Co-Production of Electricity and Ethanol from Biomass

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1. Abstract

A novel process using biomass for the production of ethanol on the one hand and energy on the other hand has been developed. Potential raw materials are straw, wood, waste wood, waste paper, sugarcane bagasse, domestic waste, wastes from starch processing or other lignocellulosic materials.

During the process lignocellulosic material will be partially hydrolysed, yielding hydrolysates rich in sugars derived from hemicellulose and, partially, from cellulose. These sugars will be fermented to ethanol by AGROL´s novel micro-organism. The remaining solids still have a high burning value and have a low ash contents due to the prior extraction. The low ash contents is particularly important, because the minerals in untreated biomass can cause damage to the boiler equipment. Therefore the material from this process is an excellent feedstock for electricity generation.

New equipment for biomass processing has been developed, such as a particle generator, a straw pump, an extracting system, and a superheated steam dryer.

Several raw materials have been evaluated on their suitability as a substrate for hydrolysis. The optimal hydrolysis conditions for these raw materials have been determined in batch experiments. A continuous hydrolysis pilot plant has been purchased and modified and can go into operation any time.

A thermophilic microorganism was developed, which is able to ferment all the sugars derived from hydrolysis into ethanol. This strain was further improved by identifying the key genes for product formation. Non-sporulating strains with improved ethanol yields were obtained.

It has been proved that the AGROL strain is able to grow on hydrolysates and to ferment them into ethanol. Furthermore it could be shown that the strain can produce ethanol from hydrolysates in continuous culture over a long period of time without losing its properties.

Additionally inhibitory compounds in the hydrolysate have been identified and characterised and methods for their removal have been developed.

Economic feasibility studies show that this process is viable and measures have already been taken to establish the process or parts of it in an industrial plant. The output of this project will not only make sure to meet the growing demand for fuel ethanol, which can be expected also in Europe, but will at the same time produce electricity and reduce greenhouse gases.

2. Partnership including names and addresses of coordinating institutions and 1 contact person per partner

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3. Objectives

The industrial objectives of the project are to reduce production cost for electricity and ethanol from low cost biomass such as straw and waste wood.

Existing power plants operating at high temperatures and pressures can not use straw directly because of problems deriving from the content of potassium chloride (KCl). Continuous countercurrent extraction of the KCl can solve all these problems but simultaneously a substantial amount of organic matter will be extracted. This background has formed the technologic strategy of the project after which low cost lignocellulosic biomass by wet fractionation is separated into fermentable sugars for ethanol production and solid fraction for electricity production.

The new mutant thermophilic microorganisms from Agrol have a unique capacity to produce ethanol from the mixtures of C5 and C6 sugars typically produced by hydrolysis of lignocellulosic biomass.

The combination of a series of continuous countercurrent hydrolysation and extraction processes with Agrols fermentation technology opens up for a number of industrial applications of which the strategic plan agreed by the SME´s gives top priority to the following:

1. Ethanol and electricity production on central power plants receiving a special high price for biomass based electricity.

   Raw materials will be a combination of biomass and domestic waste. The novel wet fractionation process will extract around 25% and 20% of the dry matter of the two raw materials to be used for ethanol production. The solid fraction will be pressed to 45% dm and dried with superheated steam to 90% dm to be used for electricity production.

2. Ethanol and electricity production from forestry and sawmill wastes.

   Around 25% of the dry matter will be hydrolysed and extracted as fermentation feedstock leaving 75% solid fraction as boiler fuel.

   Prefeasibility studies conducted by Ecopro are showing substantial improved gains, when the cellulose part of the solid fraction is isolated and sold as cellulose fibres leaving only the lignin part as boiler fuel.

3. Ethanol and electricity production from bagasse

   Around 50% of the dry matter will be hydrolysed and extracted as fermentation feedstock leaving 50% solid fraction as boiler fuel.

   Prefeasibility studies conducted by Agrol demonstrate a substantial gain from the ethanol production based on the fact that the bagasse is available at the sugar mill in great quantities to a very low shadow value and that the infra structure together with a great part of the needed process equipment already exists at the mill.

4. Ethanol from starch residues

   Up to 95% of the dry matter will be hydrolysed yielding high concentrated sugar solutions. Wheat crude hydrolysates can be fermented directly without addition of further nutrients. The 5% solids fraction can be used as a boiler fuel.

The process developed by this project will have the following advantages compared to conventional processes:

It will enable to use straw and other agricultural by-products in existing high efficient electricity plants by removing undesirable ash contents, especially KCl. The combustion of these substances is CO_2-neutral and will help to reduce greenhouse gas emissions.

A novel process for ethanol fermentation is established, allowing to ferment the pentoses and hexoses, which are present in straw extracts and hemicellulose hydrolysates from wood wastes and other lignocellulosic materials.

Agrol has developed a novel thermophilic strain for ethanol fermentation which has the following properties:

1 It can produce ethanol from mixtures of C_5 and C_6 sugars, which is an absolute necessity when low cost biomass are going to be used as feedstock.

2 Its productivity is 10 times faster than yeasts and even faster than that of the competing microorganisms such as recombinant *Zymomonas mobilis* bacteria and *Escherichia coli* K011. It produces ethanol at temperatures up to 70° C which almost eliminates the risk of contamination. Therefore the fermenter can be operated in long continuous campaigns of at least 2000 hours, at a very low cost.

3 Furthermore the high fermentation temperature makes it possible simultaneously to recover a substantial part of the ethanol by condensation of the water/ethanol vapour leaving the fermenter along with the CO_2/air mixture.

This strain makes it possible to turn straw extraction liquour and hemicellulose hydrolysates from wood and agricultural waste material into fuel ethanol while at the same time the effluents from straw extraction are processed and wood wastes and other agricultural wastes are reduced and turned into a valuable product.

The main use of ethanol is as a gasoline additive or replacement. As such it is CO_2 neutral, not adding to the greenhouse effect and hence receives growing attention by governments to increase its use largely through subsidies and tax incentives.

4. Technical description

In order to achieve the objectives of the projects the following tasks were completed:

4.1 Design of Novel Equipment

4.1.1 Straw Pump

The transport of straw or other particulate solid products into a hydrolysis reactor, a steam dryer or a high temperature boiler meets serious difficulties because:

- the product has to be transported between zones of different pressure
- straw is a non flowing product and has very strong bridging properties.
- straw has a high content of abrasive silicon.
- straw has a low density (loose shredded straw app. 50 kg/m^3).

These obstacles means that a method and apparatus able to handle straw in relation to pressurised equipment will be able to handle almost everything else such as woodchips, coal, residential garbage, by-products from slaughterhouses etc..

To be reliable the apparatus must meet the following requirements:

- machine parts should only to a very limited extend “cut through” the product, in order to avoid wear and jamming.
- the risk of bridging should be eliminated by forcing the product through the critical zones. This means that forced loading and unloading of sluice chambers are absolutely necessary.
- it should be possible to compress low density products to a higher density in order to obtain a suitable capacity within reasonable dimensions.

Sicco has developed a straw pump that eliminates these obstacles and has filed a patent application August 2000. A full scale prototype was constructed by O. Brandt Hansen and tested by Elsam.

4.1.2 Particle Generator

For the operation of the straw pump a particle size smaller than 10 cm was found to be optimal. Too many larger particles can lead to capacity problems. However, traditional equipment using hammermills for cutting straw has serious drawbacks:

- The consumption of electricity is as high as 35-50 kWh per ton of straw depending on the moisture content.
- It is necessary to impose an upper limit for moisture contents of the straw to avoid problems.

In relation to a wet fractionation process it is absurd to reject good straw because of a high moisture content. On the contrary it could be commercially interesting to offer the farmers contracts with simple payment for delivered dry matter without any upper limit for moisture content.

Sicco designed a novel particle generating system which reduces energy consumption and can be operated at any moisture content.

4.1.3 Novel Equipment for Hydrolysation and Extraction

The fermentation process developed by Agrol is using pentoses and hexoses which are derived from hemicellulose in lignocellulosic materials like straw, wood, and agricultural residues. In order to convert the hemicellulose into the fermentable sugars a dilute acid hydrolysis process is used. Such a process yields a liquid hydrolysate which is rich in hemicellulose sugars and a solid residue that is composed of lignin and cellulose and will be used as a boiler fuel for electricity generation. A hydrolysation plant must comprise of a feeding system, a hydrolysis reactor, an extractor, and a dewatering device. The feeding system must be able to transport the material between zones of different pressure and avoids plug formation of the material. A continuous hydrolysis reactor should transport the material constantly forward while maintaining a constant temperature and pressure. An extraction is necessary to remove the sugars that are adherent to the solid material. The dewatering device is used for separating the liquor from the solid residue. Sicco has designed an integrated process for hydrolysation and extraction including the novel equipment that has been developed in this project.

4.1.4 Steam Dryer

Solid material after hydrolysis/extraction can be dewatered by pressing to a dry matter content around 45%. This means that 1 kg of water has to be evaporated per kg of dry product with 90% d.m.

The most economic drying process for this task is drying with superheated steam as the drying media, because most of the energy input can be recovered from the produced low pressure steam and used as energy input for distillation and stillage concentration. A pressurised steam dryer producing low pressure steam at 3-5 bar will give the best value of the steam produced, and by maintaining the high temperature of the dry biofuel during the transport to the boiler, also the thermal energy of the solid fraction will be utilised.

Beside very low drying costs a pressurised steam dryer has the advantage to be completely free of any outlet to the atmosphere.

The existing pressurised dryers will have problems with the transport in and out of the dryer, when the product is voluminous and fibrous like for instance straw and bagasse. These problems can however be solved by the straw pump. A more difficult problem to solve is the fact, that the existing pressurised steam dryers are more or less tailor made to dry well defined products such as sugar beet pulp and cellulose pulp. All round steam dryers do exist on the market based on rotary drum dryers, but they are not pressurised, which means, that the steam produced along with the drying process has a lower value as input energy for multistage column distillation and multistage evaporation. Sicco has developed a novel steam dryer which combine the flexibility of the rotary drum dryer with the high value steam production of the pressurized dryers, and has filed a patent application dec.2000.

4.2 Hydrolysis of Lignocellulosic Raw Materials

4.2.1 Development and Evaluation of Analytical methods

Several standard and fast methods for raw material analytics and determination of the compounds that can be found in hydrolysates have been established at IFA Tulln and tested for their suitability as methods for routine analysis for a hydrolysis process.

4.2.2 Batch Hydrolysis

Batch hydrolysis was carried out on a 20 - 50 l scale. The aim of the experiments was to test different raw materials for their potential as substrate for hydrolysis and to find out the optimum hydrolysis conditions for each substrate. Statistical experiment design was used in order to estimate the effects of temperature, reaction time, acid concentration, and dry matter concentration on the yield of hemicellulose sugars and on the formation of sugar by-products. The results of these experiments were used to calculate response surface models, which allow to locate the optimum conditions. Hydrolysate samples were forwarded to Agrol, in order to test their fermentability.

The materials that have been tested were:

- softwood chips (spruce)
- wastewood (shredded pannelboard and pallets)
- sugar cane bagasse
- pentose rich starch processing waste

4.2.3 Continuous Hydrolysis

For continuous hydrolysation, a Czech pilot plant was jointly purchased by Agrol Ltd. and IFA-Tulln. This hydrolysation plant is capable of continuous hydrolysation of up to 50 kg drymatter per hour. The equipment consists of 2 single screw hydrolyser units with appropiate feeding and expansion units. Steam and hot oil for achieving operation temperatures are generated in an electrically heated steam generator. Maximum temperature is 230°C at a pressure of 29 bar. Retention time in the hydrolyser can be varied between 5 and 16 min by changing the rotation speed of the screws. The feeding unit consists of a single screw and can be used for particles less than 5 cm length.

4.2.4 Evaluation of Bark as a Raw Material

Bark is an interesting material because it is a major waste-product of sawmills. Currently most of it is burned. because there are no high value applications. If sawmill wastes are considered as a substrate for hydrolysis it is evident that bark should be included. However, the composition of bark is differing from wood. Especially the contents of extractives is higher. Since these substances can be inhibiting to fermentations a study has been performed on IFA-Tulln in order to evaluate the properties of bark regarding hydrolysation and to determine possible strategies for removing these compounds.

4.3 Economic Evaluation

4.3.1 Feasibility Study for an Ethanol Plant in Belgium

Ecopro carried out a study including the following items:

- Availability and potential suppliers of wood wastes
- Market studies for ethanol
- Market studies for the co-products (paper pulp, energy)
- Contacting potential buyers for product and co-products
- Selection of a site for an ethanol production plant based on waste wood

4.3.2 Feasibility Study for the Production of Ethanol, Power, and Building Materials from Sugar Cane Bagasse

The cost calculation for a bagasse refinery plant refining 750 t bagasse per day conducted by Agrol comprises the following items:

- Calculation of capital costs
- Operation and production costs
- Sensitivity analysis

4.3.3 Prefeasibility Study for Co-Production of Electricity and Bioethanol

A prefeasibility study for a plant using a feedstock of 150 000 t of straw and 150 000 t of domestic waste was conducted by Elsam. A preatreatment step includes counter current impregnation and two stage hydrolysation-extraction of straw and wet warm fractionation of domestic waste, and pressing. The press-juice will be used for ethanol fermentation. The presscakes of straw and domestic waste organic residues will be united and dried with superheated steam to be co-fired with coal-dust in a boiler with advanced steam data.

4.4 Ethanol Fermentation

4.4.1 Strain Development

AGROL initiated a strain development program in order to overcome strain limitations.

4.4.2 Bench Scale Fermentations

Hydrolysates derived from softwood, wastewood, and starch processing waste were evaluated for their suitability for ethanol fermentation. Inhibitory concentrations of the hydrolysates were determined and nutrient requirements for different hydrolysates were tested.

4.4.3 Inhibition Studies and Detoxification of Hydrolysates

During hydrolysis the lignocellulosic material releases not only sugars but also various other substances that can be found in the hydrolysates and can cause serious inhibition to fermentation processes. These substances can be classified as follows:

- sugar degradation products
- lignin derived compounds
- autohydrolysis compounds
- metal ions originating from the hydrolysis equipment

Experiments were conducted in order to determine the toxicity of specific compounds to the Agrol strain.

Hydrolysates cannot be fermented directly after acid hydrolysis because the low pH will inhibit any growth. Different methods for neutralising were tested and evaluated on their effect on microorganisms growth. Furthermore a range of detoxification methods were tested on their efficiency for the Agrol strain.

5. Results and Conclusion

5.1 Design of Novel Equipment *(Owner is Sicco)*

5.1.1 Straw Pump

A straw pump which is based on a sluice system has been designed. This device allows to transport straw or other particulate solid products between zones of different pressures. Such a machine can be used for feeding biomass into pressurised processes such as steam treatment, hydrolysation. solvent extraction, pulping, explosion pulping, gasification, or drying with superheated steam.

The advantages of the straw pump compared to known methods are:

- The “cutting through” of the product is reduced by introducing a portioning device.
- The risk of bridging of the straw is eliminated by force loading using a piston screw.
- The piston screw also makes it possible to compress low density products to a higher density in order to obtain a suitable capacity within reasonable dimensions. The degree of compression can be controlled via the rotation and axial movement of the piston screw.

The straw pump has been filed for patent application.

Based on the description and design in the patent application a full scale prototype was constructed by O. Brandt Hansen, Sicco, and Swea A/S, which was successfully tested by Elsam under “worst case” conditions.

5.1.2 Particle Generator

- Sicco designed a novel particle generation system providing the following advantages:
- it can operate with any level of moisture content – the more the better.
- the electricity consumption is only around 12 kWh per ton of straw i.e. about 30% of the traditional set of equipment.
- The cost of wearing parts will be reduced about 50%.
- The investment cost will be somewhat lower.

Patent protection is under consideration.

5.1.3 Novel Equipment for Hydrolysation and Extraction

Based on the possibilities of the straw pump, Sicco has designed an integrated process for hydrolysation and extraction. This process could be carried out preferably in three steps (impregnation, 2 hydrolysis steps) The system comprises an oblique twin screw reactor which is fed by the straw pump. The solid fraction will be extracted with the liquid fraction from the next step followed by pressing.

5.1.4 Steam Dryer

A novel superheated steam dryer was designed, based on the principle of the rotary drum dryer, but working under pressurised conditions. The invention has been filed for patent by Sicco.

5.2 Hydrolysis at IFA Tulln *(Owner is AGROL)*

5.2.1 Development and Evaluation of Analytical Methods

Analysis of raw material and solid residues was carried out according to standard methods, which were adapted to the specific needs. For carbohydrate analysis different photmetric and HPLC methods were evaluated.

5.2.2 Batch Hydrolysis

The results of the experiments show that temperatures between 140 and 170°C are necessary in order to reach >90% yields in hemicellulose sugars at sulphuric acid concentrations lower than 1%. Higher temperatures lead to the formation of sugar degradation products (furfural, 5-hydroxymethyl-furfural), which do not only lower the yield but also act as fermentation inhibitors. Furthermore it could be proved that the dry matter concentration has an effect on the sugar yields.

All the tested materials have found to be suitable for hydrolysis. For the waste wood, however, a pre-treatment will be necessary in order to avoid high acid concentrations.

5.2.3 Continuous Hydrolysis

The experience gained from the batch hydrolysis experiments was used to develop a continuous process, which will be tested on pilot plant scale on the Czech pilot plant, which has been adapted for this process. Straw will be used as substrate in the first experiments. The process comprises two main steps. Step 1 is carried out at low acid concentrations and moderate temperatures in order to obtain the hemicellulosic fraction. The solid residues submitted to an extraction to recover the sugars that are attached to the solid phase. The solid remainings are the feed for step 2, in which the cellulose fraction will be converted into glucose. For the optimisation of this process a detailed working plan has been prepared.

5.2.4 Evaluation of Bark as a Raw Material

An analysis of softwood bark has been performed and the sugar contents of approximately 40% makes it worth considering as a feedstock for hydrolysis. A study was conducted which lists the different compounds that can be found in bark and describes extraction methods and methods for determining tannins. Furthermore possible industrial applications for bark extracts were evaluated.

5.3 Economic Evaluation

5.3.1 Feasibility Study for an Ethanol Plant from waste wood *(Owner is ECOPRO)*

Ecopro conducted the study focused on a plant producing ethanol from waste wood B with special focus on the feasibility in Belgium. Based on this study potential suppliers for the raw material and buyers for the product and co-products were selected. Market prices for raw materials and products were investigated. A site for the erection of a plant was selected.

5.3.2 Feasibility Study for the Production of Ethanol, Power, and Building Materials from Sugar Cane Bagasse *(Owner is AGROL)*

This study shows that the proposal of treating sugarcane bagasse for the production of ethanol and a clean fuel for power production shows significant economic benefits. Assuming an average market price for ethanol of 500.00 $/ton a return on the total capital employed of 44% can be expected. Even considering the risk of investing into a new technology this potential return is very promising.

5.3.3 Prefeasibility Study on Co-production of Electricity and Bioethanol *(Owner is Elsam)*

A plant using 150 000 t of straw and 150 000 t of domestic waste is feasible. Products are ethanol, cell mass, stillage, CO_2, and energy in the form of electricity and heat. Furthermore subsidies for the clean removal of domestic waste can be expected.

5.4 Ethanol Fermentation *(Owner is AGROL)*

5.4.1 Strain Development

Physiological manipulation and selection for strains with superior growth characteristics on hydrolysate feedstocks has been achieved in continuous culture, whereas a more targeted genetic approach has been used to engineer strains with greater stability and superior production characteristics. Since AGROL's strains originate from an uncharacterised novel isolate, little was known about gene sequence, regulation of gene expression, and subsequent regulation of enzyme and product formation. Genetic techniques such as plasmid transformation were first developed from systems that already exist for thermophilic bacilli. Several genes involved in ethanol and lactate formation were then cloned and sequenced. Finally, techniques for specific gene inactivation and gene expression were developed for genetic manipulation of primary metabolism resulting in several new strains with improved stability and ethanol productivity.

5.4.2 Bench Scale Fermentations

It could be proved that the AGROL strain is able to grow on hydrolysates and to ferment them into ethanol. Furthermore it could be shown that the strain can produce ethanol from hydrolysates in continuous culture over a long period of time without losing its properties.

5.4.3 Inhibition Studies and Detoxification of Hydrolysates

The toxicity of potential fermentation inhibitors was tested on an Agrol strain. The tests were performed in microtiter plates on standard media containing varying concentrations of the inhibiting substance. Inhibition was calculated by relating the growth on inhibiting compound to a positive control. Different alkaline compounds were used for neutralising the hydrolysates. Agents that additionally reduced the concentration of ions were found to yield better fermentable hydrolysates. Several methods for the reduction of inhibitors were evaluated on their effect on growth.

5.4.4 Cell Mass Upgrading and Utilisation

Biofiber has developped a cell mass technology characterized in:

- That the cell mass by enzymatic treatments is converted into a peptone solution which can be concentrated by multistage evaporation, and used as a high value protein source in food and feed.
- That no trace of DNA activity from the cell mass will be transferred to the end product.

Biofiber has conducted shadow price calculations which identifie milk replacers to be the most profitable market segment to start with.

Biosifer has tested the novel cell mass technology in semi-industrial scale and found that it can be used to upgrade other cell mass products than Agrol´s novel micro-organism. Biofiber has entered into agreement with Agrol and Sicco according to which Agrol takes over the global exploitation of the novel cell mass technology when the micro-organism derives from Agrol and Sicco takes over the global exploitation when the nicro-organism derives from other than Agrol.

6. Exploitation Plans and Anticipated Benefits

Each of the S.M.E.´s Agrol, Ecopro and Sicco will take responsibility for the implementation of their own technology.

The S.M.E. Biofiber has decided to hand over exclusive rights to their technology covering upgrading and utilization of cell mass to Agrol when the cell mass is a microorganism from Agrol and to Sicco when the cell mass is deriving from other than Agrol.

6.1 Novel Equipment

The initial plan for development of novel equipment comprised only the Straw Pump and adaptation of the Straw Pump to a continuous pressurised hydrolyzation process and to a continuous drying process with superheated steam under pressurised conditions.

During this development work, Sicco identified some other possibilities to achieve cost reductions within the total process. The fact that cost reductions for co-production of electricity and ethanol from biomass were the central objective of the project caused Sicco to direct extra resources into these options.

The results have been very positive and it is obvious that great synergy effect will arise from an approach combining all the novel equipment. Therefore the novel equipment in exess of the initial plan has been included in the implementation plan.

6.1.1 Novel equipment for particle generation from baled straw

Sicco has split up the machinery in 2 parts and entered into negotiations with 2 Danish companies (S.M.E.´s) Champion Danmark A/S and Seelen A/S about manufacturing agreements for the 2 parts.

With Seelen A/S the negotiations also includes sales agreement for the complete machinery on the global market.

6.1.2 The Straw Pump (In the market it will be called: The Particle Pump)

Sicco has also split this machinery up in 2 main parts and entered into negotiations with 2 Danish S.M.E.´s Swea Production A/S and Bjornkjaer A/S about manufacturing agreements for the 2 parts.

Introduction on the market will be pioneered by pilot scale equipment for specialized laboratories and full scale equipment for improved loading and unloading of existing pressurised process equipment.

6.1.3 Novel Equipment for Multi-Stage High Speed Hydrolyzation/Extraction

Market introduction of this process equipment will be carried out by pilot scale equipment for specialized laboratories.

Besides the Particle Pump the process equipment comprises a novel oblique twin screw reactor and a novel vertical single screw press with reciprocating screw.

Negotiations with potential manufacturing companies have been initiated.

A preliminary proposal has been prepared for Risoe National Laboratories Denmark to rehabilitate an existing wet oxidation pilot plant. The proposal comprises replacement of an excenter pump by the Particle Pump and modification of the existing reactor.

A preliminary proposal has been prepared for an industrial wet oxidation process with the capacity of 10 t/h of straw for one of Risoes clients.

6.1.4 Novel Equipment for Drying with Superheated Steam under Pressurized Condition

Patent application filed Dec. 2000.

Negotiations about manufacturing will be started ultimo 2001 when the patent situation has been clarified. The plan is to enter into license agreement with 3-4 companies to cover the global market.

6.1.5 Novel Equipment for Simultaneous Ethanol Fermentation and Recovery.

Patent application is under preparation and will be filed ultimo 2001. Thereafter negotiations about license agreement will be initiated.

Complete plants for co-production of electricity and ethanol from biomass.

In addition to the introduction of the different examples of novel equipment Sicco will engage in the establishment of complete plants including one or more examples of the novel equipment.

In co-operation with Elsam a proposal is under preparation covering a complete plant for exploitation of 150 000 t p.a. of straw and 150 000 t p.a. of domestic waste.

The location under consideration is the power plant Fyensvaerket nereby Odense, Denmark. The feasibility studies conducted by Elsam have demonstrated a good economy.

6.1.6 Industrial Plant

Agrol commissioned a Bio-ethanol Concept study, with the technical support and input of a large engineering company. The document is of such detail so as to allow meaningful economic modelling of the capital and operating costs associated with a proposed Bio-ethanol production plant with an annual capacity on 15,000 tonnes of industrial grade ethanol.

The plant is proposed to utilise, potentially, a range of biomass feedstocks and to employ Agrol proprietary technology for the key fermentation stage of the conversion process. The preferred feedstock, studied in detail, is wheat straw.