BALTIC COMPASS

REPORT

# Assessment of biogas projects in Belarus

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Baltic Sea Region Programme 2007-2013

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# Introduction

This report is made by PlanAction, Denmark for Agro Business Park in spring 2012, and is based solely on visual inspection of the facilities and interviews with owners/management staff during visit in Belarus in end March 2012. Statements and conclusion are solely made by and the responsibility of PlanAction.

During the visit the following plants in operation were visited:

- Zapadny
- Belorussky
- Snov

Besides these plants in operation the university dairy farm at Zazerye was visited and the plans for the construction of a biogas plant at this farm have been examined at a meeting on the university.

In the visit participate besides Lars Baadstorp, PlanAction, Denmark also:

- Nikolay Kapustin, RUE SPC NAS Belarus for agricultural mechanization, Minsk, Belarus
- Ekaterina Kuzina , University of Kiel, Germany
- Henning Lyngsø Foged, Agro Business Park, Denmark

Thanks to Nikolay Kapustin for organizing the visits and to Ekaterina Kuzina for translations as well as assistance on taking notes on the locations.

For all plants the assessment is given below in the report and a short data sheet is given for the plants in Appendix 1.

# Objective

The objective of the mission was, with reference to Terms of Reference, to provide an overall assessment of the actual plants in relation to the Belarusian context. It is the objective to highlight possible problems on the individual plants and provide overall recommendations for possible changes to be further analyzed as well to be taken into consideration for the future development of biogas in Belarus.

# Summary and overall conclusions

### *Summary*

This assessment of the situation on selected biogas plants in Belarus is based on visits to three existing biogas plants and assessment of plans for a coming plant on a large dairy farm. The visits/meetings were made in end March 2012.

The conditions for setting up and operating biogas plants in Belarus are favourable, mainly because of:

- Many large scale animal farms
- Relative high feed-in tariff for electricity produced on biogas
- Professional staff on the farms

The main challenges are:

- Adoption of the biogas to the Belarusian context
- Handling of large quantities of liquid manure
- Handling of solid manure/deep litter
- Optimized utilization of digested biomass

The development up to now of biogas plants in Belarus have been based on transfer of standard technology and plants for digestion of mainly energy crops mainly from Germany. The main conclusions in using this technology in the Belarusian context are:

- The plant technology made for handling mainly energy crops (maize silage) is not suitable for handling the biomasses availed in Belarus (manure)
- Standard size farm-scale plants are normally too small for the large scale farms in Belarus
- Some of the plants are constructed in a too low quality to secure stable and high performance.

Another “spin-off” from the energy-crop-technology is that the handling of the digestate has not been an integrated part of the plant set up and values of the nutrients are therefore lost.

The main technical/operational challenges identified are:

- Accumulation of sand in the digesters
- Handling solid manure in the intake system
- Handling so much relatively low quality biomass (manure) that the expected production can be reached
- Too high process heat demand
- No sanitation of biomass (possible problem where manure from more farms and where organic residuals are used)
- Two of the plants are small standard plants that only can utilize a minor part of the biomass resources available on the farm

The recommendations for the future development of biogas in Belarus are:

- Building up of local based biogas knowhow that enable local companies to install and service biogas plants

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- Development of Belarusian biogas technology based on experiences gained in similar conditions (large quantities of manure as e.g. in Denmark)
- Documentation and acceptance of digested biomass as a high quality fertilizer

# Zapadny

## *General impression*

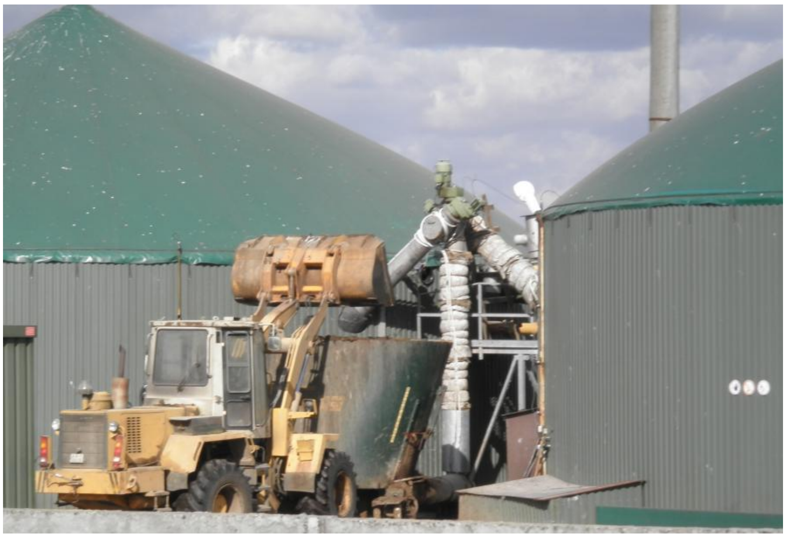
The farm is a very large scale pig farm and the biogas plant seems much too small to be a significant improvement in the manure handling as well as in the energy supply of the farm.

The plant is made as a standard energy-crop-plant and therefore designed for handling mainly maize silage and not manure as the main /only input as is the case on this farm, and is therefore not configured in a suitable way.

The handling of part of the manure as separation solids is not optimal in relation to the productivity and operations of the biogas plant.

The handling of the digestate as well as of non-digested manure in ponds as a waste water product means that large quantities of valuable plant nutrients are lost.

The plant is in general well-kept and the staff seems professional.



## *Context*

The plant is located on a large scale pig farm. It is processing part of the manure produced as the solid fraction of separated manure mixed with liquid manure as well as slaughterhouse residuals from an on-farm slaughterhouse, fish waste and residual feeds.

The plant is a standard energy crop plant as known in Germany. In the Belarusian context the main biomass is manure.

## *History*

The plant was constructed by Biogas Nord, Germany in 2005 as one of three pilot plants. The plant was from the start equipped with a 340 kW electric biogas engine. Later a 180 kW electric biogas engine was added.

## *Technical set up*

The plant consists of:

- Intake system for solid biomass (direct feeding into the digester)
- Intake tank for liquid manure

- Digesters 2*1,500 $m^3$ (total volume)
- Gas storage 2*400 $m^3$ on top of the digesters
- Buffer storage for digestate
- Gas engines: 1*340 kW + 1*180 kW

The solid biomass is fed directly to the digester and the manure pumped into the digester. The digestate is taken from digester one to digester two and to the buffer storage by overflow.

The biogas is cleaned for sulphur by a biological process in the digesters.

## *Biomass and production*

The biogas production is not metered at the plant. The production is therefore assessed based on information on the inputs and the electricity production. The gas production is not sufficient to operate both engines continuously.

The plant treats approx. 90 t of biomass per day. This is a mix of:

- Separation solids from pig manure
- Raw pig manure
- Residuals from own slaughterhouse
- Fish waste
- Residual feed

The retention time in the digesters is two times approx. 15 days when there is no accumulation of sand in the digesters. The organic load is approx. 10 kg VS/$m^3$ digester/day. Accumulation of sand shortens the retention time and raise the organic load. According to experiences on operation of mesophilic plants the retention time is too low and the organic load in particular too high. This reduces the gas yield for the plant.

A theoretical calculation on the potential biogas production on the actual input biomass shows a potential gas production in accordance with Danish experience on approx. 4,500 - 4,700 $m^3$ $CH_4$ per day equal to approx. 660 - 700 kW electricity. The relatively low production can be explained mainly by the relatively short retention time/high organic load of the digesters in relation to the low digestion temperature, but also from the fact that the biomass is not crunched before feeding into the digester.

## *Operational issues*

There were several operational problems identified at the plant:

- High $H_2S$ content in the gas/insufficient gas purification
- Too low production in relation to input
- Frost problems in the intake system for solid biomass
- Accumulation of sand in the digester

Potential problems identified

- The plant treats slaughterhouse waste in a mesophilic digestion process. This process does not provide sanitation which can be problematic in relation to spreading of diseases.
- The heat demand is very high – approx. 40% of all heat produced is used for process heat.

- Problematic setup of the pump in a small container also containing electrical installation and with no drains will unavoidably give problems when the pump is opened for cleaning.

More of the problems can be related to the fact that the plant is constructed as an "Energy crop plant" but treats manure and industrial residuals. The $H_2S$ purification system is insufficient because it is designed for energy crops that normally results in a low $H_2S$ content in the gas whereas the biomass used (manure and the residuals) typical results in minimum 2,000 ppm $H_2S$.

The use of manure instead of energy crops means that more biomass must be treated in the plant. This reduces the retention time meaning tendency for overloading of the process which again means a relatively low production. The manure also contains more sand than energy crops and that causes accumulation of sand in the digesters when an insufficient system for discharge of digestate – overflow – is used.

Besides this a general low quality of the plant causes problems, e.g. too poor insulation of digesters (8-10 cm in the walls and no insulation in the plastic membrane top) and therefore too high heat consumption as well as frost problems in the intake that are not traced as required in the Belarusian climate. Beside this the location of a pump in a container with electric installations and no drain can cause operational problems and damage the electric system if the pump leaks.

## *Handling of digestate*

The digestate is together with non-digested manure from the farm led to large, open lagoons where a stepwise de-nitrification and evaporation of nitrogen in the manure takes place. This means that nutrients in the manure is not utilized and therefore wasted.

A rough estimate is that the entire farm has a production of approx. 120,000 t manure per year containing approx. 550 t N, 125 t P and 220 t K. Assuming an efficiency of the N at 60% and on P and K on 90% and prices on N and K at 1 €/kg and P on 1.5 €/kg the value of the manure as fertilizer is approx. 700,000 €/year. From this must be withdrawn cost of storage and spreading. This equals more or less half of the value so a net value of approx. 350,000 €/year for using the manure as fertilizer can be gained.

## *Recommendations*

Desires for enlargement of the plant have been expressed from the staff. This can be combined with solving problems located at the plant.

The digester volume as well as the digester design is insufficient to produce enough gas for the engines. At the same time the operation of the digesters causes problems in relation to too high heat demand and accumulation of sand.

It is recommended to set up a new high quality primary digester and to use the existing digesters as secondary digesters. To take out sand from the digesters it is recommended to install a pumping system from the bottom of the digesters. The new primary digester can be made for a larger capacity e.g. by installing a 3,000 $m^3$ thermophilic silo digester that can treat approx. 200 t biomass per day. Installing a thermophilic digester will provide sanitation of the biomass which will secure sound health conditions on the farm.

To provide an optimal biomass for such a new digester a new separation system for manure designed for production of optimal biomass for biogas production must be installed. The solid fraction from the separated manure is made on a screen separator. The biomass is not analyzed but from tests on similar products it is known that this biomass is relative bad for digestion in particular in relative short retentions times as on the present plan, because there are mainly low digestible fibres in the solid fraction, whereas the high digestible small particles and suspended solids is in the separation liquids. On the other hand is it advantageous to separate the manure before digestion to avoid passing huge amount of water through the plant.

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To ensure a stable and efficient operation of the engines it is recommended to install a gas purifying filter e.g. a biological scrubber.

Enlargement of the plant requires more CPH engine capacity. It is recommended to install one new engine for the entire enlarged gas production, e.g. as an approx. 1.5 MW biogas engine. The existing engines can either be sold or kept as back up.

To secure a service friendly operation and handling of liquid biomass it is recommended to construct a separate house for installing of input and outtake pumps, valves, etc.

The digestate is not at present used as fertilizer. To enable this utilization it is recommended to install storage capacity for the digestate as covered storage – lagoons or better tanks – equal to 6-8 month storage and modern efficient spreading equipment as a slurry tank with hoses.

# Belorussky

## General impression

The plant is very well kept, it is clean and the staff seems professional.

The plant itself is a small standard plant more or less similar to the plant at Zapadny as described above. It is an energy-crop-plant not suitable to handle all biomass available on the farm and not made for handling of large quantities of manure.

## Context

The biogas plant is located on a large scale poultry production with large quantities of solid manure. Solid and liquid dairy manure is supplied into the plant.

## History

The plant is part of the same program that supported the establishing of the Zapadny plant assessed above, and similar except form the feeding system and engine set up. The plant is constructed in 2008 and has never been on full production.

The plant is supplied by Biogas Nord, Germany as a turnkey supply.

## Technical set up

The plant consists of:

- Intake tank (300 $m^3$) for liquid manure and mixing with solid manure
- Digesters 2*1,500 $m^3$ (total volume)
- Gas storage 2*400 $m^3$ on top of the digesters
- Buffer storage for digestate
- Gas engines: 1*400 kW

The solid biomass is fed directly to the digester and the manure pumped into the digester. The digestate is taken from digester one to digester two and to the buffer storage by overflow.

The biogas is purified for sulfur by biological process in the digesters.

## *Production results*

The biogas production is not metered on the plant. The production of biogas is insufficient to operate the engine, wherefore natural gas is added to operate the engine. The gas production can therefore not be assessed.

## *Input biomass*

The plant treats approx. 80 t of biomass per day. This is a mix of:

- Dairy manure (liquid)
- Dairy manure (solid)
- Chicken manure (solid)

The manure is mixed in a tank and from there pumped into the digester. The mixed substrate can be handled at a dry matter content of approx. 9-10%.

This mix is regarded as fine for biogas production. The mix should be able to provide approx. 2,300 $m^3$ $CH_4$ per day equal to a production of approx. 330 kW electricity. This should be enough for operating the engine.

## *Operational problems identified by the staff*

There were more operational problems identified at the plant:

- Accumulation of sand in the digester
- High $H_2S$ content in the gas/insufficient gas purification
- Too low gas production in relation to input
- High heat demand

The accumulation of sand in the digesters is the main operational problem caused by outtake of digestate using overflow, which is not suitable for plants that are treating manure as described above.

Because of the accumulation of sand in the digesters, and the fact that the heating system is floor heating combined with heat coils, there are problems with ineffective heating of the digesters.

The digesters are insufficient insulated for the Belarusian climate (8 cm insulation in the walls and no insulation besides the air in between the two membranes on the top. This causes too high heat demand and problems in heating the digester in the cold periods.

Besides the problems with heating the digester, the accumulation of sand reduces the active digester volume causing insufficient digestion, and the plant is stopped/has a reduced gas production in periods when the digesters are cleaned.

The staff wants to install a device for direct feeding of solid biomass into the digester, which could ease feeding of the digester. To achieve a sufficient gas production from the solid biomass it is recommended to provide a new intake system with a macerator or similar. It is also important to assess if the mixing system in the digesters have sufficient capacity to handle a higher dry matter content of the substrate.

To get the optimal result from a new feeding system the problem of accumulation of sand must be solved (see below).

The high sulphur content in the gas is related to insufficient purification system for manure digestion.

## *Recommendations*

The main problem of accumulation of sand can be solved by installing a pumping system for outtake of digestate from the digesters. Also on this plant the input pump is mounted in the same container as the electrical system, which is problematic, and installing a new outtake pump must therefore be made in a separate building, where the intake pump also can be located.

To ensure a stable and efficient operation of the engines it is recommended to install a gas purifying filter, e.g. a biological scrubber. It is remarked, that it ought to be possible to purify the relative low gas production in the digesters by adding air. As a first step it can be tested to increase the amount of air. In Denmark normally 3-6% of air in relation to the biogas is used. To avoid any safety problems it is recommended to install an oxygen meter on the gas out of the digesters to secure that not too much air is added.

If the farm wants to treat more biomass an enlargement of the digester capacity and the engine capacity must be made. It is recommended that a possible enlargement of the digester capacity is made as a new primary steel silo digester that is installed in front of the existing digesters, which could then function as secondary digesters. The most rational way of enlargement of the engine capacity is to install a new larger engine, and then sell or keep the existing engine as reserve.

# Snov

## *General impression*

The plant is new and has only been in operation for approx. 3 month but the quality seems higher than the two Biogas Nord plants described above. The fact that the plant is owned and operated by the supplier seems positive in relation to follow up and to secure stable operation. It can be seen that the technology provider is used to operate on energy crops rather than large quantities of manure and this can cause bottlenecks in the operation mainly in the input system and the $H_2S$ purification. The plant is a large scale and the operation parameters seem robust even when the plant reaches full capacity.


## *Context*

The biogas plant is located on a large scale pig farm using all manure from this farm plus manure from an adjacent dairy production.

The plant is owned and operated by the supplier (Eco Tech, Switzerland). The farm gets a small part of the profit but have no responsibilities in relation to the operation.

## *History*

The plant is brand new and the commissioning took place in the end of 2011. End of March 2012 three out of four primary digesters were in operation and the engines were operating on 40% of full load.

The plant is supplied by Eco Tech, Switzerland as a turnkey supply as well as owned and operated by this company.

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## Technical set up

The plant consists of:

- Intake tank (300 $m^3$) for liquid manure and mix with solid manure
- Primary digesters 4*2,600 $m^3$ (total volume 10,800 $m^3$)
- Secondary digesters 3* 2,600 $m^3$ (total volume 7,900 $m^3$)
- Gas storage on top of the digesters
- Gas engines: 2*1 MW

The solid biomass is fed to a mix tank where it is mixed with liquid manure and then pumped into the digester.

The biogas is purified for sulphur by biological process in the digesters.

## Production results

The plant is under commissioning and in the end of March it produced approx. 800 kW electricity on 3 out of 4 primary digesters. The secondary digesters were not put into operation yet. The production equal approx. 40% of the planned production.

This is produced on approx. 185 t of biomass per day.

An estimate based on the actual inputs shows that the actual production is a little lower than the production expected from the actual biomass, probably because the plant not yet is fully commissioned.

## Input biomass

The plant is planned to treat approx. 490 t biomass per day, equal to a retention time of 22 days in a mesophilic process. The biomass will (as during the commissioning) be a mix of

- Dairy manure (liquid and solid)
- Pig manure (liquid
- Chicken manure (solid)
- Maize silage

## Operational problems identified by the operational staff

There were more operational problems located at the plant:

- Insufficient purification of $H_2S$
- Insufficient feeding capacity for solid biomass feeding
- Insufficient mixing in the mix tank
- Feeding device not suitable for handling manure

From the lay out assessed on the site it can be expected that this plant also will have accumulation of sand in the digesters because the digester is emptied using overflow.

## Recommendations

Purification of the gas was discussed at the meeting on the plant. The recommendation from the supplier is a relative low quantity of air intake to the tank for purification. It is recommended to raise this quantity to approx. 4-6% air in relation to the gas and to mount oxygen metering on the outlet gas to secure that the oxygen content is kept low so no explosion risks occurs.

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The feeding of the solid material can be improved by installing an additional feeding device because the capacity in handling manure is limited. This second device could possible feed directly into a digester. To improve gas production and ease handling in the digesters it is recommended to provide the feed in device with macerators.

The potential problem of accumulation of sand in the digesters can be solved by installing pipes from the bottom and pumps for the outtake.

# Zazerye (university dairy farm)

This plant is being planned, and the assessment is therefore made on basis of the plans as they were presented at a meeting on the university end of March 2012.

## *General impression*

The dairy farm is very well operated and the majority of the cows will be housed in new stables that are under construction. The farm has already storage capacity for manure in two tanks and is constructing lagoons to increase the storage capacity.

The farm has presently 500 dairy cows + young stock, and is currently being expanded to 800 dairy cows + young stock. The dairy cows are kept in cubicle stables with solid floors, and the young stock in houses with deep bedding. The following table shows an indicative calculation of amounts of livestock manure and its content of N and P, as it will be when the expansion has been finalised.

| | Number / places | Ton per Place | Ton per Year | Kg N per ton | Kg P per ton | kg N per year | Kg P per year |
|---|---|---|---|---|---|---|---|
| **Cattle slurry - dairy cows** | 800 | 24.57 | 19,656 | 5.17 | 0.9 | 101,622 | 17,690 |
| **Deep cattle litter – calves, 0-6 months** | 213 | 1.89 | 403 | 14.1 | 1.73 | 5,676 | 696 |
| **Deep cattle litter – heifers, 6-27 months** | 747 | 5.52 | 4,123 | 9.47 | 1.36 | 39,049 | 5,608 |
| **TOTAL** | | | **24,182** | | | **146,347** | **23,995** |

Amounts and qualities of the livestock manure in the table is based on Danish standards (Damgaard et al., 2011), and these may not be suited for the situation in Belarus in general and for Zazerye in specific, but is anyway giving an indication of to the total annual production of livestock manure and its content of N and P. It should be noted, that rather large quantities of washing water from the milking parlour will increase the required capacity for storage of livestock manure or digestate, and also rain water, unless the stores are covered.

The biogas plant is purchased in accordance with a development contract. This can be very fine because the owner can influence the set up in the planning phase. It seems at the moment that the plant is based on the German systems for digestion of energy crops, and with little focus on handling manure or on optimizing the process heat demand.

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## Context

The biogas plant will treat approx. 60-70 t dairy manure from the farm per day. This amount fits quite well with the estimated annual livestock manure production in the above table.

The plant will be designed for the production of 250 kW electricity.

## Plant set up

The considered plant consists of:

| | |
|---|---|
| Intake/mix tank: | approx. 100 $m^3$ |
| Primary digesters: | approx. 1,600 $m^3$ (equal to 24 days retention time) |
| Secondary digester: | approx. 1,600 $m^3$ |
| Engine: | approx. 500 kW |

## Issues to be assessed in the final development

The digesters are planned to be insulated with only 80 mm which is insufficient. Even if the farm has a limited demand for heat and heat surplus can be expected, the poor insulation can cause problems in relation to controlling the temperature of the digesters.

The plant is planned with outtake by overflow, which can cause problems in relation to accumulation of sand, and it is recommended to consider pumps for the outtake instead.

In relation to achieve 500 kW on a relative poor quality biomass it is recommended to make the digesters bigger so that they have a higher capacity and still a relative long retention time that enables digestion of the relative hard digestible products.

It must be expected that the digestate will not provide a homogenous covering swim layer and therefore it is recommended to cover the storage for digestate as well as the new lagoons.

## Possible improvements in cooperation with Baltic Compass

The environmental benefits of the digestion of the manure can be improved by:

- Sufficient storage capacity
- Best practice storage – covered storages

The farm is constructing lagoons for storage of digestate. The lagoons will be provided with a dense membrane.

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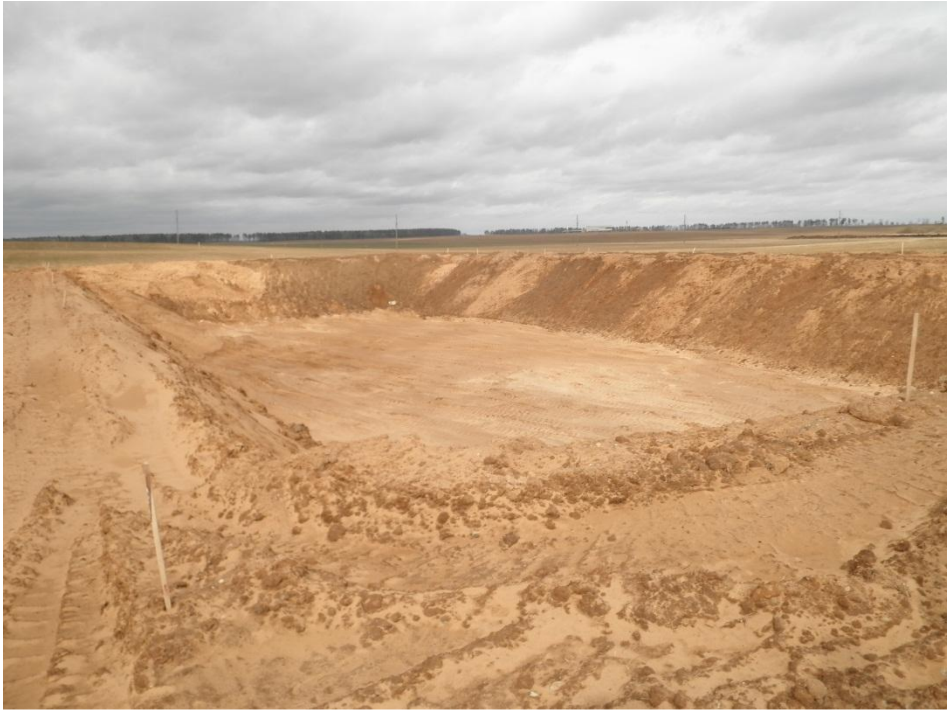

Lagoon under construction (March 2012)

The present capacity for slurry storage can together with the lagoons being built be sufficient, especially if the farm grows large areas of grass where the digestate can be used in the growth period and storage therefore only required during the winter. However, a number of investments should be prioritised in order to ensure a good manure management after the expansion of the livestock production and establishing of a biogas plant:

- **Cover on storage tanks**

  The present storage tanks as well as the lagoons being built are open. If a proper digestion is achieved in the biogas plant the digestate cannot develop a proper swim layer that will reduce evaporation of nitrogen from the tanks. It is therefore recommended to cover the tanks and the lagoons.

  It is recommended to use gas dense covers for the slurry tanks in order to extract the biogas produced here. If the gas purification in the biogas plant is insufficient as seen on other plants in Belarus it can be recommended to provide the tanks with a $H_2S$ purification system (controlled input of air that feeds a biological process). This requires that all gas is passed through this tank. Gas dense cover mounted on the storage tanks costs approx. 60,000 €.

  The lagoons should at least have floating covers, which cost approx. 45,000 €.

  Cover on slurry tanks would prevent the evaporation of about 10-15% of the N in the digestate, which in this case is about 15-22,000 kg N per year. They will furthermore prevent rain water from diluting the digestate, thus reduce the required storage capacity.

- **Separation of digestate led to the lagoon**

  It can be difficult to homogenise the content of lagoons. This problem can be avoided in case a separation is carried out on the digestate, and that only separation liquids are being stored in the lagoons. More technical solutions for separation devices are available, and the final choice must be based on an assessment of the optimisation of the use of the fractions from the separation.

  The cheapest separation equipment would cost about € 45,000. The investment should be considered as a necessary add on to the price of the lagoons themselves. The lagoons will on

Zazerye increase the storage capacity from about 4 months to more than 8 months, which in itself has an environmental effect of about 25% of the N in the livestock manure, or about 35-40,000 kg N per year (because it enables that a larger share is used for fertilising of crops in the springtime).

- **Slurry spreader with band laying system**

  The anaerobic digestion will increase the share of $NH_4$-N (ammonium) in the digestate as compared to untreated slurry. Ammonium has a higher bio-availability than organic bound N, and should therefore be spread on the fields at the same time as mineral fertiliser is spread, i.e. mainly in the spring and often on growing crops in April and May months. However, ammonium is also more volatile, and it is therefore necessary that the digestate is spread by use of band laying system.

  A slurry tanker with band laying system costs about € 150,000. It will prevent the evaporation of about 25% of the N in the digestate, or about 35-40,000 kg N per year.

None of the proposed investments would have effect on the loss of phosphorus.

# Appendix 1: Main figures for the individual plants

| | Zapadny | Belorussky | Snov | Zazerye |
|---|---|---|---|---|
| **Year of construction** | 2005 | 2005 | 2011 | 2012/13 |
| **Supplier** | Biogas Nord | Biogas Nord | Eco Tech | |
| **Process** | 2 step mesophilic | 2 step mesophilic | 2 step mesophilic | 2 step mesophilic |
| **Intake** | Direct solid feeding | Mix tanks | Solid feeding into mix tank | ? |
| **Primary digester** | 1* 1,500 | 1*1,500 | 4*2,600 | 1*1,600 |
| **Secondary digester** | 1* 1,500 | 1*1,500 | 3*2,600 | 1*1,600 |
| **Retention time** | Approx. 14 days | Approx. 16 days | Approx. 24 days | Approx. 16 days |
| **Engine capacity** | 1*340 kW el + 1*180 kW el | 1*400 kW el | 2*1,000 kW el | 1*250 kW el |