Biocatalysis in Finnoflag Biorefining – Outlines of ABOWE Results and Future Perspectives

Adj. Prof. Elias Hakalehto, Finnoflag Oy/UEF

In :"Biorefining around the Baltic Sea and Global Ecodevelopment"
Elias Hakalehto, Viikki 30.10.2014

Industry Like Nature®

Energy Flows in Nature

See figure in the forthcoming publication:

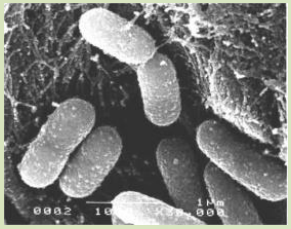
Hakalehto, E. 2015. Enhanced microbial process in the sustainable fuel production. In Jinyue, Y (Ed.). Handbook of Clean Energy Systems. J.R.Wiley & Sons USA. In Print

BIOREFINERY TECHNOLOGY

RESEARCH IDEA

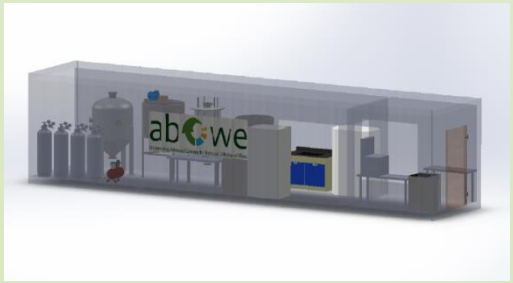
Utilization of the metabolism of the invisible microbes (and their enzymes)

- bacteria
- yeasts
- molds
- algae
- protozoa



TOOLS

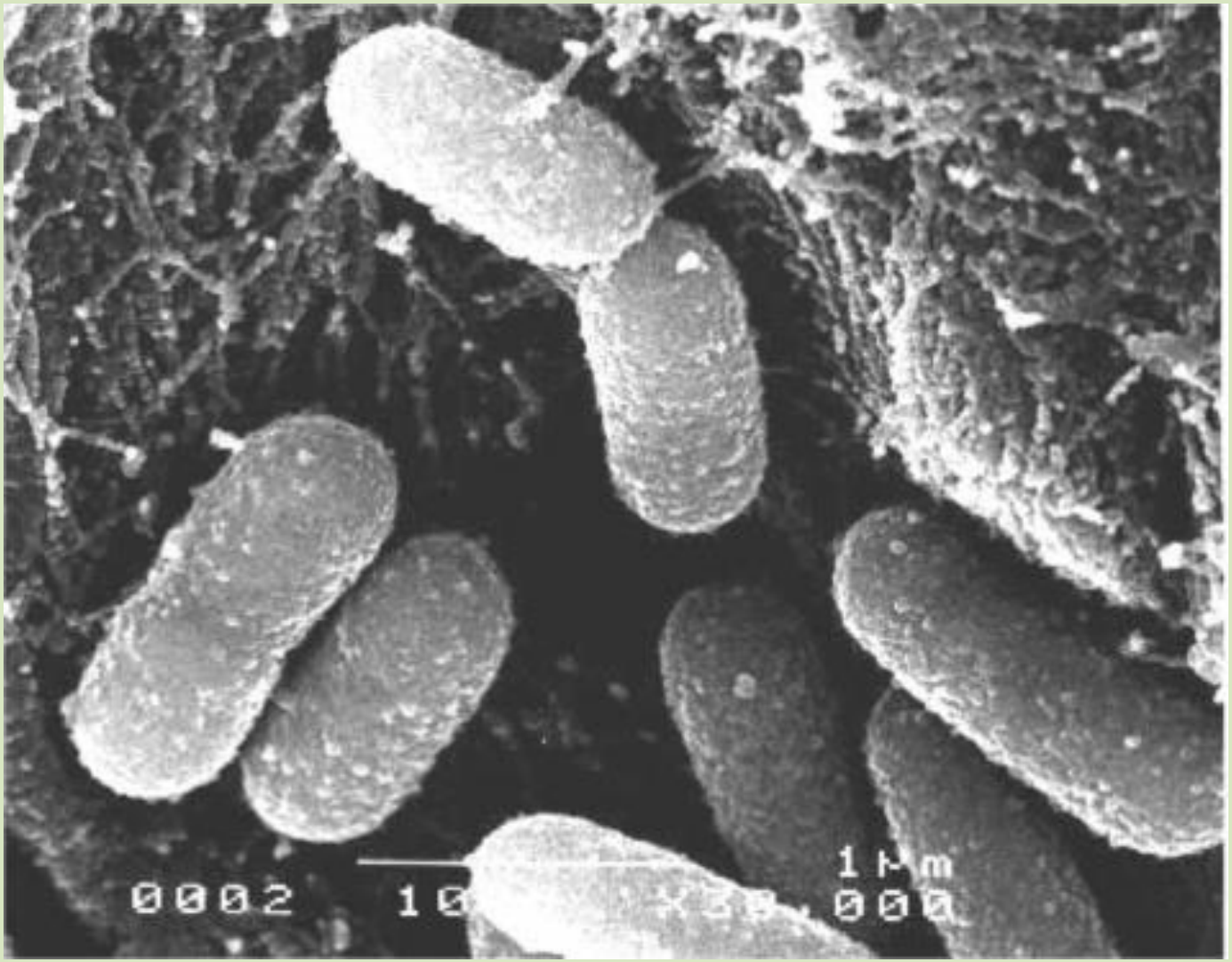
Biorefinery concept, where biological components and technological solutions have been developed hand in hand.



GOALS

Production of

- Energy
- Fuels
- Bulk chemicals
- Nutritional components
- Cosmetics
- Medicinal substances
- Purified water, air, soil



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In :"Biorefining around the Baltic Sea and Global Ecodevelopment"
Elias Hakalehto, Viikki 30.10.2014

Microbial carbon circulation in the Finnish Nature. Micro-organisms liberate carbon into the air mostly as CO2 in respiration and fermentation, and CH4 in symbiotic fermentation (by acid producing eubacteria and methane producing archae). Any anthropogenic impact on any of the parts of these sequences will eventually effect all the parts, and consequently shake the balance.

See figure in the forthcoming publication:

Hakalehto, E. 2014. Bacteriological indications of human activities in the ecosystems. In: Armon, R. & Hänninen, O. (eds.) Environmental indicators. In Print. Springer Verlag, Germany.

EXAMPLE OF PLANT AND MICROBE SEALED ECOSYSTEM

Thriving since 1960, my garden in a bottle: Seedling sealed in its own ecosystem and watered just once in 53 years David Latimer first planted his bottle garden in 1960 and last watered it in 1972 before tightly sealing it shut 'as an experiment' The hardy spiderworts plant inside has grown to fill the 10-gallon container by surviving entirely on recycled air, nutrients and water
Gardeners' Question Time expert says it is 'a great example just how pioneering plants can be'
By DAVID WILKES FOR THE DAILY MAIL
PUBLISHED: 10:45 GMT, 24 January 2013 | **UPDATED:** 09:41 GMT, 25 January 2013

EXAMPLE OF PLANT AND MICROBE SEALED ECOSYSTEM

Habitable zone: The spot under the stairs where Mr Latimer has kept the bottle garden for the past 27 years

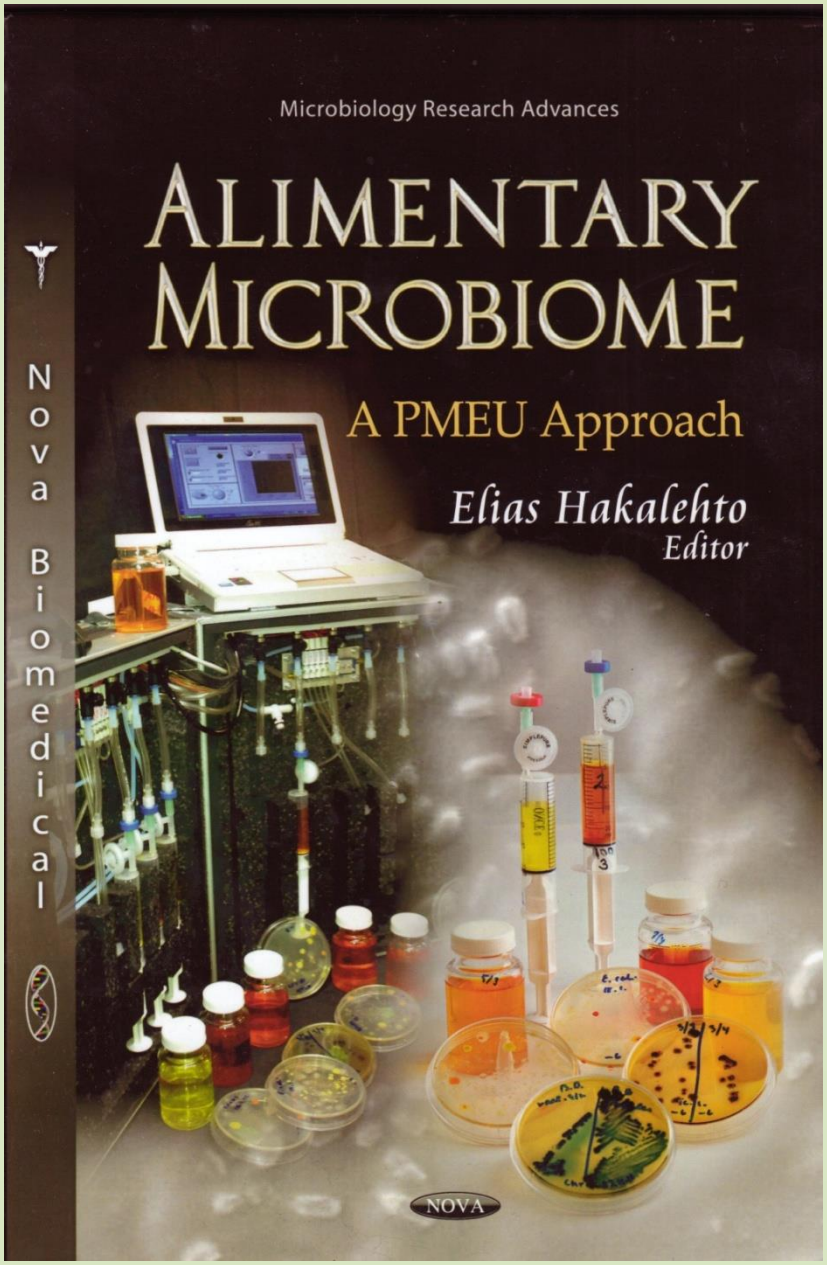
MOLECULAR COMMUNICATION

The concept came across the author for the first time some 30 years ago. It was used by Finnish microbiologist and numerical taxonomist, **Prof. Helge Gyllenberg**. It includes:

1. interactions between various microbial strains and communities

2. physicochemical signaling between the microbes and their human, animal or plant host.

Hakalehto, E. Alimentary Microbiome - A PMEU Approach. Nova Science Publishers Inc., N.Y., USA, 2012.



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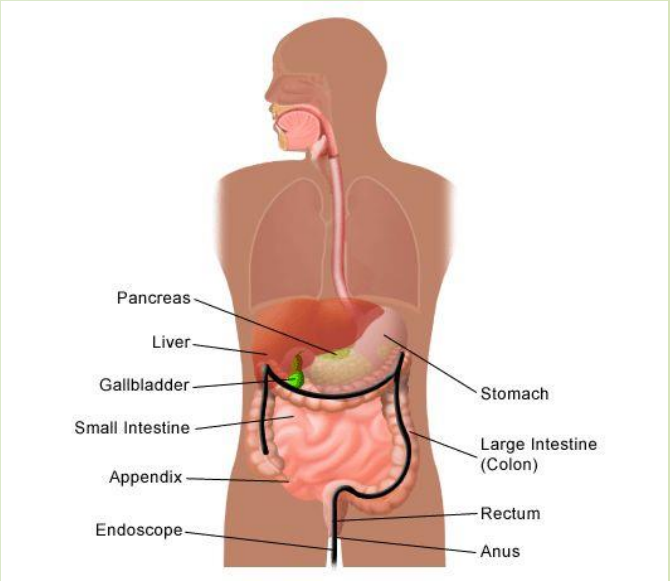
In :"Biorefining around the Baltic Sea and Global Ecodevelopment"
Elias Hakalehto, Viikki 30.10.2014

Patient no	Cardia	Antrum	Pylorus
1	*Enterococcus faecalis* (2)[a] *Str. thermophilus* *L. salivarius ssp. salivarius*	*L. salivarius ssp. salivarius (2)*	*L.s salivarius ssp. salivarius*
2	*S.. salivarius* (2)		
4	*S..sanguinis* (2) *S..salivarius* *E. faecalis*	*S. salivarius*	
5	*S. salivarius*	*Str. salivarius*	*L. salivarius*
6		*L. reuteri* *L.casei* 97%	*L.reuteri*
7		*L. reuteri* (3) *S.salivarius*	*L. reuteri*
8		*Str.sanguinis*	*Lactobacillus reuteri* (2)
9	*Lactococcus lactis ssp. lactis (2)*		*S. thermophilus*
10	*S. sanguinis*	*S. sanguinis*	*S.. sanguinis*
11	*S.salivarius* (2)	*Str. salivarius* (2)	*L. reuteri* (3)
12	*S. salivarius* 	*Str.salivarius* (3) *L. reuteri* (2)	*S.salivarius*
13	*S. salivarius* (2)		*S. salivarius*

Identified LAB (lactic acid bacteria) species enriched from the biopsies obtained from different gastric sites and cultivated with PMEU



Hakalehto, E; Vilpponen-Salmela, T; Kinnunen, K; von Wright, A. Lactic Acid bacteria enriched from human gastric biopsies. *ISRN Gastroenterol,* 2011.

The joint effect of a probiotic mixture of *Lactobacillus acidophilus, Bifidobacterium bifidum,* and *B. lactis* with prebiotic flax on *Escherichia coli* growth in the PMEU. Note that the logarithmic scale indicates approximately 100-fold restriction of the colibacteria.

See figure in the forthcoming publication:

Hakalehto, E.; Jaakkola, K.; Pesola, J.; Heitto, A.; Hell, M.; Hänninen, O. "Tendencies in Probiotic Treatments, In Hakalehto, E. (ed.) Microbiological Clinical Hygiene, Nova Science Publishers Inc., N.Y., USA, 2014, In Print.

In an ecosystem there is an interdependence between

organisms,

their metabolism

and biocatalysis

Biocatalysis

Biocatalysis is the use of natural catalysts, such as protein enzymes, to perform chemical transformations on organic compounds. Both enzymes that have been more or less isolated and enzymes still residing inside living cells are employed for this task.

Biocatalysis - Wikipedia, the free encyclopedia
en.wikipedia.org/wiki/Biocatalysis

EU Baltic Sea Region Projects

REMOWE

Regional Mobilizing of Sustainable Waste-to-Energy Production 2009-2012

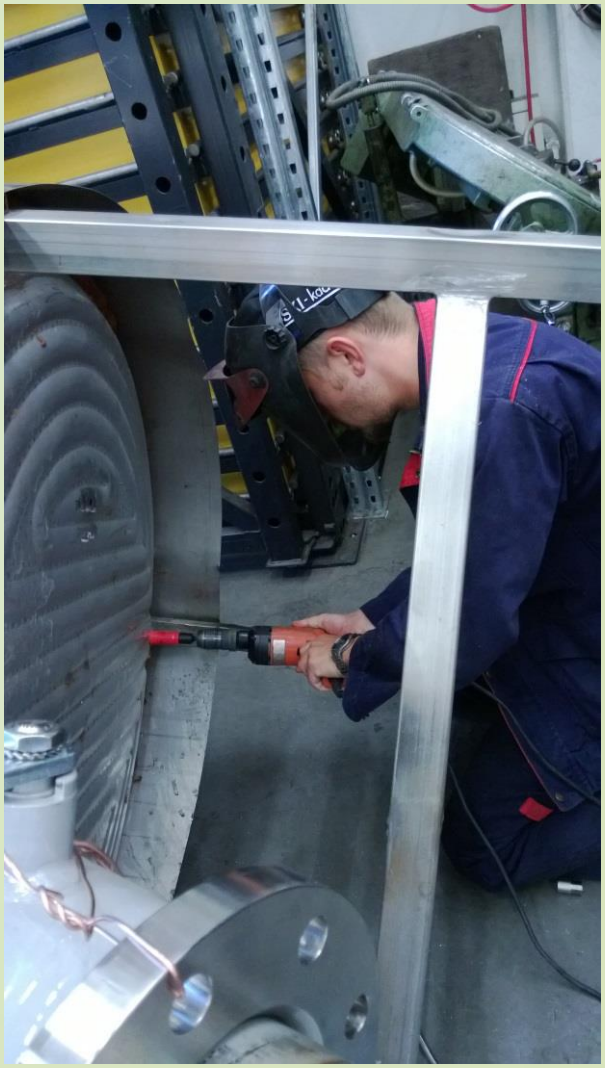
ABOWE

Implementing Advanced Concepts for Biological Utilization of Waste 2012-2014

Participating countries:

Estonia, Finland, Germany, Lithuania, Poland, Sweden

Construction of Pilot A in Kuopio, Finland Autumn 2013



Reactor manufacturing in a local work shop in Kuopio, Autumn 2013

Industry Like Nature®

In :"Biorefining around the Baltic Sea and Global Ecodevelopment"
Elias Hakalehto, Viikki 30.10.2014

Journal: Ympäristö ja yritys tänään (Environment and enterprise today) autumn 2014

Uusi biotalouden innovaatio kurkottaa isoille markkinoille

Teksti: Jouni Vornanen
Kuvat: Ari Jääskeläinen

Biojalostamo-pilottilaitos ensimmäisessä testauspaikassaan Savon Sellun jätevedenpuhdistamolla Kuopiossa.

Lahdessa viime keväänä järjestetyillä ammattikorkeakoulupäivillä palkittiin parhaat tutkimus-, kehitys- ja innovaatiohankkeet. Ensimmäisen sarjan voiton nappasi Savonia-ammattikorkeakoulun hanke ABOWE – Implementing Advanced Concepts for Biological Utilization of Waste.

Kyseessä on kansainvälisestikin ainutlaatuinen suomalaisinnovaatio, joka esiteltiin huhtikuussa tiedekeskus Heurekassa Vantaalla. Uudessa innovaatiossa muutetaan jätteet käyttökelpoisiksi tuotteiksi. Biojalostamosta odotetaan todellista päänavausta suomalaisen biotalousosaamiseen.

Liikuteltavassa biojalostamossa yhdyskuntien ja teollisuuden jätteistä ja sivuvirroista valmistetaan mikrobien avulla biopolttoaineita, arvokkaita teollisuuskemikaaleja ja lannoitteita. Lopputuotteina voivat olla esimerkiksi jäänestoaineet, teolliset kuidut sekä muovien ja synteettisen kumin sekä kosmetiikan ja lääketeollisuuden raaka-aineet.

Asetoni-butanolikäymisellä tuotetaan myös butanolia, etanolia, asetonia ja vetyä. Näistä butanoli käy lähes sellaisenaan autojen tankkiin liikennepolttoaineena. Myös vety voi nesteytettynä toimia moottoripolttoaineena, jonka merkitys tulevaisuudessa energian lähteenä kasvaa nopeasti.

Biojalostamon taustalla on kuopiolaisen dosentti Elias Hakalehdon kehittämä mikrobiologiseen käymiseen perustuva prosessiteknologia. Hakalehto arvioi markkinanäkymiä positiivisiksi.

– Mikrobien hyödyntäminen luonnonmukaisella tavalla mahdollistaa entistä tehokkaamman aineiden kierrätyksen teollisuuden prosesseissa ja maataloudessa. Korkeat lopputuotepitoisuudet, läpimenoltaan lyhyet prosessit ja monipuolinen tuotevalikoima yhdistettynä optimiin laitoskokoon tekevät investoinnista edullisen ja houkuttelevan.

Laitosta testataan Puolassa ja Ruotsissa

Biojalostamoa on testattu alkuvuoden aikana Powerflute Oy:n Savon Sellun tehtaalla Kuopiossa. Puhdistamolietteen ja jäteveden käsittelystä on saatu lupaavia tuloksia. Savonian liiketalous puolestaan vastaa kaikilla hankkeen testausalueilla paikallisten toimijoiden kanssa liiketoimintamallien ja investointimuistioiden laatimisesta. Itä-Suomen yliopisto puolestaan mallintaa tuloksia kunkin alueen näkökulmasta.

– Heurekasta pilottilaitos jatkoi matkaa Puolaan, missä sitä on testattu perunalastutehtaan jätteillä. Sieltä se kuljetettiin Ruotsiin testattavaksi luomukanalan teurasjätteellä, kertoo projektipäällikkö Ari Jääskeläinen Savoniasta.

– Tulevaisuuden biojalostamot ovat eräänlaisia keitiä, joihin toimitetaan paikallisen teollisuuden ja yhdyskuntien sivuvirtoja, ja nämä saadaan täysimääräisesti

Bioprosessin kehittäjä dosentti Elias Hakalehto biojalostamo-pilottilaitoksen prosessitilassa hetkeä ennen ensimmäisten varsinaisten kokeiden käynnistymistä tammikuussa 2014.

mikrobianalytiikan dosenttina. Hän on halunnut teknologiaan ideoita myös ihmisten ja eläinten ruuansulatuksesta.

Pilottilaitos on rakennettu laajana kuopiolaisena yhteistyönä. Savonian tekniikan yksikön vetämän ja päästössä toteuttamiin suunnittelu- ja asennustöihin on osallistunut Savon ammatti- ja aikuisopisto ja lukuisia pääasiassa kuopiolaisia teknologiayrityksiä. Monien tekniikan alojen opiskelijoita molemmista oppilaitoksista on osallistunut projektiin.

Työ- ja elinkeinoministeriö on osarahoittajana EU:n Itämeren ohjelmaan kuuluvassa ABOWE -hankkeessa. Myös Pohjois-Savon liitto on osarahoittanut hanketta Pohjois-Savon kehittämisrahastosta.

ABOWE -hanke järjestää avoimen kansainvälisen loppuseminaarin Helsingissä Viikin kampusalueella torstaina 30.10.2014. Kaikki asiasta kiinnostuneet ovat tervetulleita. ❐

Lisätietoja on saatavilla ABOWE -hankkeen kotisivuilla: www.abowe.eu

Uudessa innovaatiossa muutetaan jätteet käyttökelpoisiksi tuotteiksi.

Click on Sign to add and place signatures PDF file.

Article in Swedish press

8 Nyheter

FÖRSÖNING Pilotprojekt i Östergötlandsområdet

Slaktavfall från Enköping används i energiprojekt

FÖRVANDLING. Slaktavfall från kycklingar vid Hagby gård utanför Enköping kan förvandlas till plast och parfym.

I ett EU-finansierat forskningsprojekt tar man nu reda på hur olika typer av avfall går att omvandla till användbara produkter.

KUNSKAP "Genom projektet lär vi oss att förstå processen bättre och hur man skulle kunna tillvarata detta i en fullskalig anläggning."

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In :"Biorefining around the Baltic Sea and Global Ecodevelopment"
Elias Hakalehto, Viikki 30.10.2014

Group at Hagby farm in Enköping in the morning 9.9.2014. From right to left: Fadi Atif Fakhir, Henny Andersson, Yuiyng Li, Anneli Heitto, Erik Dahlqvist, Elias Hakalehto.

BIOREFINERIES

ABOWE up and running

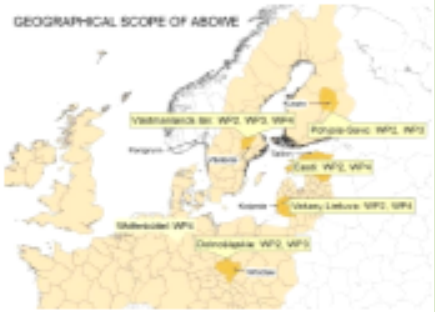
Interesting possibilities ahead

As REMOWE project (Regional Mobilization of Sustainable Waste to Energy Production) was finalized, at the same time started the extension stage project ABOWE (Implementing Advanced Concepts for Biological Utilisation of Waste) to work with two promising technologies, unlocking investments with support from the Baltic Sea Region programme.

Two mobile pilot plants will be built and tested in several Baltic Sea Region countries.

Pilot plant A is planned in Finland for testing enzymatic hydrolysis and microbiological processing (biocatalysis approach) of various wastes by Savonia UAS and Finnoflag Oy.
Pilot plant B is a German dry fermentation process, invested by Osfalia University of Applied Sciences.

GEOGRAPHICAL SCOPE OF ABOWE



The pilots form the basis for know-how transfer, compilation of investment memos and upcoming investor events as well as evaluating the new processes' economic and climatic impacts in each region.

The desired outcome from ABOWE is implementer/investor driven continuation projects targeting full scale plant investments of the two technologies.

In these Newsletters, we will inform about proceeding of these ABOWE activities. Updated information will be available at www.abowe.eu

Operational time for ABOWE is 12/2012 - 6/2014.

Ari Jääskeläinen
Project Coordinator
Savonia University of Applied Sciences

Photos: Ari Jääskeläinen

In :"Biorefining around the Baltic Sea and Global Ecodevelopment"
Elias Hakalehto, Viikki 30.10.2014

Finnish testing 1-3/2014

Savon Sellu fluting factory, Kuopio	**SITE**
Cellulosic waste	BIOMASS
Too high H_2S production	PROBLEM
Nutrient bed with seed bacteria	SOLUTION
2,3 butanediol, ethanol, butanol, butyrate,propionate, hydrogen	PRODUCTS

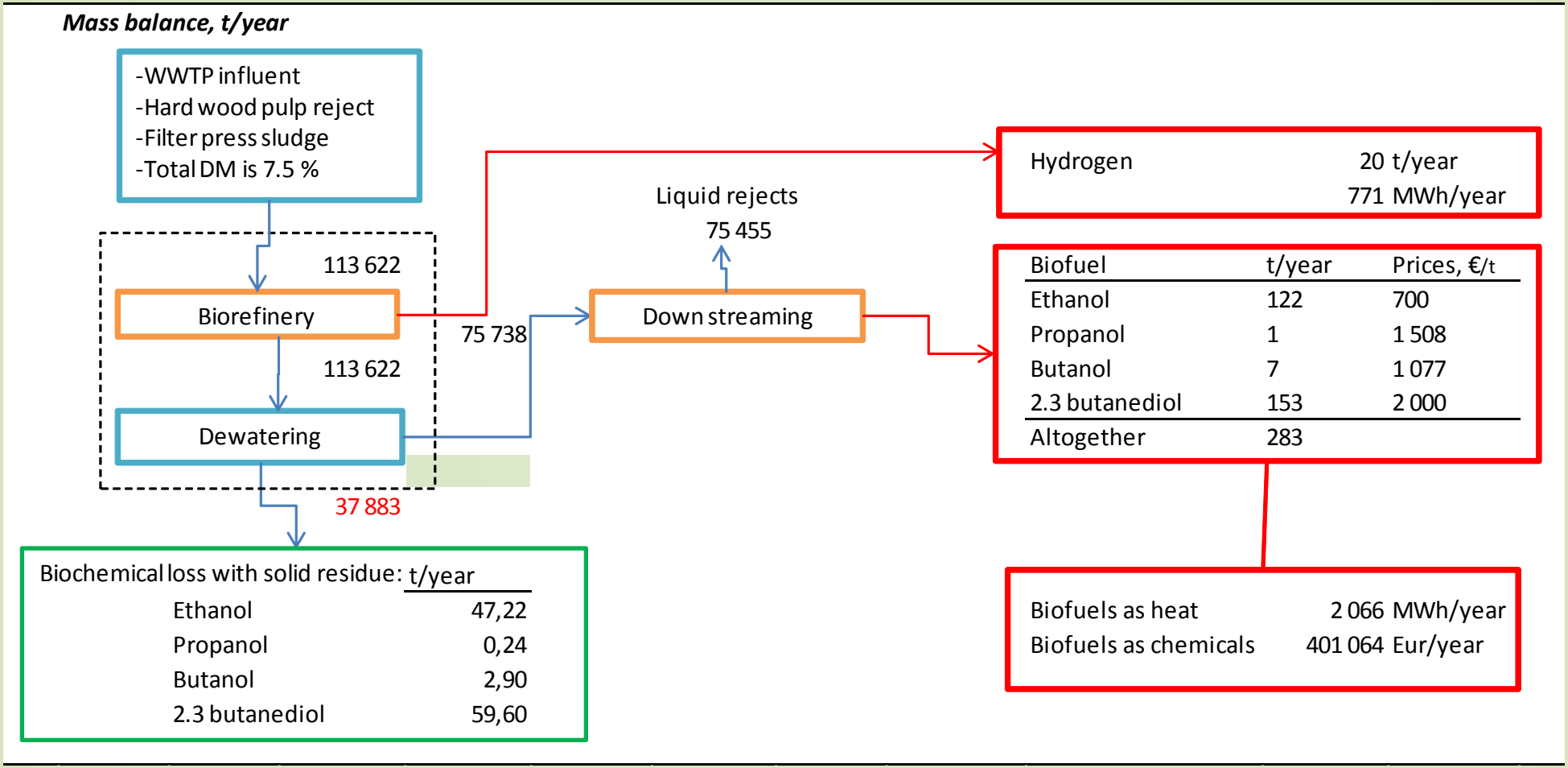
In :"Biorefining around the Baltic Sea and Global Ecodevelopment"
Elias Hakalehto, Viikki 30.10.2014

SAVON SELLU WASTE WATER TREATMENT PLANT

Hakalehto, E. 2015. Enhanced microbial process in the sustainable fuel production. In Jinyue, Y (Ed.). Handbook of Clean Energy Systems. J.R.Wiley & Sons USA. In Print.

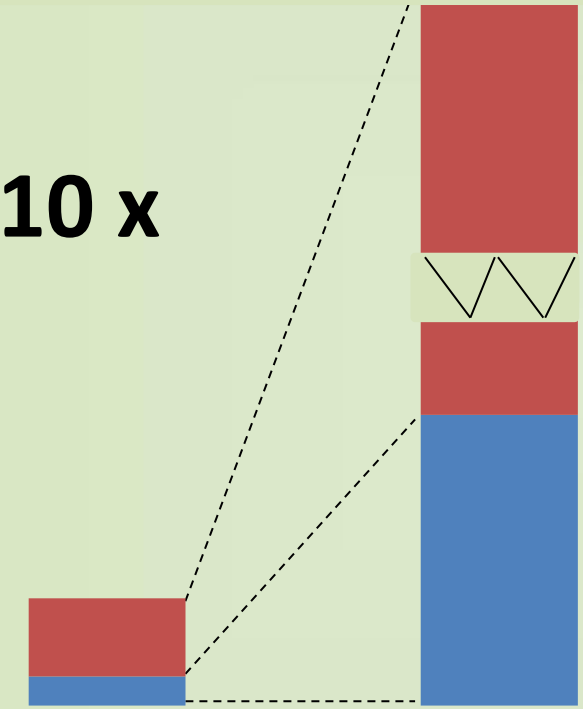
Commercial assessment Pulp&Paper: Mass balance in a WWTP application with end product potentials from one pulp mill

(based on preliminary pilot runs in Abowe project, calculated by Tuomas Huopana, UEF)



CELLULOSIC WASTE ENERGY POTENTIAL IN BIOREFINING

10 x



Energy potential in chemical substances

Energy potential in H_2

Additional Thermal Energy

2066 MWh= heating of 125 houses

771 MWh= heating of 35 houses

According to short 2 mo testing during ABOWE

Potential in the Savon Sellu waste sludge amounts

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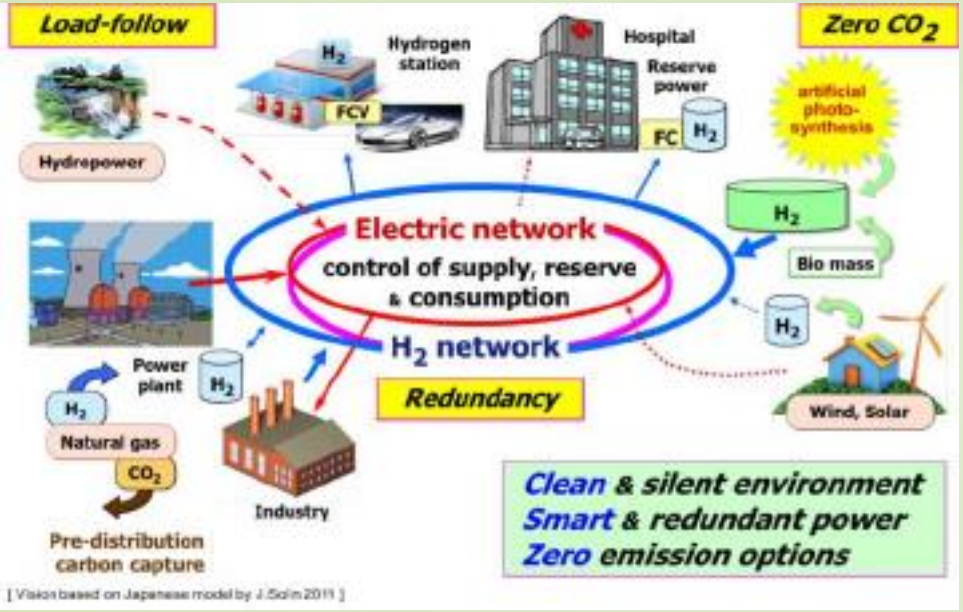
POTENTIAL AS HYDROGEN FUEL ACCORDING TO PRELIMINARY TESTS ONLY

FROM SAVON SELLU FACTORY WASTE WATER TREATMENT →

H_2 (HYDROGEN) PRODUCTION/DAY CORRESPONDING TO 10 000 -20 000 KM WITH A FCV (Fuel Cell Vehicle)

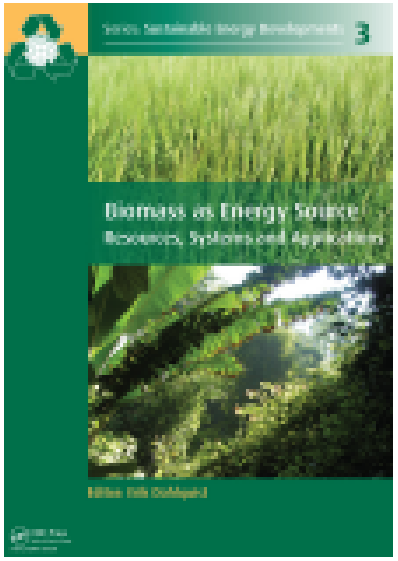
In :"Biorefining around the Baltic Sea and Global Ecodevelopment"
Elias Hakalehto, Viikki 30.10.2014

FUEL CELL VEHICLE



Full cell vehicle F-Cell -car, which is based on model B. Production 200 cars (source: Mercedes-Benz).

Interior of Pilot A during a test run with slaughterhouse waste and chicken manure/ saw dust in Enköping, September 2014



SUSTAINABLE ENERGY BOOK SERIES

Series editor
Jochen Bundschuh

VOLUME 3

Biomass as Energy Source

Resources, Systems and Applications

Edited by

Erik Dahlquist

Mälardalen University, Västerås, Sweden

Global energy use is approximately 140 000 TWh per year. Interestingly, biomass production amounts to approximately 270 000 TWh per year, or roughly twice as much, whereas the official figure of biomass use for energy applications is 10-15% of the global energy use.

This book discusses the biomass resources available and aspects like efficient energy use. One way of using energy efficiently is to use waste biomass or cellulosic materials in biorefineries, where production of fibers and products from fibers is combined with production of most chemicals we need in our daily life. Such products include clothes, soap, perfume, medicines etc. Conventional pulp and paper applications, bio-fuel for vehicles and even fuel for aviation as well as heat and power production are covered. The problem with biomass is not availability, but the difficulty to use the resources efficiently without harming the long-term productivity. This book covers all types of resources on a global scale, making it unique. Many researchers from all over the world have contributed to give a good coverage of all the different international perspectives. This book will provide facts and inspiration to professionals, engineers, researchers, and students as well as to those working for various authorities and organizations.

Erik Dahlquist, *Biomass as Energy Source: Resources, Systems and Applications*
March 2013: 246 x 174 mm: 300 Pages
Hardback: ISBN 978-0-415-62087-1, UK £ 82.00 / US $ 134.95
Order at www.crcpress.com/9780415620871

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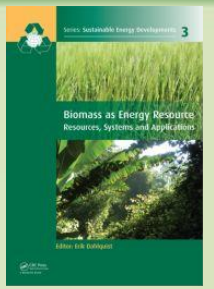
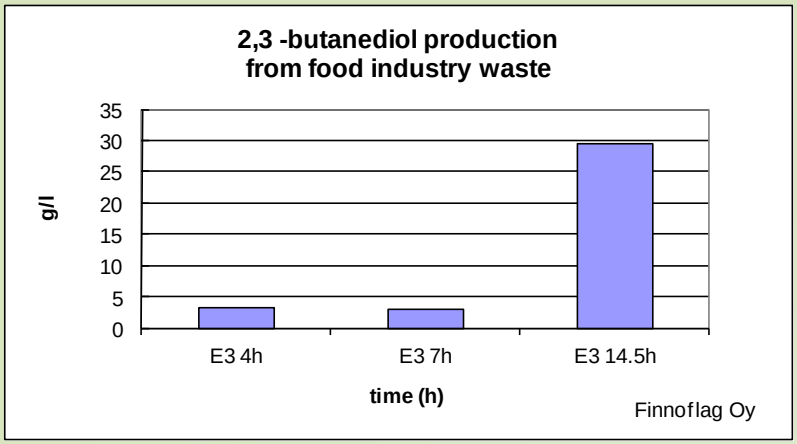
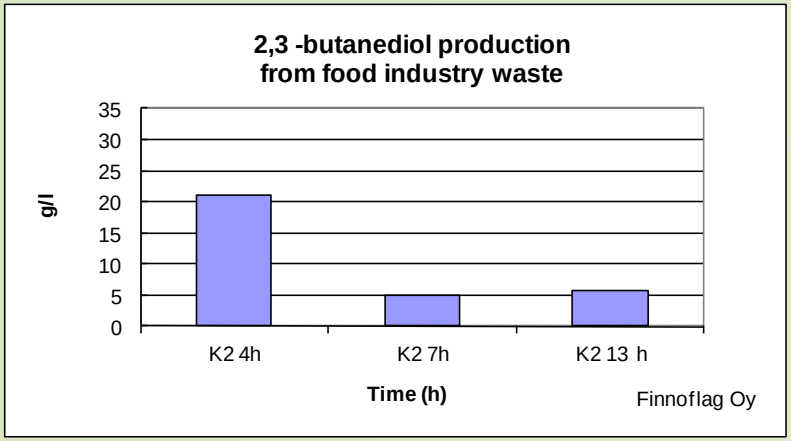


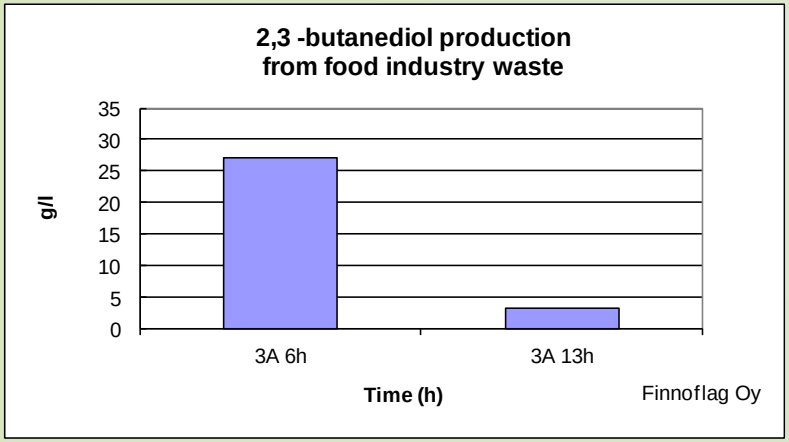
Summary

Global energy use is approximately 140 000 TWh per year. Interestingly, biomass production amounts to approximately 270 000 TWh per year, or roughly twice as much, whereas the official figure of biomass use for energy applications is 10-13% of the global energy use. This shows that biomass is not a marginal energy resource but more than capable of meeting all our energy and food needs, provided it is used efficiently. The use of food in generating energy has been extensively debated, but there is actually no need for it given the comprehensive resources available from agriculture and forestry waste.

This book discusses the biomass resources available and aspects like efficient energy use. One way of using energy efficiently is to use waste biomass or cellulosic materials in biorefineries, where production of fibers and products from fibers is combined with production of most chemicals we need in our daily life. Such products include clothes, soap, perfume, medicines etc. Conventional pulp and paper applications, bio-fuel for vehicles and even fuel for aviation as well as heat and power production are covered. The problem with biomass is not availability, but the difficulty to use the resources efficiently without harming the long-term productivity. This book covers all types of resources on a global scale, making it unique. Many researchers from all over the world have contributed to give a good coverage of all the different international perspectives.







BUTANEDIOL EXPERIMENTS IN FINNOFLAG OY LABORATORY IN 2007-2008

Production of 2,3 –butanediol (23BD) isomers from food industry waste material.

Hakalehto, E., Jääskeläinen, A., Humppi, T., & Heitto, L. 2013. Production of energy and chemicals from biomasses by micro-organisms. In: Dalhquist, E. (Ed.): *Biomass as energy source: resources, systems and applications*. CRC Press, Taylor & Francis Group.

BUTANEDIOL FOR MANY PURPOSES

2,3 -BUTANEDIOL IS A PLATFORM CHEMICAL, WHICH IS CONVERTIBLE INTO e.g.:

- PLASTIC MONOMERS
- SYNTHETIC RUBBER
- ANTI-ICING COMPOUNDS
- FIBERS AND TEXTILES
- COSMETIC PRODUCTS

THIS CHEMICAL WAS CHOSEN AS ONE OF THE MAJOR FOCUSES OF THE ABOWE PROJECT ON THE BASIS OF THE PREVIOUS GOOD RESULTS FROM THE EXPERIMENTS CARRIED OUT IN THE LABORATORY OF ADJ.PROF., DR. ELIAS HAKALEHTO AND HIS COMPANY, FINNOFLAG OY.

SUSTAINABLE BIOECONOMICS

BIOTECHNOLOGY IN THE PRODUCTION OF
ENERGY AND CHEMICALS

HENRY FORD and
MICROBES IN PLASTIC PRODUCTION

Henry Ford is known for his automobile but did you know that he once made a car with all the plastic made from soybeans - even the automobile's exterior? Mr. Ford owned a large research facility. He came to the lab one day with a huge bag of soybeans. He dumped them out on the floor and told the scientists, "You guys are supposed to be smart. You ought to be able to do something with them." In time, the scientists in Ford's labs made a strong enough plastic for the gearshift knobs, horn buttons, window frames, accelerator pedals, light-switch assemblies and ignition-coil casings. They also fashioned the exterior of an automobile from "soybean plastic." By 1935 Mr. Ford was using one bushel of beans for every car he manufactured. (60 pounds = 1 bushel) The picture above shows Mr. Ford swinging an axe at an automobile to show how tough the plastic was.

In :”Biorefining around the Baltic Sea and Global Ecodevelopment”
Elias Hakalehto, Viikki 30.10.2014

Pilot A in Poland

- Testing site: ZGO Gac Ltd
- (Zaklad Gospodarowania Odpadami Sp. z o.o.)
- Primary waste to feed in: potato waste from a chip factory near Gac
- Target product is 2,3 Butanediol -> plastics, synthetic rubber, anti-icing agents, cosmetics, textiles…
- Also separately collected biowaste has been added to the process
- Responsible person regarding the Polish tests: Assistant Professor Emilia den Boer, Wroclaw University of Technology
- Bioprocess expert: Adjunct Professor Elias Hakalehto, Finnoflag Oy
- Downstream processing: Engineer Tim Freidank and Professor Thorsten Ahrens, Ostfalia University of Applied Sciences, Germany

Polish testing 5-6/2014

ZGO Gac Ltd waste management centre, Lower Silesia	SITE
Potato industry waste, municipal source-sorted biowaste	BIOMASS
Initial conversion to lactate, acetate, H_2S	PROBLEM
Optimization of the fermentation conditions	SOLUTION
2,3 butanediol, butyrate, propionate, valerate, hydrogen	PRODUCTS

ZGO Gac Ltd.

In :”Biorefining around the Baltic Sea and Global Ecodevelopment”
Elias Hakalehto, Viikki 30.10.2014

Swedish testing 8-9/2014

Hagby farm (slaughterhouse), Enköping	**SITE**
Slaughterhouse waste, chicken manure, saw dust	BIOMASS
Inefficient hydrolysis, low soluble carbohydrate	PROBLEM
Conversion to organic acids	SOLUTION
Propionate, valerate, butyrate, butanol, hydrogen, ammonium salts	PRODUCTS

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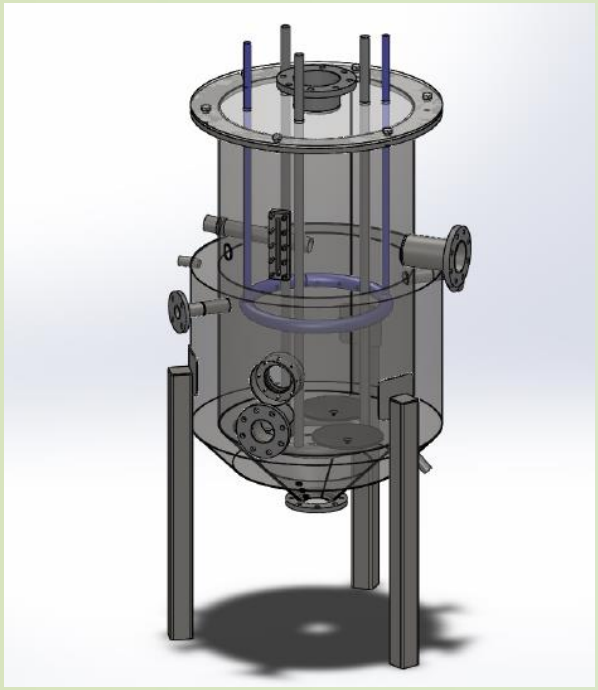
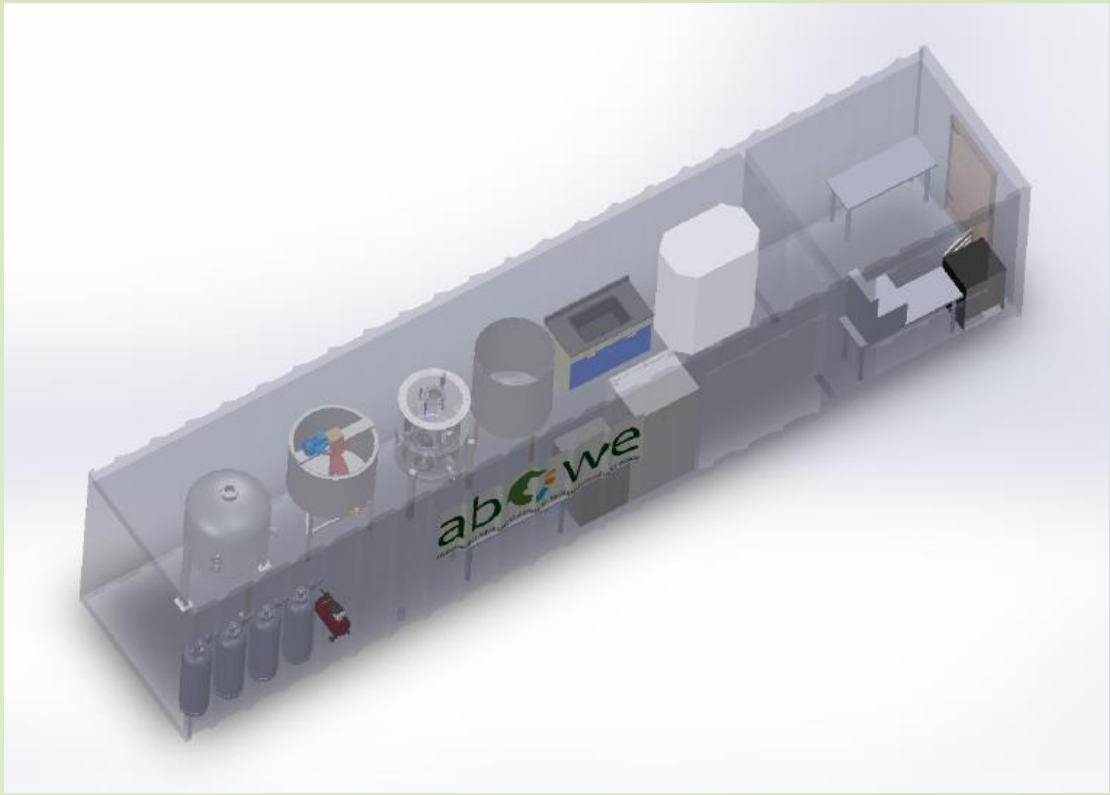
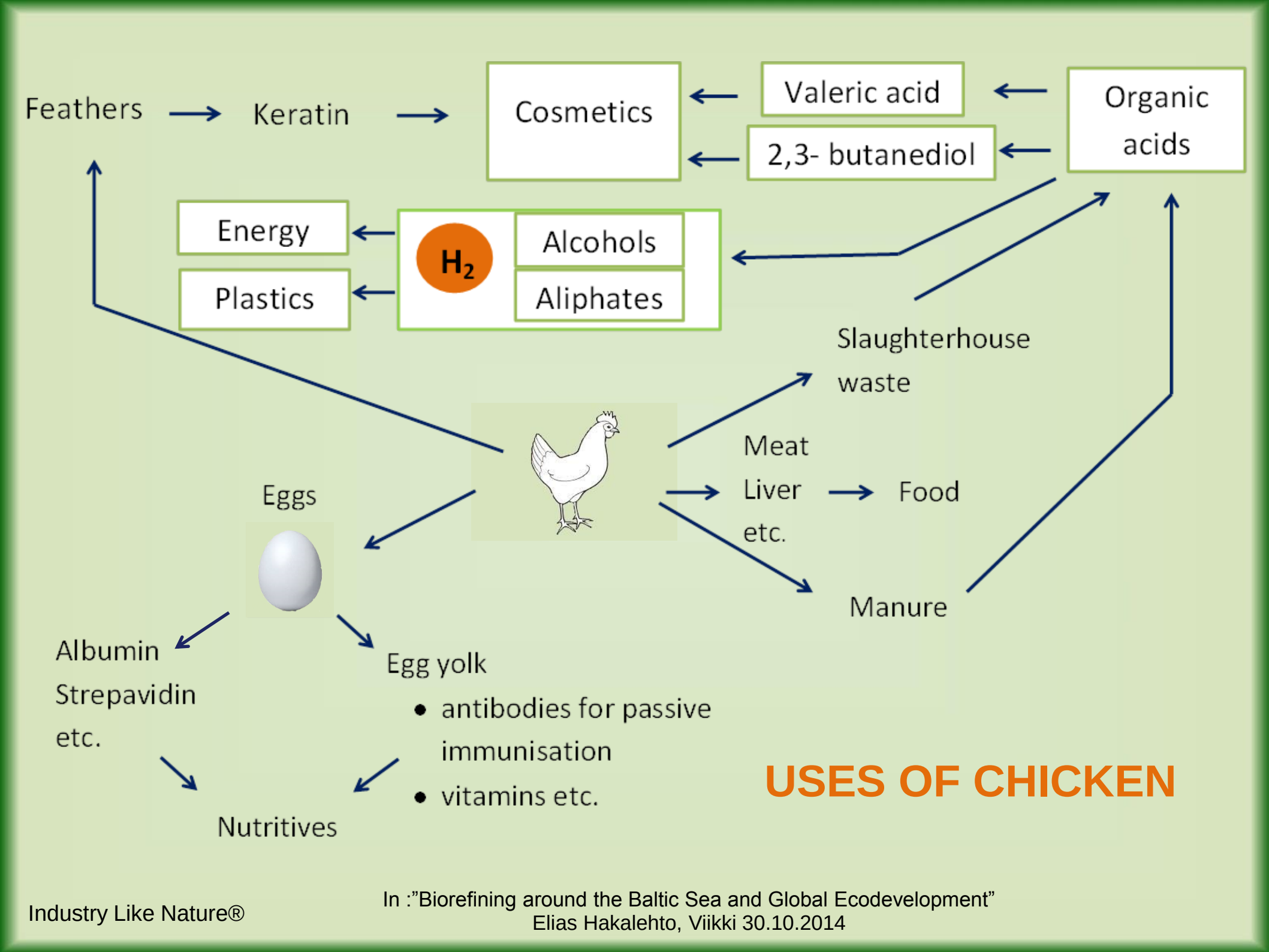
Elias Hakalehto, Viikki 30.10.2014



Patented bioreactor system



ABOWE Pilot A



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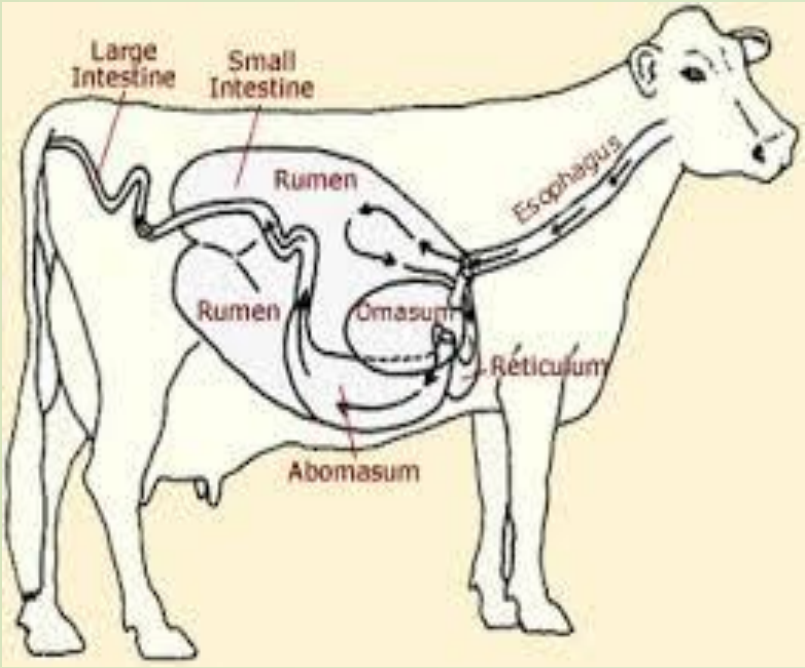
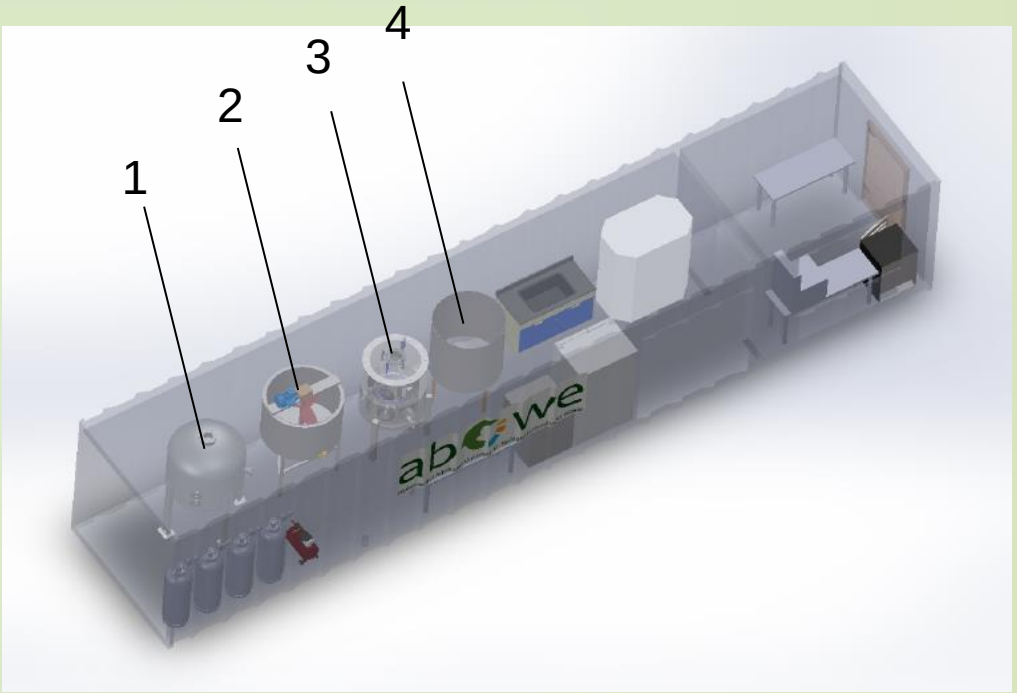
COW DIGESTION AND ABOWE PILOT A





1. **HOMOGENIZER**
2. **HYDROLYZER**
3. **BIOREACTOR**
4. **STABILIZER**

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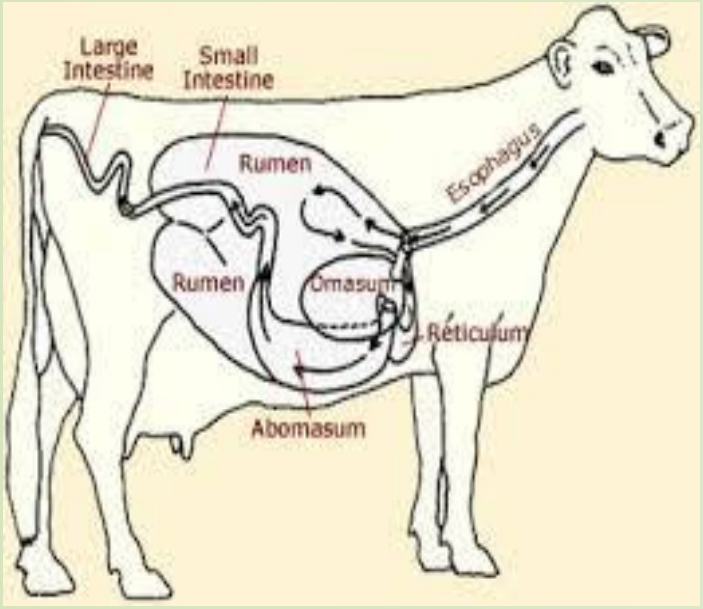
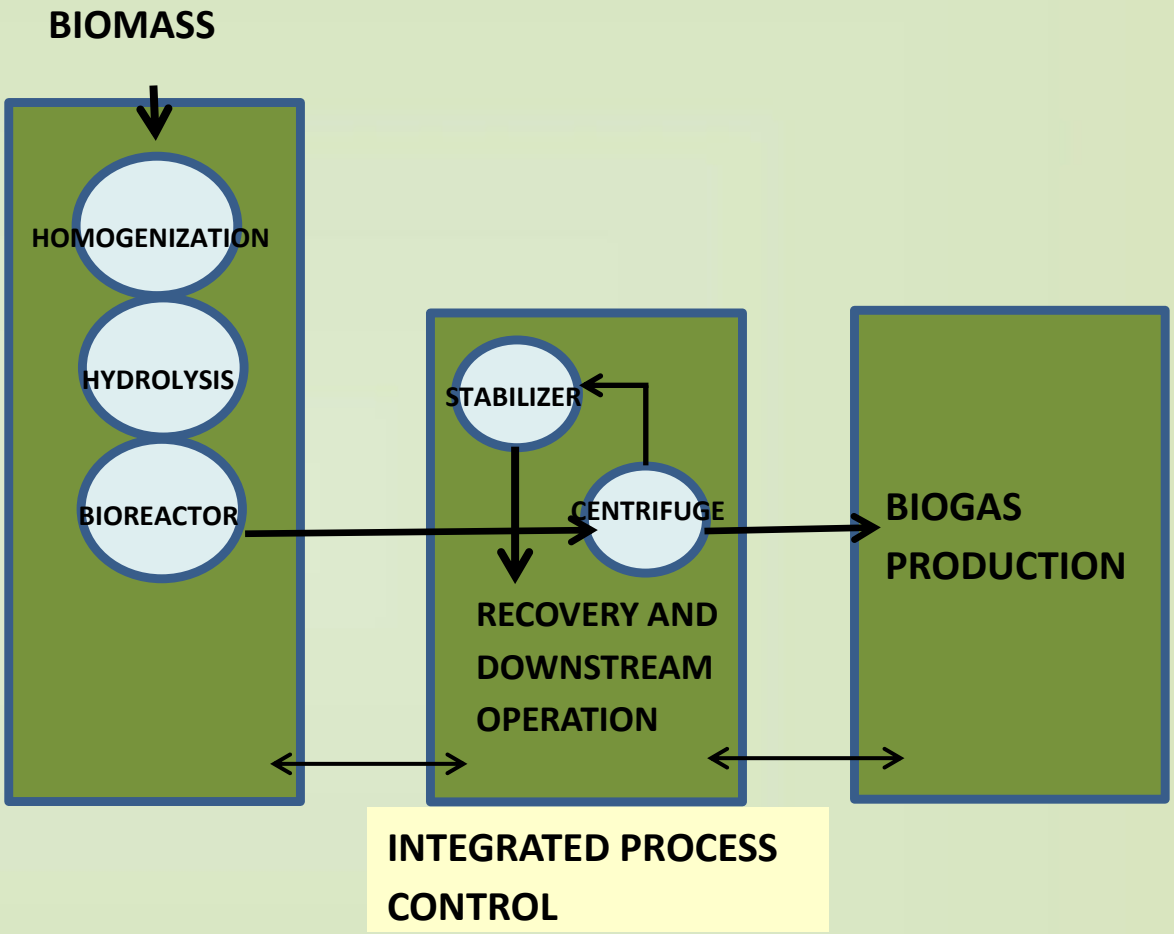
FUTURE PLANS: THREE PILOT UNITS





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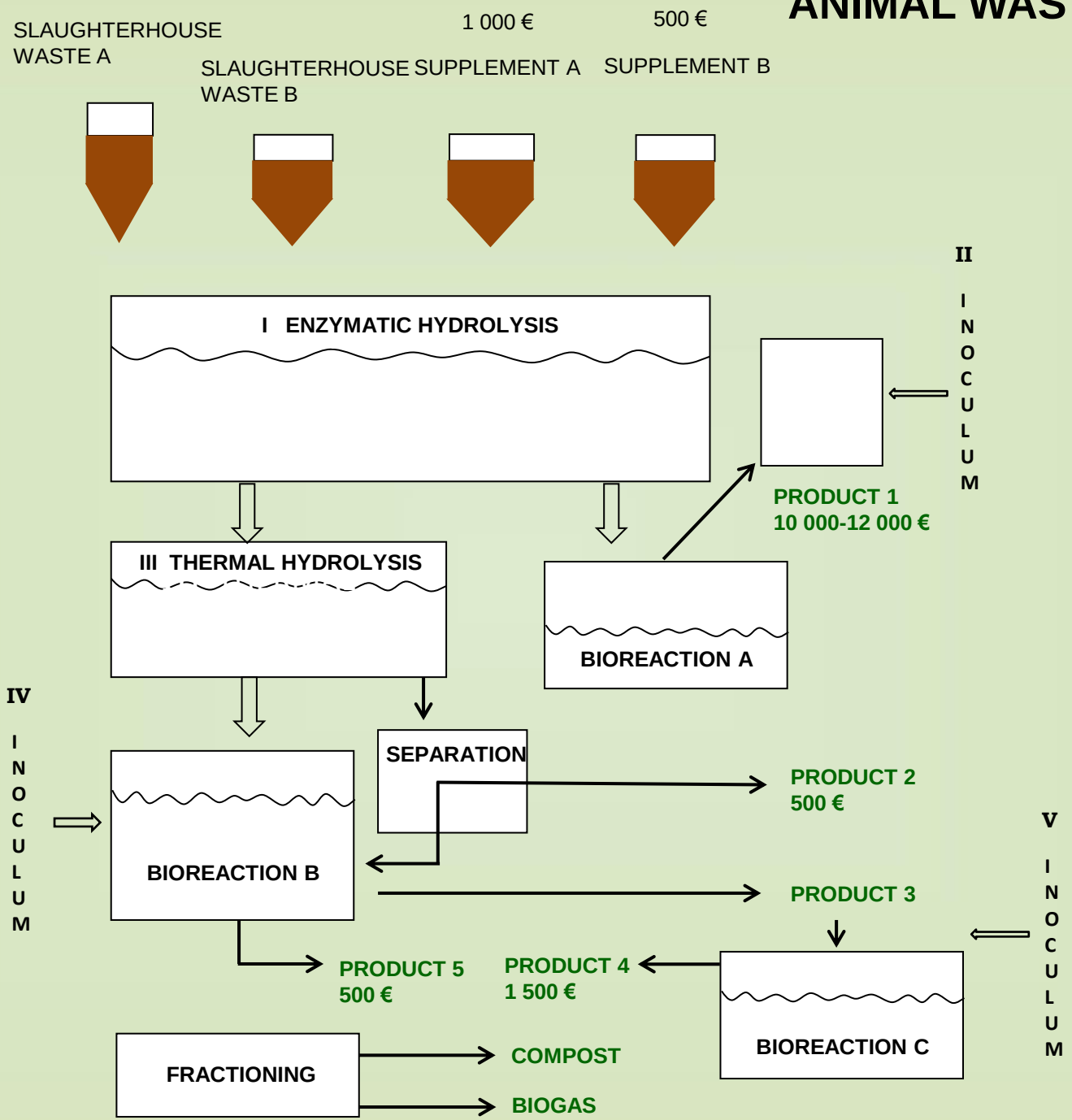
ANIMAL WASTE PROJECT



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PATENTED

Pharm Dev Technol. 2013 Mar 26. [Epub ahead of print]

Why is mannitol becoming more and more popular as a pharmaceutical excipient in solid dosage forms?

Ohrem HL, Schornick E, Kalivoda A, Ognibene R.

Source

Merck KGaA , Darmstadt , Germany.

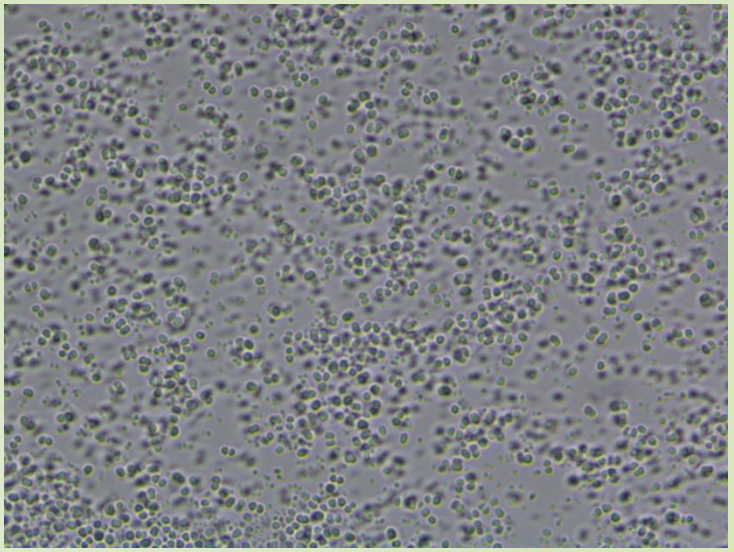
Abstract

Abstract Various fillers/binders which are applied for the formulation of solid oral dosage forms are assessed for their benefits and drawbacks, including lactose, sorbitol, mannitol, microcrystalline cellulose and calcium hydrogen phosphate dihydrate. A focus of this work was to evaluate the application of mannitol in comparison to other common fillers/binders as it was observed that this excipient is gaining more and more attention in pharmaceutical formulation development and production. While one of the main advantages of conventional fillers/binders such as lactose, microcrystalline cellulose and calcium hydrogen phosphate dihydrate is their low price level, mannitol excels regarding its physicochemical characteristics such as a low hygroscopicity, a strong inertness towards both the API and the patient's body, its good compactibility and the ability to produce extremely robust tablets. Additionally, the suitability of mannitol for the emerging formulation technology of orally disintegrating tablets is pointed out. In summary, it is emphasized that the selection of the filler/binder is highly individual, depending, for example, on the preferred characteristics of the final solid dosage form, the applied API and the available budget. However, mannitol exhibits many strong advantages which can be expected to result in a more widespread application in the near future.

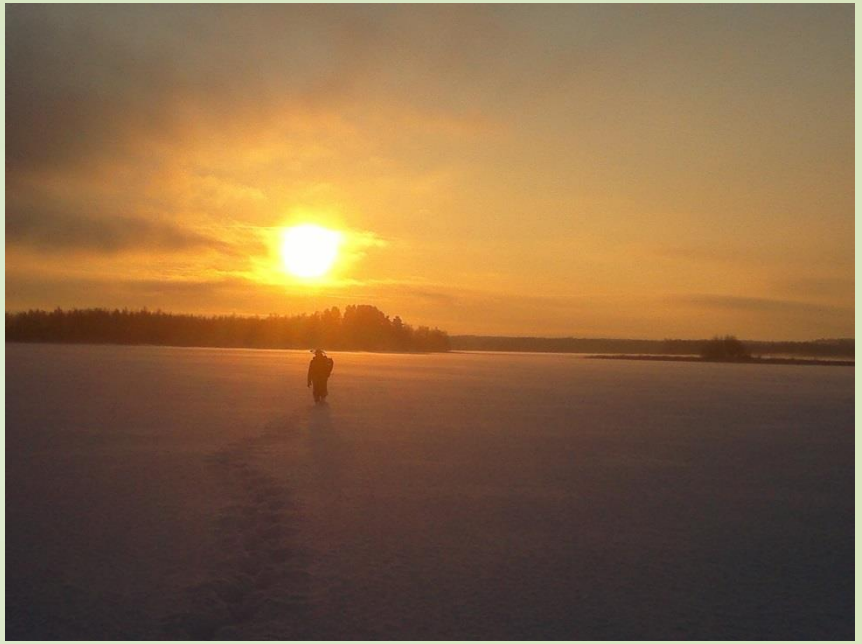
PMID: 23528124

[PubMed - as supplied by publisher]

Conversion of Lactate into Other Organic Acid in Slaughterhouse Waste Treatment



Propionibacterium acidipropionici **is accepted as safe production organism by EFSAn, (European Food Safety Association). It is used for conserving wheat or chicken meat, for example.**
http://www.journalofdairyscience.org/article/S0022-0302(98)75663-2/abstract



FINNISH LAKE SHORE IN THE MIDDLE OF WINTER (-10 C). BENEATH THE SURFACE MICROBES keep the mud unfrozen by their metabolism (left).

In :”Biorefining around the Baltic Sea and Global Ecodevelopment”
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EQUAL PROPORTION OF ORGANICS IN WINTER LAKE MUD AND SLAUGHTERHOUSE WASTE

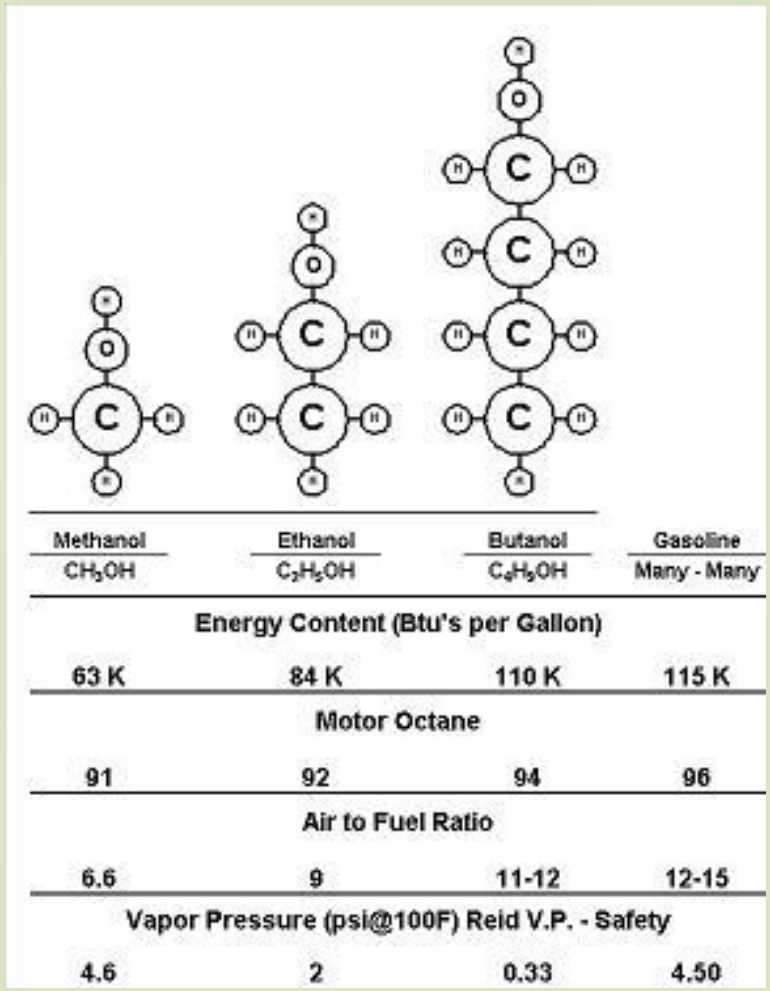
Proportions of acetate, propionate and ethanol in the natural mud sludge (above) and in the industrial waste treatment process of a slaughterhouse (below). Microbial metabolic activities in the latter one produce higher relative amounts of the latter two molecules. However, proportions to each other remained unchanged. Even in the Finnish winter conditions anaerobic metabolism in the mud was high enough to keep it unfrozen under the thick snow belt (approximately 70cm). The mud sludge was slightly basic, which also indicated the role of microbiological phenomena in keeping it unfrozen.

Hakalehto, E. 2015. Enhanced microbial process in the sustainable fuel production. In Jinyue, Y (Ed.). Handbook of Clean Energy Systems. J.R.Wiley & Sons USA. In Print

SUSTAINABLE BIOECONOMICS

BIOTECHNOLOGY IN THE PRODUCTION OF ENERGY AND CHEMICALS

- Acetone-butanol-fermentation; *Clostridium acetobutylicum*
- Products: acetone, butanol, ethanol, hydrogen
- Butanol is important raw material for chemical industry and a potential liquid fuel
- Tested during ABOWE



Methanol CH_3OH	Ethanol C_2H_5OH	Butanol C_4H_9OH	Gasoline Many - Many
Energy Content (Btu's per Gallon)			
63 K	84 K	110 K	115 K
Motor Octane			
91	92	94	96
Air to Fuel Ratio			
6.6	9	11-12	12-15
Vapor Pressure (psi@100F) Reid V.P. - Safety			
4.6	2	0.33	4.50

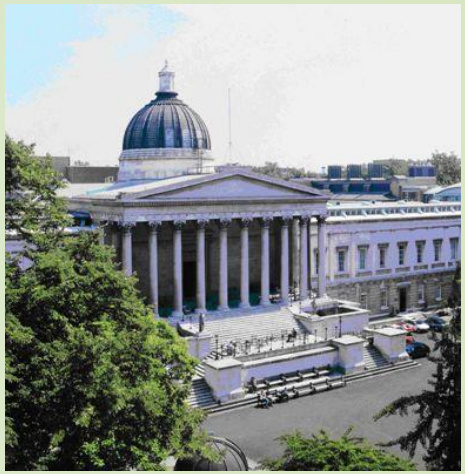
Source: www.butanol.com

UNIVERSITY COLLEGE LONDON
PILOT PLANT BIOENGINEERING

- Prof Jack Drummond: vitamins 1930

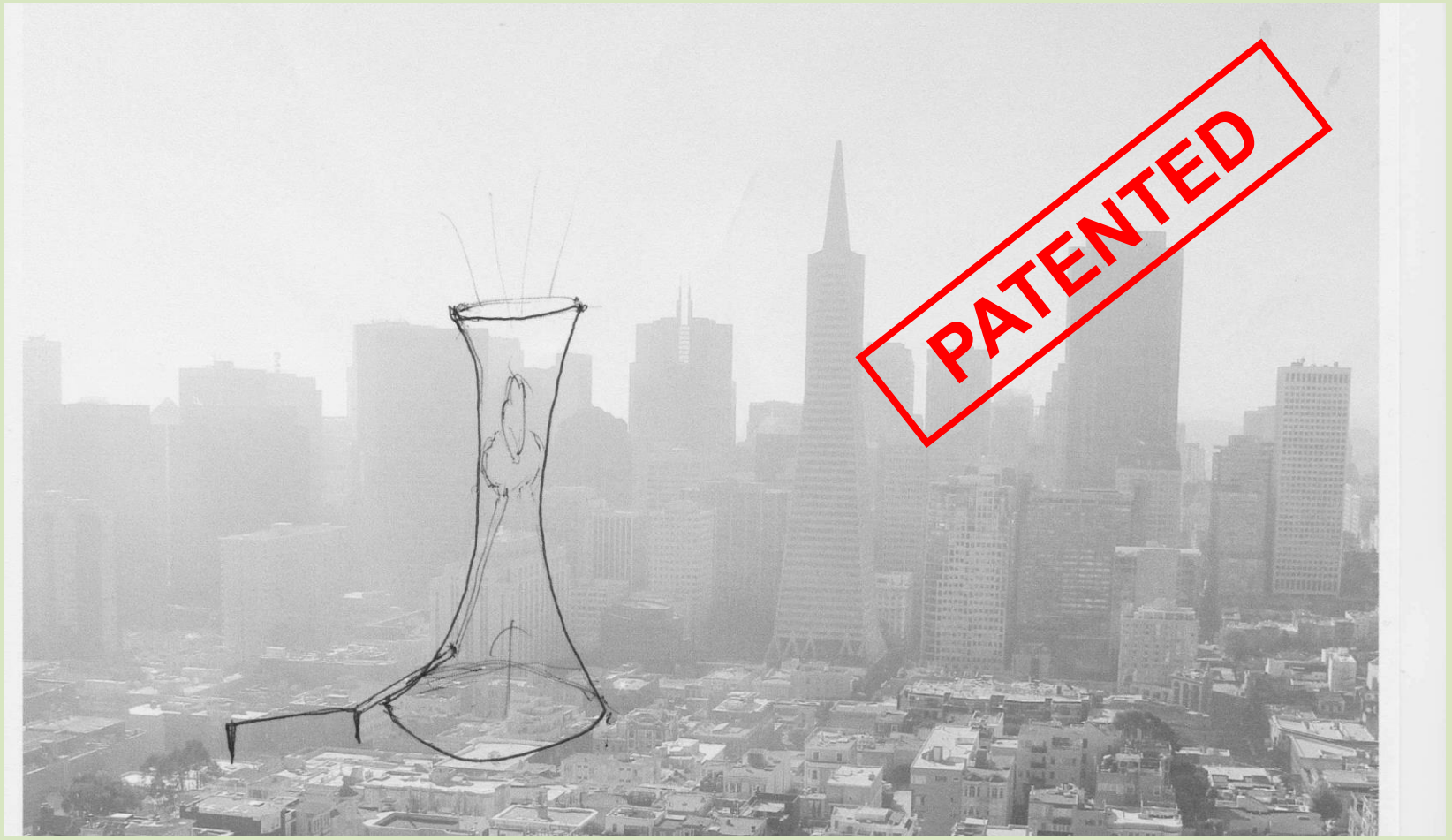
-studies on antibiotic and enzyme fermentation started about 50 years ago, e.g. Prof Malcolm D. Lilly

- development of bioreactors



Hydrogen is universally produced from biomass

DESIGN OF NOVEL HYDROGEN PLANT



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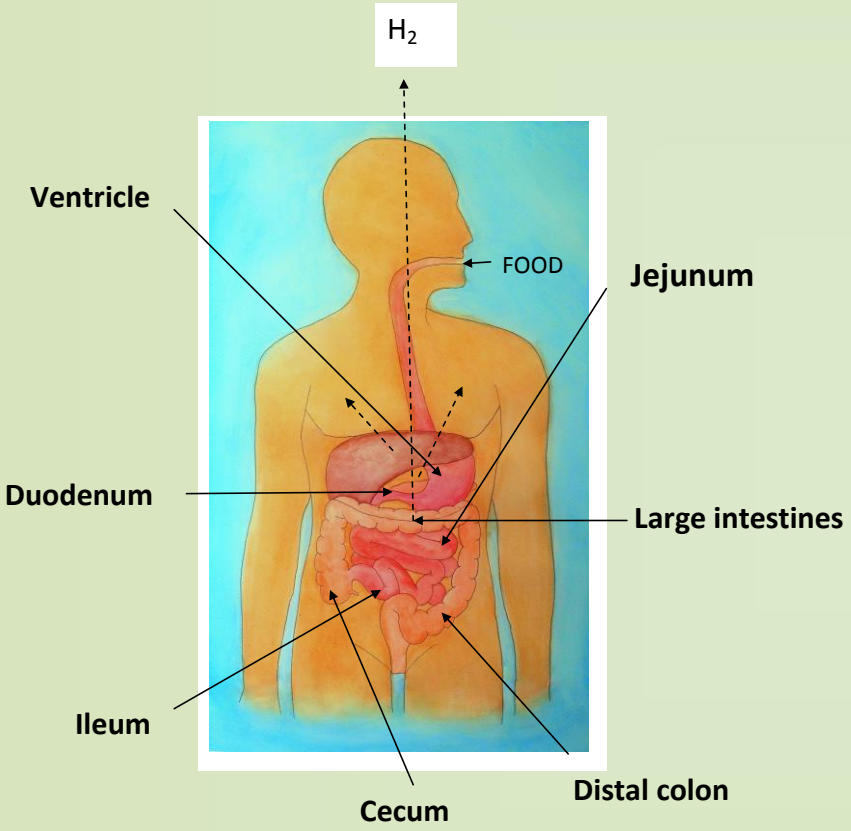
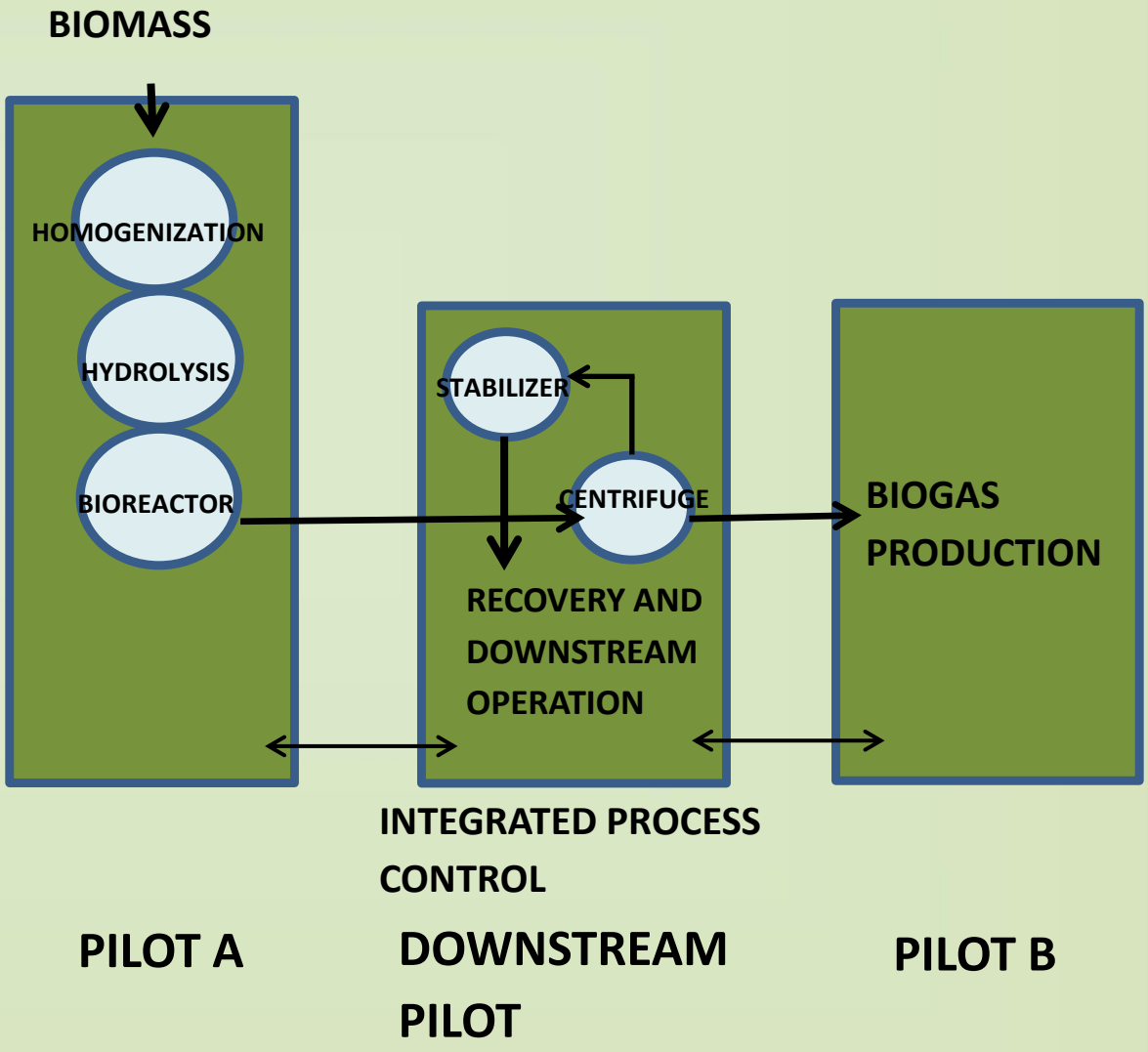
DIGESTION AND BIOREFINERY





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EVEN THE DIRTIEST TRADITIONAL INDUSTRIES CAN BE CONVERTED SUSTAINABLE BY THE AID OF MICROBIAL BIOTECHNOLOGY

Photo: National Geography

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MAJOR ENVIRONMENTAL PROBLEMS IN LIGNITE (BROWN COAL) UTILISATION

- GREENHOUSE GAS EMISSION (e.g. oxides of Carbon)
- LIBERATION OF GASEOUS SULPHUR COMPOUNDS
- ACIDIFICATION
- VARIOUS TOXIC COMPOUNDS (e.g. heavy metals)
- ROBUST RECALCITRANT POLYFENOLS (e.g. lignins)
- EUTROPHICATION OF LIGNITE PROCESS WASTE WATERS
- COAL DUST POLLUTION

Photo: National Geography

In :"Biorefining around the Baltic Sea and Global Ecodevelopment"
Elias Hakalehto, Viikki 30.10.2014

POINTS FOR IMPROVEMENT

- TOTAL ECONOMY OF ENVIRONMENTAL PROTECTION MEASURES
- BETTER RECOVERY OF RAW MATERIALS
- ECOLOGICAL SUSTAINABILITY OF THE PROCESSES
- REDUCTION OF LOCAL ENVIRONMENTAL EFFECTS
- DIMINISHED GLOBAL EFFECTS OF ACIDIFICATION AND GREENHOUSE GASES

Photo: Vicente Serra

SOLUTIONS BY BIOREFINING

GOALS CAN BE ACHIEVED WITH FINNOFLAG BIOPROCESS TECHNOLOGIES UTILIZING THE NATURAL MICROBES

=> BETTER, ELEVATED LEVEL OF ACCEPTANCE FOR THE COAL INDUSTRY AS A FORCE FOR CHANGE FOR ECOLOGICAL FUTURE INDUSTRIES - ACHIEVABLE WITH LOW INVESTMENT COSTS USING SENSIBLE PLANNING AND DESIGN.

In :”Biorefining around the Baltic Sea and Global Ecodevelopment”
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Microbial Techniques Make the Burning of Coal Sustainable

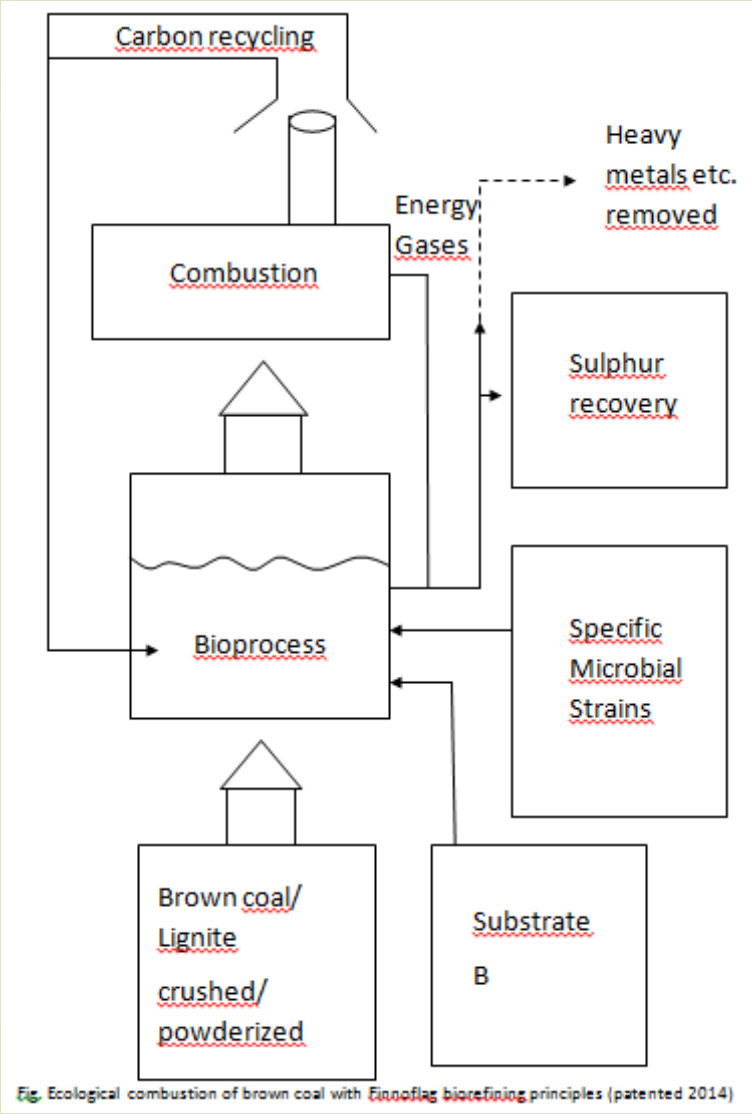

Fig. Ecological combustion of brown coal with Finnoflag biorefining principles (patented 2014)

PATENTED

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Carbon Dioxide and Carbon Monoxide from Combustion Circulated back to the Bioprocess

LanzaTech capturing carbon. fueling growth.

IS REUSING THE CARBON FROM IRON WORKS EXHAUST GASES

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Elias Hakalehto, Viikki 30.10.2014

EXHAUST GASES OF ONE MICROBIAL CULTURE EXPLOITED BY THE SUBSEQUENT ONES

Hakalehto, E. 2013. Interactions of *Klebsiella* sp. With other intestinal flora. In Pereira, L.A. & Santos, A. (eds) *Klebsiella* infections: Epidemiology, pathogenesis and clinical outcomes. Nova Science Publishers, Inc. New York, USA.

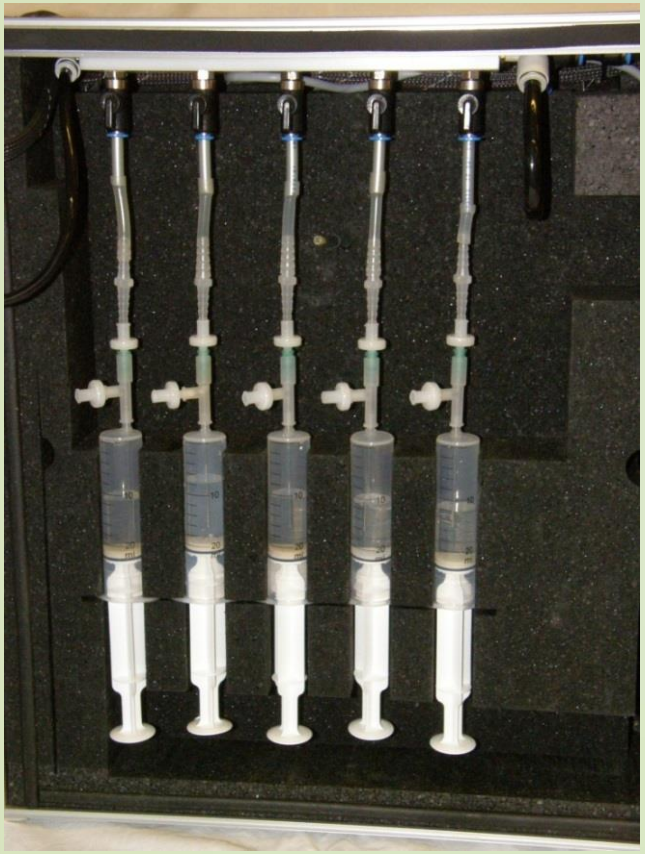
CO_2 IS BOOSTING THE BIOPROCESS

PMEU Spectrion® cultures of *Clostridium acetobutylicum* strain ATCC 185 were cultivated in a constant nitrogen (100 %) flow into the cultivation syringes (see also Hakalehto & Hänninen 2012). This flow was in some cases interrupted with pulses of 45 % CO_2 with 15-30 min duration in or near the beginning of the cultivation. The triggering CO_2 impulses produced bacterial growth in few hours as illustrated below.

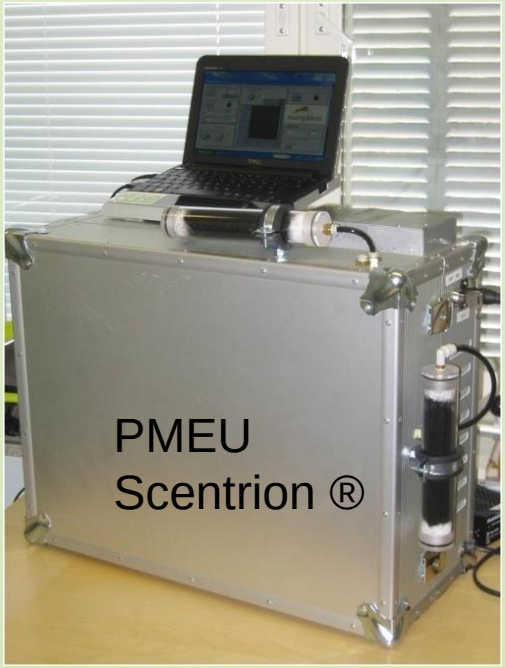
Hakalehto, E. 2015. Enhanced microbial process in the sustainable fuel production. In Jinyue, Y (Ed.). Handbook of Clean Energy Systems. J.R.Wiley & Sons. USA. In Print.

PMEU versions

PMEU Spectrion ®



Syringes in the PMEU (Portable Microbe Enrichment Unit)



PMEU Scentrion ®

PMEU with Automated Sample Collection System

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PMEU technology in Finnish POLARIS study for water quality verification

PMEU Spectrion®

Data updated

every 10 minutes

The server of Polaris

Internet

Industry Like Nature®

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Coliline PMEU™ for automated water department hygiene monitoring licenced to Berner Oy

Pilot A - Movable experimental biorefinery unit

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SUNFLOWER REMOVES RADIOACTIVITY FROM THE GROUND

In Tšernobyl nuclear power accident (Ukraina 1986) sunflower was used to clean the areas. It also removes heavy metals, such as lead and cadmium. Also in Fukushima, Japan, sunflower is used for clean up. In phytoremediation also toxic organic compounds can get degraded with plants and microbes, and their biocatalysis.

www.luontoportti.com

In an ecosystem there is an interdependence between

organisms,

their metabolism

and biocatalysis

Microalgae in biorefining technology

- “Microalgae” is not a taxonomic group or class but includes a variety of unicellular or simple filamentous species, such as bacteria (*Cyanophyta*), plants (for ex. *Chlorophyta* and *Rhodophyta*) and protozoa (for ex. *Euglenida*).
- Amount of species estimated to be tens of thousands, depending on microalgae definition.
- Microalgae have remarkable ability to adjust their metabolism to the prevailing abiotic factors.
- Great variation may occur within lipid, protein and pigment composition following the change in abiotic factors of cultivation (such as temperature, pH, salinity, N and P levels and radiation).
- Microalgae production could be combined with industrial processes to exploit warm or nutrient consisting waste waters. Algae would “filter” CO2, nitrogen and phosphorus out of waste water to produce biomass containing high quality protein, lipids, carbohydrates, pigments and a number of other valuable biochemical compounds.
- Several different kinds of cultivation methods exist, such as open pond cultivation (hardly suitable for Finnish climate), closed photobioreactors, continuous growth tubes, fermentation tanks etc. Cultivation methods may vary depending on purpose and environmental conditions, such as temperature and amount of sunlight.

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Open pond cultivation (http://www.nature.com/nature/journal)

Indoor photobioreactors (http://english.qibebt.cas.cn/ic)

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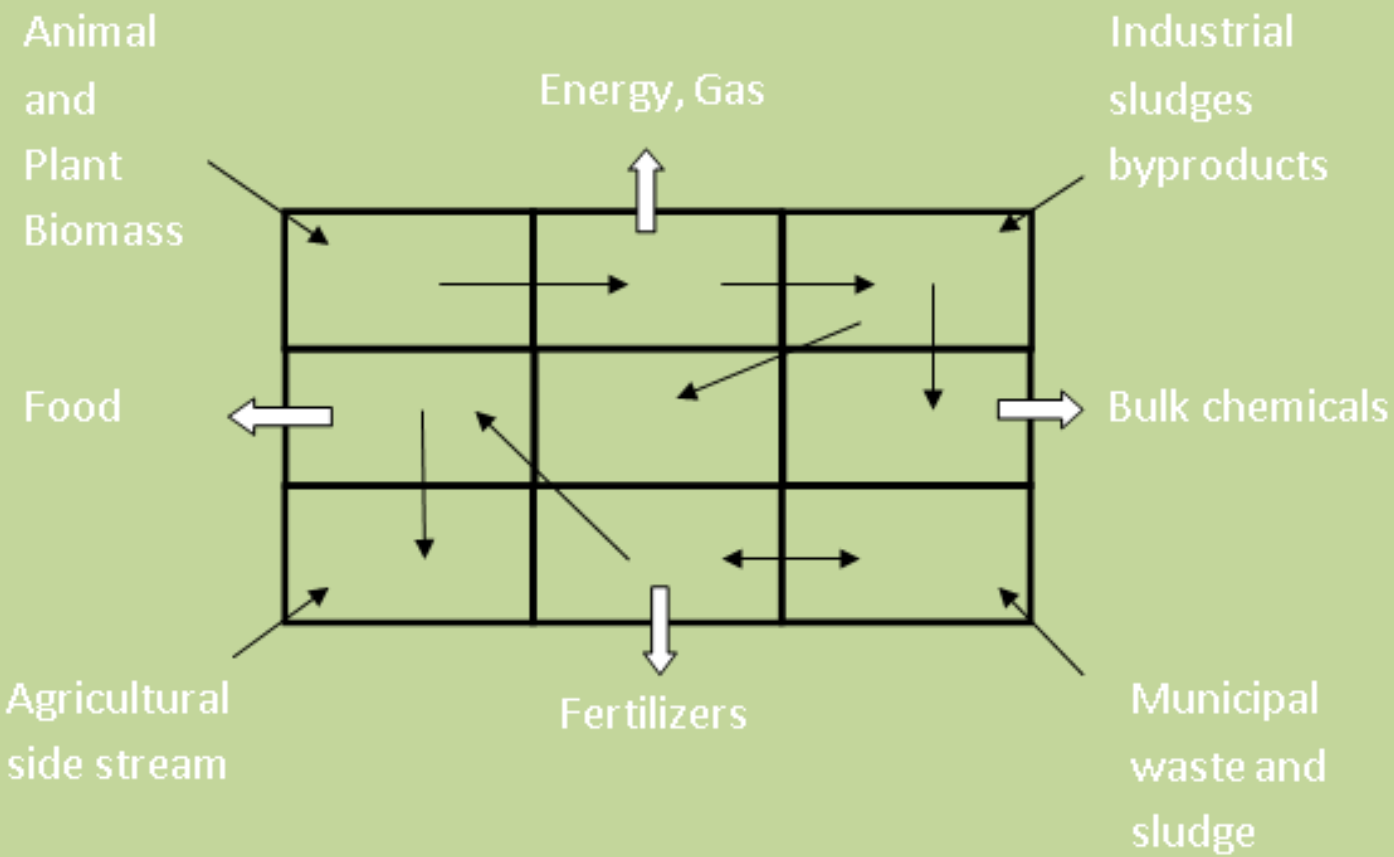
BESIDES ALL THIS ENERGY
WE GET

- CHEMICALS
- NUTRIENTS
- FERTILIZERS
- CLEAN WATER AND AIR

WITH ZERO WASTE,
WITH THE HELP OF MICROBES AND THEIR ENZYMES

FUTURE BIOREFINERY IS A FIELD



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Prof. Emer. Osmo Hänninen, Elias Hakalehto, and late veterinarian Seppo Haaranen in Finnoflag Oy's laboratory, Siilinjärvi, Eastern Finland. In that district Dr. Haaranen did his remarkable work being e.g. among the first ones to report about the lack of trace element selenium in soil (about 50 years ago), and its contribution to heart diseases in animals and man. On the basis of his findings, selenium is nowadays added to the fertilizers in Finland for public health objectives. During the design phase of ABOWE, the author had several fruitful discussions with Dr. Haaranen on the ruminant digestive system, and its similarities with a biorefinery plant.

The pioneer of biotechnological NMR studies, Prof. Reino Laatikainen, School of Pharmacy, University of Eastern Finland, Kuopio, Finland. He has developed remarkable skills and software for interpreting the NMR graphs.

VISIONS OF JULES VERNE 1/2

"And what will they burn instead of coal?"

"Water," replied Harding.

"Water!" cried Pencroft, "water as fuel for steamers and engines! Water to heat water!" …

Yes, my friends, I believe that water will one day be employed as fuel, that hydrogen and oxygen which constitute it, used singly or together, will furnish an inexhaustible source of heat and light, of an intensity of which coal is not capable...

The Mysterious Island (LÍle Mysteriéuse 1874), by Jules Verne

VISIONS OF JULES VERNE 2/2

...Some day the coalrooms of steamers and the tenders of locomotives will, instead of coal, be stored with these two condensed gases, which will burn in the furnaces with enormous calorific power. There is, therefore, nothing to fear. As long as the earth is inhabited it will supply the wants of its inhabitants,and there will be no want of either light or heat as long as the productions of the vegetable, mineral or animal kingdoms do not fail us. I believe, then, that when the deposits of coal are exhausted we shall heat and warm ourselves with water. Water will be the coal of the future."

The Mysterious Island (LÍle Mysteriéuse 1874), by Jules Verne

BIOPROCESS RESEARCH AT FINNOFLAG SINCE 1997

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Invest in Biocatalysis™

This was the story of ABOWE and Finnoflag biorefining until this day

- We develop tomorrow ´ s technologies today

KIITOS! THANK YOU!

Elias.Hakalehto@finnoflag.com

Photos: Vicente Serra

Industry Like Nature®