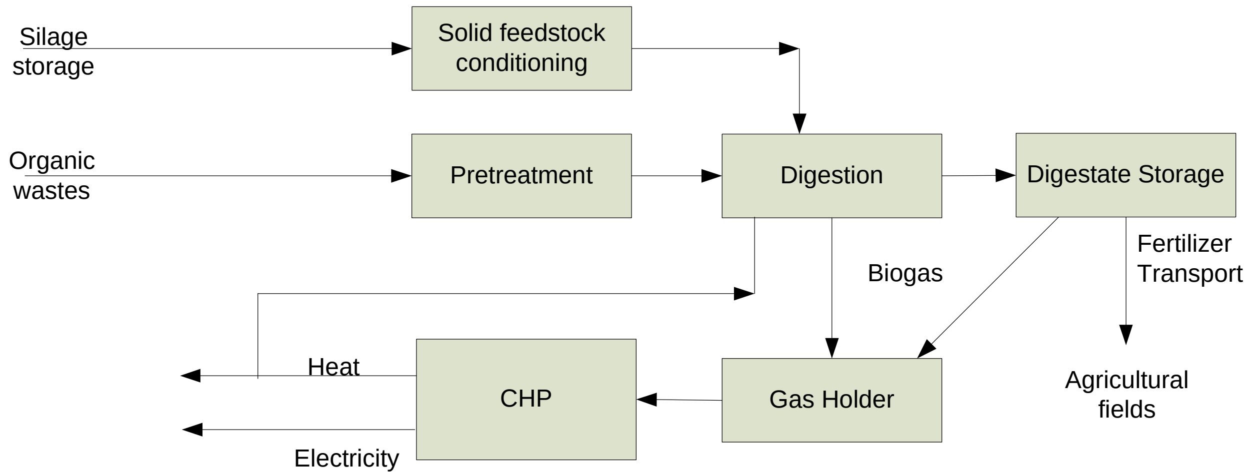

Fig.1.1. Block diagram showing the overall production process

The mass balance of biogas plant is as follows (see fig. 1.2):

Average totals solids of input materials	7,1 %
Input into biogas plant	39500 t/year
Average amount of produced biogas per ton of input material	27 m³/t
Average quality of the produced biogas	56,3 %CH4
Average produced biogas per year	1081000 m³/year
Average produced biogas per hour	123,4 m³/h
Necessary digestion volume (Digester capacity)	1200 m³
Average remaining biogas sludge without separation	38257 m³/year
Average remaining TS in biogas sludge without separation	4%

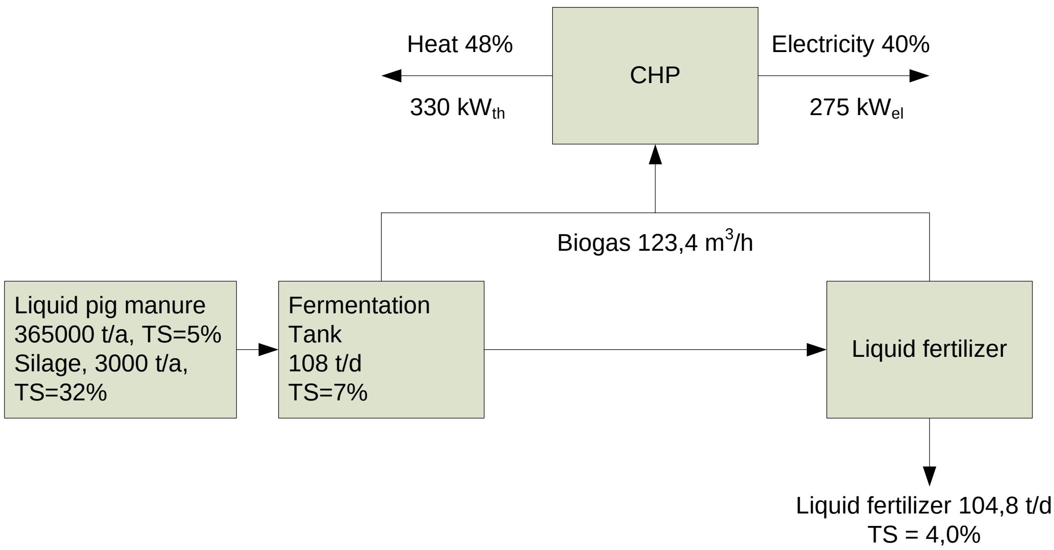

Fig.1.2. Block diagram showing the mass balance

1.2. Technology Specifications

Liquid pig manure is pumped into the pre-treatment tank and then to the digester. Silage is tipped by a loader and then fed into the digester by solid feedstock feeding system. The insertion of the feedstock into the digester has to be air-tight and should not allow leak of biogas. The armatures and pipelines used in biogas installations must be corrosion proof and suitable to handle specific types of materials (biogas and biomass). Biomass pipelines should have a diameter of 300 mm.
The digester (bioreactor) will be vertical completely mixed steel tank. Feedstock heating will be done both during the feeding process (pre-heating), and inside the digester, by heating elements. Digesters must be insulated. Appropriate stirring should be provided.
Low-pressure biogas storage should be provided.
Biogas desulphurization and drying should be provided.
The storage tanks for digestate will serve as post-digesters and should be covered with gas tight membrane. Digestate can be stored in concrete tanks or in lagoon ponds, covered by natural or artificial floating layers or by membrane covers.
Appropriate process parameters control should be provided.
Combined heat and power (CHP) generation will be used for biogas utilization. Heat produced will be used for feedstock and digester heating in the winter and for farm needs.

1.3. Economical specifications

Based on plant design (inputs and outputs) and technological solution in this chapter the economy of project is described. To calculate the project economy the BiG>East biogas calculation tool elaborated by Tobias Finsterwalder is used.

Assumptions

In order to estimate the basic economic project parameters, the following assumptions were made:

Low standard plant – 3100 €/kW (leading to 850000 € total investments)
Personnel costs – 3 €/h or 500 €/month, full time
– one operator and one administrator engaged full time
Costs for maintenance as % of investment per year:
Construction/Buildings – 2% (5800 €/year)
Machinery – 6% (12600 €/year)
Electrical equipment – 4% (2800 €/year)

Other – 2% (1000 €/year)
CHP and grid access – 0.01 €/kWh (22450 €/year for 275 kW_{el})
Gas production
14 m^3/t for pig manure with TS=5%
190 m^3/t for sunflower sillage with TS=32%
No rent for the site – own lands
No insurance – not a practice
Other costs – 0,5 €/t (20000 €/year)
Costs of biomass:
Costs for pig manure handling to get it to the plant – 0 €/t
Costs for silage – 28 €/t
Cost for (revenue from) electricity – 0,07 €/kWh
Heat selling – 60% of theoretical production (70% in winter, 50 % in summer)
Electricity selling – 93% of theoretical production
Revenue from heat – 0.015 €/kWh (currently, 120 t/year heavy fuel oil is used)
Interest rate (for the banks) – 8%
Credit period – 15 years
Liquid assets – 20000 €

Summary

Economical specification is summarized in tables below:
Economical specification

Investment Cost: „Pig-breeding farm" – JSC Kalchevo	**Euro**	**Comments**	**Data input from economic tool**
Construction / Buldings / Earth works	290000	*Incl. VAT and delivery*	*Calculation B12*
Machinery	210000	*Incl. VAT and delivery*	*Calculation B13*
Electrical equipment	70000	*Incl. VAT and delivery*	*Calculation B14*
Planning and site supervision	50000		*Calculation B15*
CHP and grid access	180000	*Incl. VAT and delivery*	*Calculation B16*
Others	50000		*Calculation B17*
Liquid assets	20000		Summary *C7*
Total Financial Demand	850000		Summary *C6*

Profit and Loss: Pig-growing farm Kalchevo	**Euro**	*Comments*	*Data input from economic tool*
Economic Yield from Plant Operation			
Yield from electricity sale	158500	*Value from Year 1 of operation**	*Summary C30*
Yield from heat sale	26000	*Value from Year 1 of operation**	*Summary C31*
Plant working costs			
General Busines Cost	81500	*Value from Year 1 of operation**	*Summary C34*
Biomass purchase	95000	*Value from Year 1 of operation**	*Summary C19*
Purchase of electric energy	11000	*Value from Year 1 of operation**	*Summary C35*
Discharge of sludge	0	*Value from Year 1 of operation**	*Summary C36*
Earnings before Interest	8000		*Summary C38*
Internal Return Rate (IRR)	< 0		*Summary C40*
Capital Cost	104000		*Summary C42*
Total Earnings	-96000		*Summary C44*

** The annual costs are difficult to determine because they vary significantly over the years (which has strong effects on the economic feasibility e.g. the biomass prices). The complete economic calculation sheets are attached as Appendix 1.*

Discussions

It can be clearly seen that at the current situation biogas project is not economically feasible. In order to determine the necessary regulatory and technical changes so that the project becomes economically viable, some assumptions will be changed.
Some of the parameters that can be used to improve the economy of the project are:

- increase in preferential prices of electricity
- better conditions for bank loans
- lower cost for biomass
- different quantity of energy crops

Type and quantity of biomass		36500 t manure	36500 t manure, 3000 t silage	36500 t manure, 8000 t silage
Power	kW	140 kW	275 kW	500 kW
Technology	€/kW	4000	4000	2800
Investment	€	560000	1100000	140000
Plant operational and capital costs				
Personel	€/year	12000	12000	12000
Maintenance total	€/year	26276	52000	78000
Maintenance CHP	€/year	11200	23000	42000
Biomass +energy	€/year	5496	95100	244200
Other	€/year	18250	24250	34250
Capital costs (bank interest rate 6%)	€/year	62400	118000	149000
Capital costs (bank interest rate 8%)	€/year	70434	133500	168500
Capital costs (bank interest rate 12%)	€/year	87800	167000	211000
Economic Yield from Plant Operation				
Revenue – heat (at 0,015 €/kWth)	€/year	13000	30500	48000
Revenue - electricity (at 0,07 €/kWel)	€/year	78500	158500	288000
Revenue - electricity (at 0,09 €/kWel)	€/year	101000	204000	370500
Revenue - electricity (at 0,12 €/kWel)	€/year	135000	271500	494000
Earnings before Interest				
Operational balance (at 0,07 €/kWel)	€/year	29478	5650	-32450
Operational balance (at 0,09 €/kWel)	€/year	51978	51150	50050
Operational balance (at 0,012 €/kWel)	€/year	85978	118650	173550
Total Earnings (bank interest rate 8%)				
Total balance (at 0,07 €/kWel)	€/year	-40956	-127850	-200950
Total balance (at 0,09 €/kWel)	€/year	-18456	-82350	-118450
Total balance (at 0,12 €/kWel)	€/year	15544	-14850	5050
Critical price	€/kWel	0.105	0.129	0.121

The following conclusions could be made based on the table above (bank interest rate - 8%, silage - 28 €/t):
- if feed in tariffs are 0,09 €/kWh or below than revenue from energy sale is less than costs for silage
- if feed in tariffs are 0,12 €/kWh than investments could be covered for plants on agricultural wastes and low standard robust plants using energy crops.

1.4. Organizational structure

The owner and the operator of the plant will be the privately owned Pig-reproduction farm – JSC Kalchevo. Most of the feedstock will be provided by the manure management system of the farm and energy crops grown on own or rented lands. If appropriate preferential prices for selling electricity are passed as state regulations than additional corn silage could be bought. Long term contracts for silage could be established.

Contracts for utilization of the liquid fertilizers produced are needed also.

1.5. Risk management

The primary risk factor for the biogas project is technological due to the lack of local experience in planning, construction, supervision, operation and maintenance of biogas plants. Successful cooperation between experienced foreign consulting and local engineering company could provide the necessary biogas know-how and local technical support, training and oversight.

Other major concern are prices of silage that is used as energy crops – they can vary from less than 25 €/t to more than 55 €/t. This is mitigated from the fact that basic feedstock is pig manure and silage own production. In addition, contracts for residues from sunflower mill "Papas-oil" and from wheat processing plant in Kalchevo could be established.

Possible risk for any waste management project is increased attention to the ecological problems of the site, which can lead to unexpected additional requirements and expenses.

2. Biogas Show Case: Mekom JSC, Silistra, Sitovo

2.1. Basic plant design

The main biogas sources available at the farm are pig manure and slaughter wastes:

- 43000 m^3 liquid pig manure per year with total solids content of 3÷6%
- 5500 t/year slaughter wastes

This feedstock determines the process technology, basic plant design and dimensions. Electrical output would be 350 to 450 kW (400 kW for the calculations).
Agricultural biogas plant operate with four process stages (figure 2.1):

1. Transport, delivery, storage and pre-treatment of feedstock
2. Biogas production (Anaerobic Digestion)
3. Storage of digestate, eventual conditioning and utilization in CHP
4. Storage of biogas, conditioning and utilization

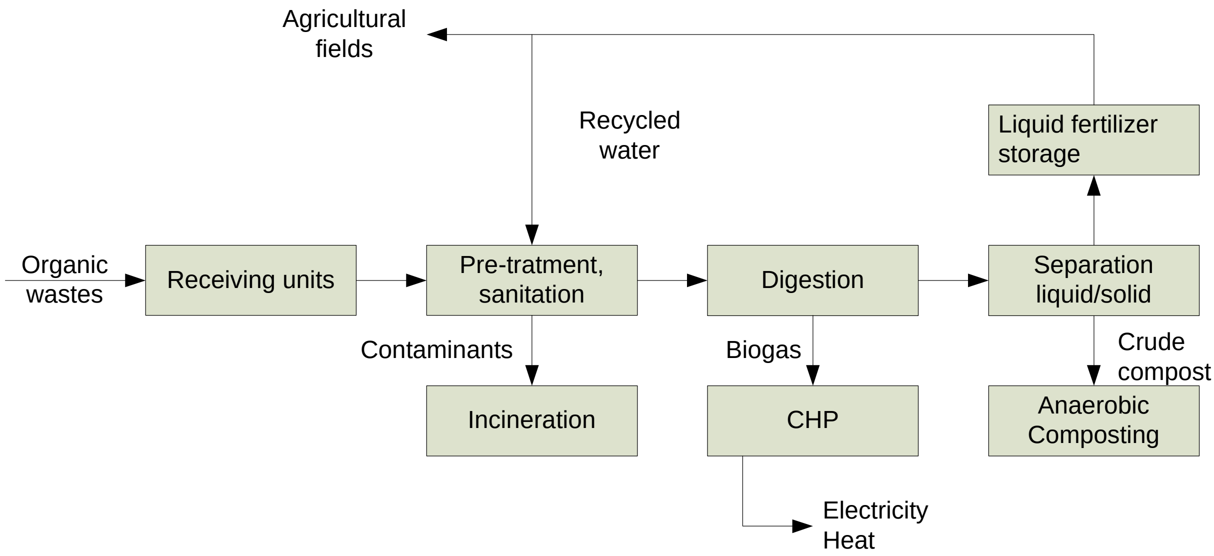

Fig.2.1. Block diagram showing the overall production process

The mass balance of biogas plant is as follows:

Average totals solids of input materials	10.5 %
Input into biogas plant	48500 t/year
Average amount of produced biogas per ton of input material	32 m^3/t
Average quality of the produced biogas	57 %CH_4
Average produced biogas per year	1550000 m^3/year
Average produced biogas per hour	177 m^3/h
Average remaining biogas sludge without separation	46800 m^3/year
Average remaining TS in biogas sludge without separation	7,1 %
Average remaining Biogas Sludge liquid phase TS =5%	42823 m^3/year
Average remaining compost TS=25%	3897 m^3/year

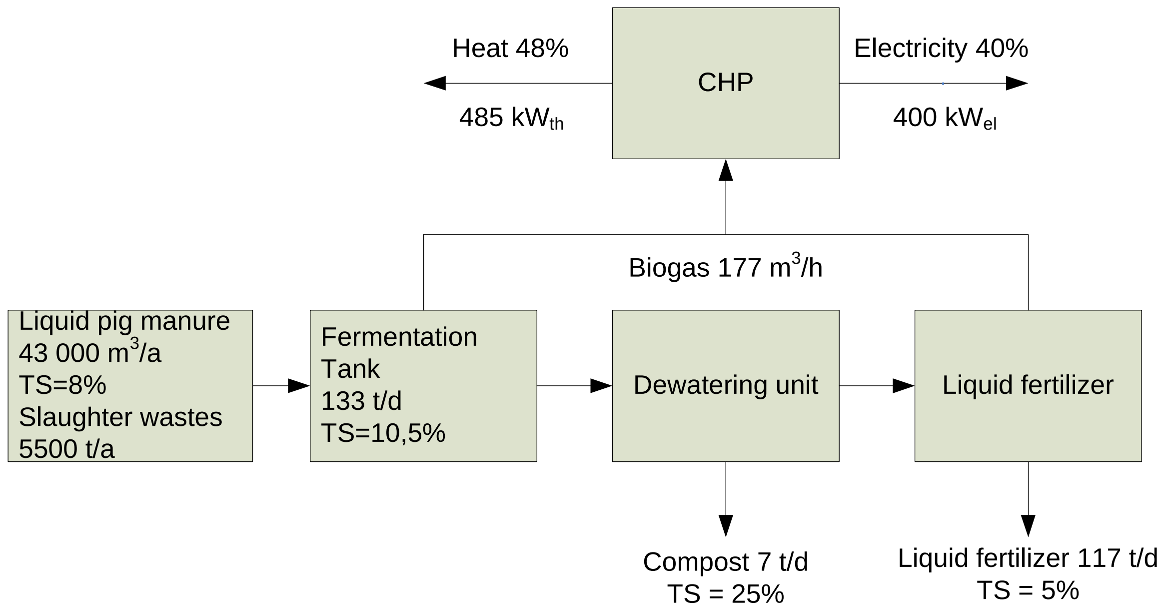

Fig.2.2. Block diagram showing the mass balance

2.2. Technology Specifications

Biogas plant will use complete mix digester with appropriate equipment for mixing, heating, filling and protection.
Appropriate sanitation and conditioning of slaughter wastes should be provided.
Advanced process parameters control and indication should be provided. Condition. Effective control of pathogens shall be assured (livestock health control, feedstock control, etc.).
Additional details concerning technology are provided in Show Case 1 description (sec. 1.2).

2.3. Economic specifications

Economical specification is summarized in tables below, assuming:

High standard plant – 4500 €/kW (leading to 1800000 € total investments)
Revenue from electricity – 0,09 €/kWh (hypothetical)
Other assumptions – see Show Case 1

Economical specification

Investment Cost: Mekom, Silistra, Sitovo	**Euro**	**Comments**	**Data input from economic tool**
Construction / Buldings / Earth works	-600000	*Incl. VAT and delivery*	*Calculation B12*
Machinery	-450000	*Incl. VAT and delivery*	*Calculation B13*
Electrical equipment	-150000	*Incl. VAT and delivery*	*Calculation B14*
Planning and site supervision	-140000		*Calculation B15*
CHP and grid access	-350000	*Incl. VAT and delivery*	*Calculation B16*
Others	-110000		*Calculation B17*
Liquid assets	-20000		Summary *C7*
Total Financial Demand	-1800000		Summary *C6*

Profit and Loss: Mekom, Silistra, Sitovo	**Euro**	*Comments*	*Data input from economic tool*
Economic Yield from Plant Operation			
Yield from electricity sale	296500	*Value from Year 1 of operation**	*Summary C30*
Yield from heat sale	38500	*Value from Year 1 of operation**	*Summary C31*
Plant working costs			
General Busines Cost	136800	*Value from Year 1 of operation**	*Summary C34*
Biomass purchase	16000	*Value from Year 1 of operation**	*Summary C19*
Purchase of electric energy	16000	*Value from Year 1 of operation**	*Summary C35*
Discharge of sludge	0	*Value from Year 1 of operation**	*Summary C36*
Earnings before Interest	182000		*Summary C38*
Internal Return Rate (IRR)	5,2%		*Summary C40*
Capital Cost	215000		*Summary C42*
Total Earnings	-33550		*Summary C44*

** The annual costs are difficult to determine because they vary significantly over the years (which has strong effects on the economic feasibility e.g. the biomass prices). The complete economic calculation sheets are attached as Appendix 2.*

2.4. Organizational structure

The owner of the plant will be the meat – processing company “Mekom” JSC. The operator of the plant could be the pig farm in Sitovo or a separate enterprise established for the purpose of waste management – also owned by “Mekom” JSC. The feedstock will be provided by the manure management system of the farm and wastes from slaughter houses. Most of the organizational structures will be internal for the company.
Contracts for utilization of the liquid fertilizers produced are needed.

2.5. Risk management

The primary risk factor for the biogas project is technological due to the lack of local experience in planning, construction, supervision, operation and maintenance of biogas plants. Successful cooperation between experienced foreign consulting and local engineering company could provide the necessary biogas know-how and local technical support, training and oversight.

Possible risk for any waste management project is increased attention to the ecological problems of the site, which can lead to unexpected additional requirements, penalties and expenses.