TOP–NEST

Project number: RD 2011-42

Value chain analysis of biofuels:

Weyland

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20. September 2013

Supported by:

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Nordic Energy Research

Weyland AS was established by Karl Weydahl and Knut Helland in 2001 in order to commercialize a technology for the production of ethanol from cellulose, so-called second-generation bioethanol. The technology is a result of research and development conducted in cooperation with the Bergen University College since 1987. In 2010, Weyland built a pilot plant to demonstrate that their core technology – a process related to the recovery and recycling of the acid used in the hydrolysis process – works as intended. Weyland's business plan is to provide hardware for 'strong acid hydrolysis for bio refineries and license their technology to other manufacturers, in addition to some consulting work.

1. Basic input/output structure

1a. Main activities/segments

Feedstock provisioning

Weyland develops technology for producing bioethanol from cellulosic raw material. Weyland has demonstrated that the technology can be used to produce bioethanol from multiple cellulosic feedstocks, including sugarcane bagasse, corn stover, corn cobs, rice straw, hardwoods, softwoods, wood wastes and paper wastes. Weyland describes the versatility of feedstocks that its production technology might handle as a competitive advantage[1].

In their interview, Weyland expressed that their production technology has a competitive advantage when it uses cellulose as feedstock.

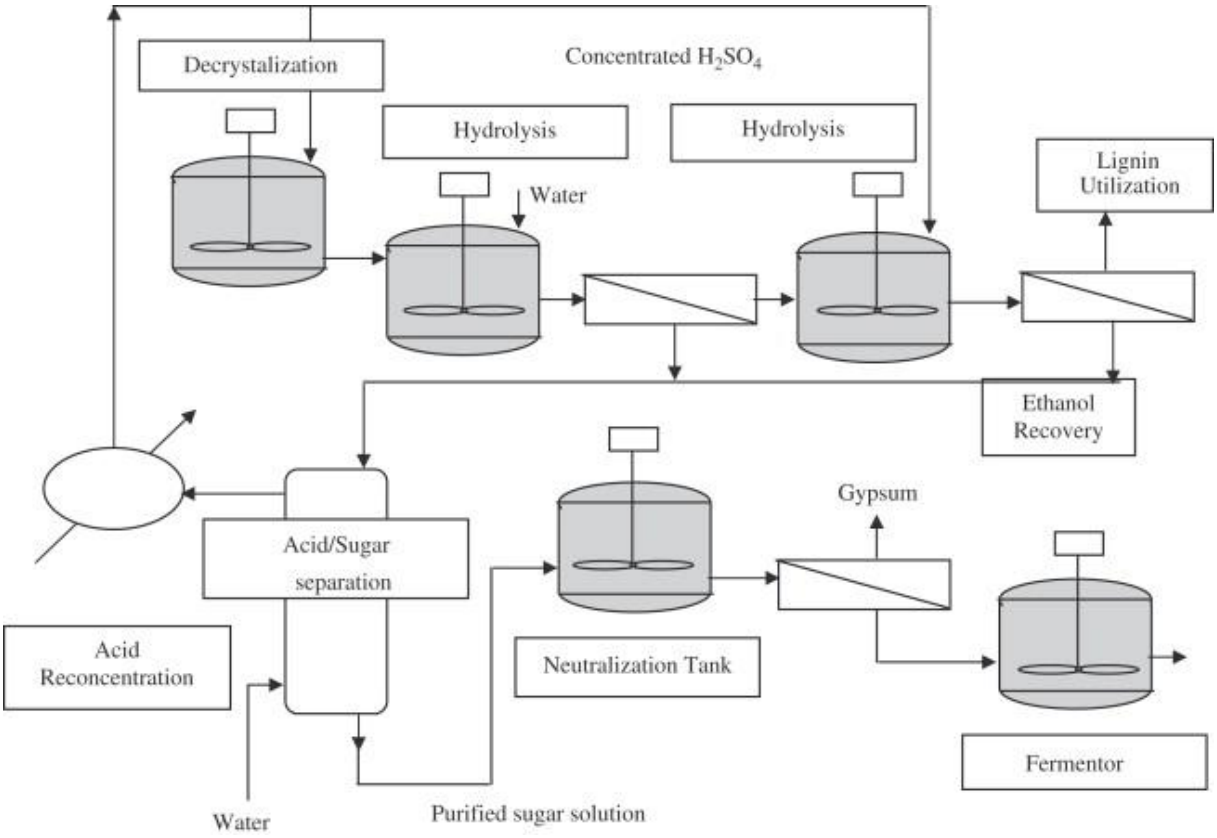
Processing

Weyland has developed technology for producing bioethanol using concentrated (strong) acid hydrolysis. Bioethanol can be produced through two main types of pathways: *thermo-chemical pathway or biomass-to-liquid (BtL) approach* – which involves gasification of the biomass into a synthetic gas from which the fuel is extracted – and *bio-chemical pathway* – which involves freeing sugar molecules from cellulose using enzymes, acids, steam heating, or other pre-treatments. The hydrolysis technology Weyland uses follows is the bio-chemical pathway. There are currently three types of bio-chemical processing technologies used to produce bioethanol – *biologic hydrolysis* using enzymes**,** *diluted acid hydrolysis* using acid and heat and *strong acid hydrolysis* using concentrated acids. Weyland uses strong acid hydrolysis, and it is their technological innovation to recycle the acids that their business is based on.

Weyland's production of cellulosic ethanol is similar to other bio-chemical production processes and can be divided into the same five main phases: pre-treatment, hydrolysis, fermentation, distillation, and separation. It is primarily in the hydrolysis phase that Weyland's approach differs from other bioethanol producers. In this phase, it makes use concentrated acid and its patented process technology to recycle most of the acid (98,5%) that it uses in the hydrolysis process. Concentrated acid hydrolysis has the added advantage over diluted acid hydrolysis of higher sugar yields and low operating temperature[2]. *(Weyland points out that diluted acid hydrolysis is for all practical purposes not used, due to its high costs).*

[1] http://www.ethanolproducer.com/articles/7089/pilot-scale-cellulosic-plant-opens-in-norway
[2] http://bada.hb.se/bitstream/2320/2959/2/5_Taherzadeh.pdf

Figure 1: Concentrated acid hydrolysis process (generic)



Use of waste products

As for other types of bioethanol production, lignin is a by-product of the production process. The lignin can, among other things, be used as a fuel in the ethanol production plant boilers or burnt in power plants. Weyland does not state a particular use of their waste products since their pilot plant is built primarily to demonstrate their technology.

Weyland uses residues from lumber production as feedstock – which is in itself a waste product.

Integration with other energy production technologies

The bio refineries that Weyland might potentially help build in the future will for the most part be integrated with other energy producing technologies in the same way as other bio refineries. One exception is that that Weyland's concentrated acid hydrolysis process requires less heat than for instance diluted acid hydrolysis, and therefor there is less need to redistribute excess heat into other uses.

End use

The ethanol produced in the pilot plant and other potential plants based on their technologies can be used in many areas, such as car care, paint, vanish, the pharmaceutical industry and as a biofuel. The biofuel can be used in busses and as an addition to petrol.

Weyland is primarily a technology and hardware provider and has no plans to operate bio refineries themselves. Their end users are therefore companies that want to construct and operate bio refineries. Weyland is in the process of developing and demonstrating its technologies.

Weyland *points out that in the last 2-3 years most biofuel companies have come to the realization that bioethanol will not be competitive against fossil fuel. The technology is not efficient enough, the costs are too high and no one are willing to build large-scale facilities. The introduction of shale gas in the US have made future prospects bleak. Therefore, Weyland have decided to focus on using its technologies for plants that produce other products than bioethanol from cellulose, such as different types of bio-based polymers and bio-chemicals.*

Distribution, marketing and sales

Weyland is primarily in the process of developing and demonstrating its technologies and has limited commercial activity (see financial figures below). *The main commercial areas that Weyland are interested in are:*

- *Some hardware components in the concentrated acid hydrolysis process*
- *Licensing of their technology*
- *Some consultancy work*

1b. Main supporting activities

- Weyland has since 2007 received funding from the Research Council of Norway (RCN) to carry out four R&D projects to further develop its technologies. The latest started in September 2010 and will be finalized in 2012.
- In 2010, Weyland received support from Transnova to carry out a feasability-study for the construction of a demonstration plant together with Elkem – Salten Bioetanol
- Weyland has participated in a Nordic Top-level-initiative – the project Sustainable Biofuel: Innovations in Bioethanol Production Technologies. In these projects, Weyland collaborates with Sintef (principle investigator), PFI, Statoil, Inventia from Sweden, VTT from Finland, Denmark's Technical University and Matis-Food from Island. The project will go over five years and received 12.5 million NOK funding.
- Weyland received in 2009 subsidies from SkatteFunn and Innovation Norway.
- Weyland AS has been backed up by several investors, such as Fana Stein & Gjenvinning with 5 million NOK, Sarsia Seed with 6.3 million NOK, StatoilHydro 6 millions NOK and Sparebanken Vest. The company has expressed investment needs for a full-scale facility around 300-400 millions NOK [33].

Weyland pointed out that one of the main inhibitors were a lack of capital and investments in the company. They said that all the financial capital were directed towards property, oil or shipping

1c. Type of companies involved in each segment

Feedstock provisioning

Weyland can make use of a wide range of feedstocks in their pilot plant, including sugarcane bagasse, corn stover, corn cobs, rice straw, hardwoods, softwoods, wood wastes and paper wastes. The purpose of the pilot plant is, nevertheless, to verify and document the unique features of the process, and to demonstrate the commercial viability of the technology and it is therefore put into

full-scale commercial production. What kind of feedstock that will be used when their plants are built commercially, is too soon to say and will depend on who the customers are and the research results from the pilot plant.

Processing (biosolids and biowaste treatment)

Weyland has – through the sponsorship of Statoil and Innovation Norway – built a pilot plant with a capacity equivalent to approximately 200,000 liters ethanol output per year. The Pilot plant was officially opened in October 2010, and they have since then demonstrated that the Weyland process related to the recovery and recycling of the acid works as intended. The purpose of the pilot plant is to verify and document the unique features of the process, and to demonstrate the commercial viability of the technology. The pilot plant also serves as a platform to scale the technology towards commercial size plants, and is well suited to run comprehensive experiments with different types of feedstock in semi industrial scale.

1.d. Lead firms

Weyland could be described as one of the lead firm on developing concentrated acid hydrolysis equipment. There are only a few competitors in this segment, among others Arkenol Inc. and Masada Resource group which are developing two plants based on the same concentrated acid hydrolysis in North America[3]. Nevertheless, Weyland has no ambition of being a lead firm in bio refining. It has stated that it wants to become an equipment provider for other bioethanol companies.

2. Key technologies

2.a. Technologies for main and supporting activities

Weyland has developed technology for producing bioethanol using concentrated (strong) acid hydrolysis. This technology is in itself fairly old. It was discovered in the beginning of the 19th century. Nevertheless, Weyland's main technological innovation is a process of recycling most of the acid (98,5%) that it used in the hydrolysis process. This technology is still in the development phase.

Weyland points out that its concentrated acid hydrolysis have some competitive advantages over rival technologies – such as enzyme based hydrolysis and biomass-to-liquid approaches. Compared to:

Enzyme-based hydrolysis

- *Enzymes need to be fresh and deteriorate quickly, limiting its geographical scope*
- *Enzymes are oligopolies and the costs of enzymes can be high*
- *The process takes more time*
- *And the feedstock need to be pre-treated*
- *Popular process used by 9/10*

Biomass to liquid approaches:

- Very efficient process
- Need very large facilities and very large facilities need a lot of feedstock
- A lot of feedstock increased the transportation costs and they can be significant

[3] http://bada.hb.se/bitstream/2320/2959/2/5_Taherzadeh.pdf

Weyland also point out they their technology produced sugar in a way that created few 'inhibitors,' which made it easier to further refine it into new products.

2.b. Assessment of technological development stage

Weyland is in the process of establishing the viability of its concentrated acid hydrolysis process and the technology can therefore be described as embryonic.

2.c. Is the technology disruptive or path-following/incremental?

Weyland's concentrated acid hydrolysis technology is mostly path-following, since most of the bio ethanol production process follow the same stages and use the same technology as other bioethanol producers.

2.d. Market characteristics

Weyland operates in the hardware/technology market. Potential customers include all bio refineries. *Nevertheless, Weyland points out that they have a competitive advantage in producing sugar from cellulose – particularly from lumber/lumber residues found in the Northern hemisphere (e.g. Norway, Minnesota).*

Weyland believes that bioethanol might have some prospects in the future, when the technology has matured substantially. They believe that there will always be demand for liquid fuels and bioethanol can also be used in fuel-cell based vehicles. They believe that a likely alternative to ethanol is butanol.

2.e. Energy and environmental performance

3. Geographic scope

The scope of Weyland's operations is fairly limited since its technology is under development.

Weyland pointed out they believed that their main market would be in the US in the future, especially Minnesota. They felt that they were not receiving sufficient interest from the Norwegian woodworking industry.

4. Governance

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5. Institutional context

[Same as in the Borregaard case study]

The White Paper on Climate (St.meld. nr. 34, 2006–2007) stated the ambition for target oriented and coordinated policy measures for an increased use and expansion of bioenergy up to 14 TWh by 2020 and that the target of an increase of 14 TWh before 2020 is maintained. The White Paper highlighted the need for 2GB in Norway. The Norwegian government introduced in 2006 a tax exemption for bio-ethanol if this bio-ethanol would constitute the main part of gasoline. In response to that, in May 2006 Statoil launched a new gasoline including 85% bio-ethanol, the so-called E85. However, this was not necessary second generation bio-ethanol: in a specification Statoil admitted that it is based on

corn from Europe and sugar cane from Brazil. In 2007, ethanol or flexi-fuel cars (that is E85 cars) were allowed a reduction in the Vehicle Import Duty, equalling NOK 10 000.

Since 1999 biodiesel was exempt from fuel tax (NOK 3.02 per litre) and CO_2 charges (NOK 0.54 per litre). At the end of 2009 the removal of the tax exemption for bio-diesel led to a high debate on framework conditions for the development of biofuels in Norway. However, some financial incentives are still in place, such as the tax exception for high blends of bio-ethanol with gasoline and a reduced one-off motor vehicle registration tax for flexi-fuel cars, both favouring bio-ethanol.

Weyland mentioned that the removal of tax exemption on bio-diesel were devastating for the biofuel business in Norway. It has made it much more difficult to get anyone to invest in this business area.

Key financial figures

Weyland AS

Organisasjonsnummer:	983 535 097
Navn/foretaksnavn:	Weyland AS
Organisasjonsform:	Aksjeselskap
Kommune:	Bergen
Antall ansatte:	11 til 15
Næringskode(r):	72.110 Forskning og utviklingsarbeid innen bioteknologi
Datterselskaper	Weyland Consult AS

Aksjonærer:

Navn	Ant aksjer	Andel i %
Fana Stein & Gjenvinning AS	138000	35.58%
Sarsia Seed AS	102320	26.38%
Weydahl og Helland AS	100000	25.78%
Sparebanken Vest	41589	10.72%
Øvrige Eiere	6000	1.55%

RESULTATREGNSKAP*	2010	2009	2008	2007	2006
Sum driftsinntekter	2 447	13 467	572	0	60
Driftsresultat	-3 263	-12 682	-4 005	-554	-52
Resultat før skatt	-3 087	-12 454	-3 848	-525	-52
Årsresultat	-3 087	-12 454	-3 848	-525	-52
Lønnskostnader	893	300	0	0	0

* 1000 NOK