ARTFuels

IEA Bioenergy

European Commission

SUCCESS STORIES OF ADVANCED BIOFUELS IN TRANSPORT

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Introduction

EU transport is almost entirely dependent on fossil fuel, and the expectation is that this will still be 90% in 2030[1]. Compared to other economic sectors such as power, industry, agriculture and buildings, the transport sector - including aviation - is the only sector that has not yet been able to significantly curb its CO2-emissions.[2]

The recast of the Renewable Energy Directive (RED II) sets the new EU framework for renewable energy in the European Union beyond 2020. Article 25 of REDII defines the minimum shares of renewable energy which Member States must achieve in the transport area: *"each Member State shall set an obligation on fuel suppliers to ensure that the share of renewable energy within the final consumption of energy in the transport sector is at least 14 % by 2030 (minimum share)"*, while *"the contribution of advanced biofuels and biogas produced from the feedstock listed in Part A of Annex IX as a share of final consumption of energy in the transport sector shall be at least 0,2 % in 2022, at least 1 % in 2025 and at least 3,5 % in 2030".*

In the field of Alternative and Renewable Transport (ART) fuels, directly contributing to the advanced biofuels target as set in RED and RED II, the industrial technology developers achieved significant progress over the last few years on several value chains, most being today ready for commercialization or, if not there yet, close to it.

Some important recent examples of technological progress in the field of ART fuels are mentioned below:

- ENI-VERSALIS acquired from Biochemtex the first commercial plant on ethanol from lignocellulosic feedback, built at Crescentino in Italy. This was among the first of such plants at a global scale. CLARIANT has also announced two industrial-scale commercial facilities;
- EU enzyme and yeast companies such as NOVOZYMES, DSM and LEAF are world leaders in the lignocellulosic ethanol field;
- Algae production facilities have been under development in the EU. These will be the largest facilities built in the EU with significantly high productivity;
- The BTG EMPYRO biomass Fast Pyrolysis oil plant in the Netherlands and FORTUM's plant in Joensuu in Finland are the first commercial scale bio-oil plants, replacing fuel heating oil. In addition, a significant expansion of Fast Pyrolysis Oil capacity in the EU Nordic Countries is expected, where new plants adopting BTG technology will be installed;

[1] *SWD(2016)418 final, Impact assessment for the REDII proposal, page 237.*
[2] *Greenhouse gas emissions from transport continue to rise, and in 2017 were 20% higher than in 1990, COM(2018)733, page 22.*

- The CHEMREC Bio-DME project has been the first project to demonstrate the conversion of black liquor to bio-dimethyl-ether;
- NESTE, ENI, TOTAL & UPM lead on hydrotreated oils/wastes to renewable hydrocarbons (both road and aviation), with some 4 Million ton per year installed capacity in the EU, to be further increased in the next years. News plants for road and aviation fuels have been announced or are being expanded, such as the ones by UPM, PREEM and SkyNRG;
- Biomethane is spreading all over Europe, with Italy and Germany leading. A new sustainable model has been developed from this value chain (Biogas Done Right).

Industrial stakeholders and market actors remark that there is significant untapped potential. The main market and policy barriers still hindering further expansion of the sector can be identified as:

- Lack of strong, stable and long terms (beyond 2030) policies to give confidence to investors. In this respect the recently issued EU RED II is welcome, and the transposition of RED II into Member State legislation will be a key element for further market development, together with the adoption of additional legislations as the RED II related Delegated and Implementing Acts;
- Lack of dedicated innovative financial instruments. These state-of-the-art technologies are at the same time first-of-a-kind plants with all inherent risks, which creates an additional cost disadvantage compared to the fossil fuel they aim to replace.

In order to provide evidence of the status of the ART fuels technologies in relation to market uptake and readiness, this document briefly highlights the progress recently made at industrial scale. "Success stories of Advanced Biofuels in transport" have therefore been collected for each of the sectors/areas of the ART Fuels Forum, providing an overview of advanced industrial-scale technical solutions, lessons learnt and successful policy implementation, showing eventually the potential and possibilities in ART fuels technologies.

A success story is here defined as a project/initiative which provides a step forward towards industrial-scale technological development, commercialisation and longer-term sustainable bioenergy use. The project can be at demonstration, pre-commercial or commercial stage, but always in an operational environment. An important component is the replicability and scale-up potential of the project, and its contribution to sustainable development goals (SDGs). Where possible, success factors and constraints are also highlighted.

The collection of success stories in Alternative and Renewable Transport Fuels was based based on the previous relevant publications of IEA Bioenergy[3]. Building upon the work of

[3] https://www.ieabioenergy.com/iea-publications/success-stories/

IEA Bioenergy this publication has a more focused scope on Advanced Biofuels for Transport applications, i.e. other sectors such heat and power are not considered. Further, an effort was made to consider TRL 7 as the minimum for the collected projects. For each presented story, information about feedstock supply, possible by-products, financing support received, stakeholders involved, was gathered, while the contribution to the EU's GHG reduction targets, and the alignment to the UN SDG is presented. Success factors and constraints, as well as the scale-up potential are discussed under the perspective of the most crucial factors determining the wider market penetration of ART fuels.

Overall, 20 success stories have been collected in a continuing effort that will continue throughout the operation of the ART Fuels Forum. The main observations made so far can be summarized in the following points:

- Each story represents a distinct "lesson learnt", either technology- or business model-wise;
- Out of the collected 20 success stories, 9 plants reached full commercial scale (technology readiness level 9), while 8 are sub-scale commercial demonstration plant (TRL 8) and 7 are pilot plants (TRL 7). As reported in Table 1 below, as far as this survey is concerned, Lipids-based biofuels (mostly HVO) technology leads the scene of full commercial scale plants, followed by biomethane and interesting new developments of Power-to-X technologies;
- Almost half of the collected stories are located outside Europe, with an impressive development in India (this fact is consistent with the outcomes from the 1st and 2nd EU-India Advanced Biofuel conference, co-organised by EC-DG Energy and the Indian Ministry for Petroleum and Natural Gas, with the support of ART Fuels Forum[4]);
- In most cases, there is also a secondary market (by-product of the process);
- A wide range of stakeholders were involved in the value chains;
- The most critical factors appear to be:
  - secured biomass supply/local feedstock availability
  - Feedstock price
  - Stability of the regulatory framework, longer perspective, binding mandates
  - CAPEX dimension
  - Financing

[4] https://ec.europa.eu/info/events/renewable-energy-events/eu-india-conference-advanced-biofuels-2019-mar-11_en

Table 1 Number and state of the art of technologies based on the success stories received

TECHNOLOGIES							
TRL	**Lipid-based biofuels (HVO)**	**Biochemical**	**Thermochemical**	**Algae based biofuels**	**Future Concepts**	**Power to X**	**Biomethane**
Commercial	3	1	1	1		1	
Demonstration		3	2	1	1		3
Pilot		2			1		

Data on advanced biofuel production within the EU

The overall **EU biofuel production** accounted for 15,300 ktoe in 2017[5], to which advanced biofuels (as defined in Annex IX part A) contributed by some 3493 ktoe. Based on estimations, it is noted that the overall EU biofuel production corresponds to the average fuel consumption of approximately 29 million passenger cars.

The 2018 global **HVO Renewable Diesel** estimated production capacity (both conventional and advanced) corresponded to ~4,700 ktoe. The global production capacity is expected to increase to around 11.4 million tonnes, by 2022, from the announced projects including both new dedicated refineries as well as retrofits not initially designed for renewable feedstock. In the EU, HVO production, including production from double counted Annex IX-B feedstocks, was approximately 2,028 kton in 2017[6] (mostly supplied by two commercial plants based in Finland and Sweden)[7].

As regards **ethanol**, in 2017 the production of EU ethanol from lignocellulosic feedstock/other REDII-Annex IX/other feedstock accounted for 198.5 kton, according to ePURE data collected among its members[8]. It is estimated that in the same year, at EU level, 39.7 kton of advanced lignocellulosic ethanol had been produced by a number of small-sized demo and commercial scale plants, located in several EU countries[9,10].

In 2017, ~240 Mm^3 of **biomethane** were used in transport in EU, which included both conventional and advanced feedstocks[11]. Germany is responsible for 75% of the total EU production, with an average of 90% of it based on waste and residues; Sweden is the second largest producer of biomethane in the EU, and by far the largest national gas-powered transport market, since more than 75% of its biomethane is used in the transport sector[12]. There were just above 500 operating plants in

[5] Eurostat, SHARES tool 2017. Available at: https://ec.europa.eu/eurostat/web/energy/data/shares
[6] European Biodiesel Board Statistical data. Available at: http://www.ebb-eu.org/stats.php
[7] I. Landälv, L. Waldheim, K. Maniatis, Continuing the work of the Sub Group on Advanced Biofuels - Technology status and reliability of the value chains: 2018 Update, 2018.
[8] ePURE, European renewable ethanol - key figures 2017, 2018. Available at: https://www.epure.org/media/1763/180905-def-data-epure-statistics-2017-designed-version.pdf
[9] Biofuture Platform, Creating the Biofuture: A Report on the State of the Low Carbon Bioeconomy, (2018) 2018. Available at: http://biofutureplatform.org/resources/
[10] USDA, EU-28: Biofuels Annual GAIN Report 2018 - NL8027, 2018. Available at: https://www.fas.usda.gov/data/eu-28-biofuels-annual-0
[11] EBA and NGVA data
[12] EBA, Biomethane in Transport, Brussels, 2016. Available at: http://european-biogas.eu

2017, where biogas is upgraded to biomethane; 200 of them are placed in Germany, almost 100 in the UK and 65 are based in Sweden[13].

[13] I. Landälv, L. Waldheim, K. Maniatis, Continuing the work of the Sub Group on Advanced Biofuels - Technology status and reliability of the value chains: 2018 Update.

Table 2 Overview of the success stories received

No.	Title	Country	Year	Technology	Products/Market	Capacity	Feedstock	Feedstock Capacity	TRL
1	Neste's renewable diesel	Finland, the Netherlands Singapore	2007 - 2011	HVO (NEXBTL technology)	Renewable diesel, renewable propane, renewable aviation fuels, renewable chemicals	2,9 - 4,5 Million tons/year	Vegetable oils, waste and residues	Global feedstock sourcing	9
2	Crescentino cellulosic ethanol commercial plant	Italy	2013	Enzymatic hydrolysis of cellulosic biomass and fermentation to produce 2G ethanol (Proesa technology)	2G EtOH sold as transport fuel, residual lignin is used as solid fuel into a power station	Design capacity is 40,000 tons/year 2G EtOH from Arundo donax (or 24,000 tons/year 2G EtOH from straw/wood)	dry (straw) ad fresh (Arundo Donax) feedstock, hardwood	5 -5,5 tons/tons of EtOH	9
3	UPM Biorefinery	Finland	2015	Hydrotreatment of Crude tall oil (CTO)	Renewable diesel as main product for transport sector, renewable naphtha for transport and as feedstock for petrochemical industry (e.g. bioplastics), renewable pitch and turpentine for chemical industry	100kt of renewable diesel and naphtha	Crude tall oil (CTO)	Majority of CTO from UPM´s own pulp mills	9
4	AgroGas (2G BioCNG)	India	2016	Anaerobic digestion to produce 2nd generation (2G) BioCNG from agro residue	Product: AgroGas (2G BioCNG) By Product: Digestate (bio-manure) 642kg/d i.e. > 250 ton till date	100 kg/d i.e. 35 t/y max	Domestically available Agro residue with 10% moisture	280 t/y, supply of feedstock	8
5	Biomethanation of organic waste (IOC)	India	2018-2019	Anaerobic digestion (biomethanation)	Transport fuel, electricity, fertilizers	5 Ton biogas/day	Food waste, municipal solid waste and crop residues	1500 T/y	8

No.	Title	Country	Year	Technology	Products/Market	Capacity	Feedstock	Feedstock Capacity	TRL
6	The DBT-ICT 2G-Ethanol Technology	India	2016	Fermentation	ethanol, silica (with rice straw), inorganic mineral fertilizer, and, food-grade Carbon Dioxide	3 KL ethanol / day	Rice Straw and Cotton Stalk will be used as raw material in Bathinda plant	10 tons biomass per day	8
7	DBT IOC Centre for Advance Bio-Energy Research	India	2018	Carbon dioxide to high value lipids	Omega 3 fatty acids, Biodiesel	100 litre reactor	Carbon dioxide	10 kg/day of CO_2	7
8	Beijing Shougang LanzaTech New Energy Science & Technology Co., Ltd.	China	2018	Gas fermentation	Transport fuel, Jet fuel feedstock (ATJ-SPK), biomass for animal feed and biogas for use at steel mill.	48k MTA	Steel mill off gas	Design flowrate 59,000 kg/hr	8
9	IOC 2G Ethanol Technology Development	India	2012	2G Ethanol technology from Agricultural wastes: enzymatic hydrolysis and fermentation	Ethanol	250 kg/day	Agricultural residues like Rice straw, Wheat straw, Bagasse	10-12 kg/hr biomass	7
10	DBT IOC Indigenous Enzyme Technology development	India	2012	Indigenous Enzyme Technology development	2G Bio-ethanol Plants/bio-refinery	5 KL	Pre-treated Rice straw , bagasse , agriculture residue etc	5KL	7
11	Praj's Advanced Biorefinery	India	2016	Praj's 2nd generation Biomass to Bioethanol technology (enfinity) and biomethanation of stillage to biogas and renewable CNG	Present: Fuel ethanol, Bio-CNG, Bio-fertilizer and CO_2. In pipeline : Bio-chemicals (Xylitol)	1 million litres per annum (MLPA)	Rice straw, sugar cane bagasse, wheat straw, corn cobs , corn stover, cotton stalk, saw dust.	More than 4000 MT/Year (bone dry basis),	9

No.	Title	Country	Year	Technology	Products/Market	Capacity	Feedstock	Feedstock Capacity	TRL
12	Reliance Catalytic Hydrothermal Liquefaction	India	2016	Reliance Catalytic Hydrothermal Liquefaction (RCAT-HTL)	Transport fuel	0.5barrel per day of drop-in liquid biofuel.	Algae, wet organic biomass, Bio-waste (Food waste, ETP Sludge, Agricultural Crop Residue etc.), ETP sludge, oily sludge from refinery and petrochemicals	2 TPD (10-20% solids)	8
13	The GoBiGas Project	Sweden	2013	Biomethane production via gasification of biomass	Vehicle gas (primary market) or biomethane for combustion (secondary market) and co-production of 5 MW district heating as a by-product.	20 MW biomethane	Domestic feedstock (incl. wood pellets, wood chips based on residues from saw mills and logs of low quality, shredded bark)	30-35 MWth based on lower heating value of the dry fuel.	8
14	La Mède Total Plant	France	2018	Lipids hydrogenation process	HVO biodiesel Transport fuel	500 KTpy (HVO biodiesel)	Lipids: mix of Vegetable Oils and residual lipids	650 KTpy	8, 9
15	SUNLIQUID lignocellulosic ethanol plant	Romania	2020	Conversion of agricultural residues to cellulosic ethanol via enzymatic hydrolysis and fermentation	Cellulosic ethanol as transport fuel	50 kta of cellulosic ethanol	Domestically available agricultural residues like wheat and other cereal straw	Approx. 250.000 metric tons per year	8
16	All-Gas Project: Algae Biofuel for Vehicles	Spain	2011	Microalgae biofuel production for vehicles based on wastewater nutrients and	Compressed biomethane for fleet vehicles Co-products: biofertilizer, reuse water	biofuel production above 26,000 kgCH4/year	Nutrients contained in wastewater which are transformed in	Between 100 to 140 ton biomass per hectare and year.	9

No.	Title	Country	Year	Technology	Products/Market	Capacity	Feedstock	Feedstock Capacity	TRL
				biomethane upgrading to CNG			microalgae biomass		
17	The BFSJ project	Sweden	Under construction	Hydrolysis of wood biomass to alcohols followed by chemical synthesis to jet fuel	Fuel for aviation, road transport, heavy duty machinery	10,000 t/y	Wood waste; domestic	40,000 t/y wood waste	8
18	Empyro	Netherlands	2015	Fast Pyrolysis	natural gas as heating fuel Co-product: FPBO as a fuel for research purposes	24.000 tons/year of FPBO (Fast Pyrolysis Bio-Oil)	Wood residue (from local Dutch suppliers). Other cellulosic biomass types under investigation.	36.000 tons/year (dry matter)	9
19	Chemrec/Haldor Topsoe/VOLVO Bio-DME Project	Sweden	2011 - 2016	Gasification (BLG) Technology for production of renewable Syngas Haldor Topsoe conversion of syngas to Methanol and DME	BioDME as transport fuel for HD trucks, buses and off-road machinery BioMeOH by-product supplied as blend stock for RME production and chemical feed-stock.	600 tonDME/y	Kaft Black Liquor from Smurfit Kappa Kraftliner pulp mill in Piteå, Sweden	3 000 ton BL/y (BL: Black Liquor)	8
20	Lantmännen Agroetanol	Sweden	2001 - 2008	Biorefineries	Ethanol (Agro Cleanpower ED95, Agro Cleanpower E85, E100) Feed/Protein Carbon dioxide/Carbonic acid for foods	230 000 m3 ethanol annually	Mainly of wheat and other grains, but recycled products and industrial residues from the food industry are also used.	About 80 ton/h	9

The ART Fuels Forum

The Alternative and Renewable Transportation (ART) Fuels Forum, financed by the European Commission, brings together more than 100 high-profile experts representing leading demand and supply Industries in the area of ART Fuels. It is a single policy and proven technology forum aiming at producing evidence-based opinions and conveying the collective interest of the ART Fuels industry towards informing European decision-makers and officials. The Forum supports the production and the utilization of sustainable advanced liquid and gaseous fuels towards decarbonization of key transport sectors: automotive, aviation and maritime and promotes the widespread market deployment of these fuels. www.artfuelsforum.eu

IEA Bioenergy

The IEA Bioenergy Technology Collaboration Programme (www.ieabioenergy.com) is a global government-to-government collaboration on research in bioenergy and is the main initiative under the auspices of the International Energy Agency (IEA – www.iea.org) to develop and deploy bioenergy in a sustainable way in order to achieve a low carbon economy. IEA Bioenergy provides platforms for international collaboration and information exchange on bioenergy research, technology development, demonstration, and policy analysis with a focus on overcoming the environmental, institutional, technological, social, and market barriers to the near- and long-term deployment of bioenergy technologies.

Success Stories of Advanced Biofuels for Transport

NESTE: THE WORLD'S LARGEST PRODUCER OF RENEWABLE DIESEL

Year of plant start-up:	2007, 2009, 2010, 2011
Location:	Porvoo, Finland Rotterdam, the Netherlands Singapore
Technology:	HVO
Plant capacity	Combined: **2.9** Million tons/year (after Singapore expansion 2022: **4.5** Million tons/year)
Operational experience achieved	Commercial production
Total Capital Expenditure	1420 million euros (+ Singapore expansion 1.4 Billion euros)
Principle feedstocks:	Vegetable oils, waste and residues
Feedstock Capacity	Global feedstock sourcing
Products/markets:	HVO Renewable diesel, renewable propane, renewable aviation fuels, renewable chemicals
Technology Readiness Level (TRL):	TRL 9

DESCRIPTION

Neste (NESTE, Nasdaq Helsinki) creates sustainable solutions for transport, business, and consumer needs. Our wide range of renewable products enable our customers to reduce climate emissions. We are the world's largest producer of renewable diesel refined from waste and residues, introducing renewable solutions also to the aviation and plastics industries. We are also a technologically advanced refiner of high-quality oil products. We want to be a reliable partner with widely valued expertise, research, and sustainable operations.

In 2018, Neste's revenue stood at EUR 14.9 billion. In 2019, Neste placed 3rd on the Global 100 list of the most sustainable companies in the world.

Our renewable diesel production is based on unique and proprietary NEXBTL technology. We have state-of-the-art renewable diesel production facilities in Singapore and Rotterdam, and our annual renewable diesel production capacity is currently 2.9 Mton/a. The capacity expansion of our renewable products in Singapore will bring the total renewable product capacity close to 4.5 million tons annually in 2022.

Please find photos in: https://www.neste.com/corporate-info/news-inspiration/material-uploads. Neste photo gallery features printable high quality images and Neste -logos. You can find pictures of our refineries and station network.

Neste Rotterdam refinery

Stakeholders involved:	Proprietary NEXBTL technology, intensive R&D with global network of universities and partnerships
Financing Support:	Neste customers may use the renewable diesel to fulfil their renewable energy mandates and obligations.
Contribution to Sustainable Development Goals:	Neste has several focus areas in regards to Sustainability: Our business is built on a sustainable supply chain with traceability, human rights, combating deforestation, environmental monitoring, carbon footprint calculation over the whole life cycle.
Contribution to European targets on GHG emission reduction in transports:	Neste has customers globally, Europe being an important market area. In 2018, Neste renewable fuels helped our customers reduce global climate emissions by 7.9 million tons. This equals the annual emissions of 3 million passenger cars. Our target is to help our customers reduce their GHG emissions by at least 20 million tons every year by 2030. The share of waste and residues is over 80% of our renewable raw materials. We are innovating and exploring new lower quality renewable raw materials.
Employment:	Neste is a direct employer for ca 5500 persons. In addition, the feedstock supply chain employs thousands of people.

Replicability and scale-up potential:	The refining facilities are replicable.
Success factors:	Stable, long term renewable fuel policies are needed to motivate additional investments.
Constraints:	Regulative uncertainties.

Info provided by:	Harri Heiskanen
More information:	www.neste.com

Success Stories of Advanced Biofuels for Transport

CELLULOSIC ETHANOL COMMERCIAL PLANT IN CRESCENTINO (ITALY) BY VERSALIS

Year of plant start-up:	2013
Location:	Crescentino, VC, Italy
Technology:	Enzymatic hydrolysis of cellulosic biomass and fermentation to produce cellulosic ethanol.
Plant capacity	Confidential
Operational experience achieved	During the period of activity, the plant has produced around 20,000 tons of fuel-grade cellulosic ethanol
Total Capital Expenditure	240 Mill EUR as reported by previous owner
Principle feedstocks:	Feedstock that have been used are: Arundo Donax, wheat straw, rice straw, hardwood
Feedstock Capacity	The supply chain is directly managed by the Plant Owner.
Products/markets:	The main product is cellulosic ethanol sold as transport fuel. The residual lignin is used as solid fuel into a power station to generate 13 MW of green electricity partially sold to the national grid.
Technology Readiness Level (TRL):	TRL 9 – actual system proven in operational environment

DESCRIPTION

The Crescentino plant, located in the province of Vercelli in Italy, was the first in the world to be designed and built to produce bio-ethanol from agricultural by-products, woody material or plants not suitable for food consumption. This is a major innovation which many companies in the energy industry have been trying to achieve for years.

This has been made possible thanks to PROESA®, the technology developed from 2006 by M&G Group and currently owned by Versalis, the chemical company of ENI. The project was also supported by the European Commission as part of its Seventh Framework Program.

It has been possible to produce bio-ethanol using maize, sugar cane and other vegetable substances. PROESA®

technology (ethanol production from biomass) is capable of extracting bio-ethanol from cellulosic biomasses such as wood, energy crops or agricultural waste such as straw.

The Crescentino bio-refinery is located on a former industrial site in an important agricultural area, especially for rice, wheat and maize production. Furthermore, woody material and woody residues from other industries can be also easily procured locally in a 70 km radius from the plant.

This area was chosen because it is located in the center of an agricultural area, has its own internal rail link and is relatively close to the R&D Center in Rivalta Scrivia (Italy), where PROESA® technology was developed.

The site includes a boiler for electrical energy production from biomass and biomass derived material, a dedicated wastewater facility with full water recirculation, including the production of biogas from WWT anaerobic digestion. These features allow a further improvement of environmental footprint of the plant, making Crescentino a very efficient example of advanced biofuel production at scale. In addition, a part of the old foundry has been reused, following its conversion into a warehouse for the storage of the biomasses.

Crescentino project was started in 2010, construction work began in 2011 and the boiler started producing energy in the autumn of 2012. In January 2013 bio-ethanol production began and the plant reached continuous operational capacity in 2015. After some technical improvements, such as the introduction of a soaking section of the biomass before the pre-treatment, the operation was regular during the first half of 2017 at industrial rate. Following the acquisition in November 2018, Versalis is in the process of implementing an action plan that will lead to a full resumption of operations with implementation of some process improvements.

The expertise developed at Crescentino will enable similar plants to be built in the rest of the world.

Plant in Crescentino (Italy)

Stakeholders involved:	Relevant actors: ▪ Versalis – Technology owner/licensor, engineering and operator ▪ European commission 7th Framework Program
Financing Support:	Versalis acquired the plant as part of the M&G bio assets acquisition for an undisclosed amount
Contribution to Sustainable Development Goals:	SDG 2, 10, 12, 13, 7, 8, 9, 15
Contribution to European targets on GHG emission reduction in transports:	The PROESA® technology allows production of cellulosic ethanol from non – food feedstock with high GHG emission savings.
Employment:	The plant in Crescentino has created around 100 direct jobs and, additionally, a number of Indirect jobs in logistic and plant related services
Replicability and scale-up potential:	PROESA® technology has the potential to be adopted by multiple bio-refineries across the world. Crescentino plant can be either scaled up or scaled down depending on the logistic, geography, biomass availability. Replication and scalability of the project at regional, national and international level is very high.
Success factors:	Cellulosic biorefineries are typically large capex projects whereby large volumes of biomass are involved. As a consequence, successful deployment of cellulosic biorefineries depends on several variables: ▪ Local feedstock availability (considering also existing competing uses) ▪ Access to supporting financial measures (at least for first and/or second of a kind investment) ▪ Long term regulatory framework-longer than 10yrs-, including binding targets to minimize off-take risk (either a specific mandate, a carbon target or fiscal support)

Constraints:	The lack of investors' confidence is the main obstacle to biofuel technologies. Major risks perceived by investors are: ▪ Off take risks, as bio-based products compete against cheap fossil-based products –today cheaper than ever due to low oil price; ▪ Financial risks, as biorefineries are high-capex investment, particularly in the case of so-called advanced/second generation bioproducts/biofuels, where the level of innovation, technological development, expertise involved is pretty high. Due to their inherent level of innovation, advanced biorefineries projects are not yet easily bankable today in the European context. ▪ Regulatory risks: without a long-term regulatory framework, including binding targets (i.e. blending mandate), it is unlikely that investors would invest large capital in the European market: indeed, on a global basis, other regions offer more suitable environment for biofuels investments, thanks to large feedstock availability, consolidated market, relatively low labour cost, etc. (e.g. Far East, South America, etc).
Info provided by:	Pierluigi Picciotti –Licensing Expert Green Chemistry
More information:	https://versalis.eni.com/irj/go/km/docs/versalis/Contenuti%20Versalis/IT/Documenti/Documentazione/Licensing/Biotech_0_/Proesa.pdf https://www.eni.com/assets/documents/press-release/migrated/2020-en/02/PR-Versalis-Crescentino-8-febbraio-2020.pdf

A view of the Crescentino plant

The ART Fuels Forum brings together 100 experts and leaders representing the alternative transportation fuels Industry to facilitate discussions, elaborate common positions on policy issues and identify market penetration opportunities and barriers for these fuels. The Forum is established and financed by the European Commission under the project name "Support for alternative and renewable liquid and gaseous fuels forum (policy and market issues)".

www.artfuelsforum.eu

IEA Bioenergy, also known as the Technology Collaboration Programme (TCP) for a Programme of Research, Development and Demonstration on Bioenergy, functions within a Framework created by the International Energy Agency (IEA). Views, findings and publications of IEA Bioenergy do not necessarily represent the views or policies of the IEA Secretariat or of its individual Member countries.

http://www.ieabioenergy.com/

Success Stories of Advanced Biofuels for Transport

FIRST IN THE WORLD BIOREFINERY PRODUCING WOOD-BASED RENEWABLE DIESEL – UPM BIOFUELS

Year of plant start-up:	2015
Location:	Lappeenranta, Finland
Technology:	Process developed by UPM, based on hydrotreatment
Plant capacity	130 kt of renewable diesel and naphtha
Operational experience achieved	Commercial production started in January 2015, name plate capacity (100 kt) exceeded in 2017
Total Capital Expenditure	EUR 179 million without public subsidies
Principle feedstocks:	Crude tall oil (CTO)
Feedstock Capacity	N/A, major part of CTO from UPM´s own pulp mills
Products/markets:	Renewable diesel as main product for transport sector, renewable naphtha for transport and as feedstock for petrochemical industry (e.g. bioplastics), renewable pitch and turpentine for chemical industry
Technology Readiness Level (TRL):	TRL 9 – actual system proven in operational environment

DESCRIPTION

UPM Biofuels has developed an innovative production process from crude tall oil (CTO), a natural wood extract and a residue of pulp making process, to biofuel for transportation. The product, UPM BioVerno, is unique wood-based renewable diesel resembling fossil diesel, suitable for current distribution systems and all diesel engines without modification. The greenhouse gas emissions are reduced significantly, over 80%. In addition, tailpipe emissions, such as NOx and particles, are reduced significantly.

Converting CTO to biofuel is an innovative way to use an own process residue without changing the main process, pulp production. The key success factor is certified sustainability: feedstock is wood-based, non-food origin with no increase in harvesting or land use, and the greenhouse gas emission reduction is significant. Distributors value the high stability of this high quality, oxygen-free hydrocarbon fuel as it functions as direct replacement for fossil diesel. There is no blending limitation like in first generation biodiesels.

As a result, UPM produces a cost-competitive high quality transport fuel that truly decreases emissions.

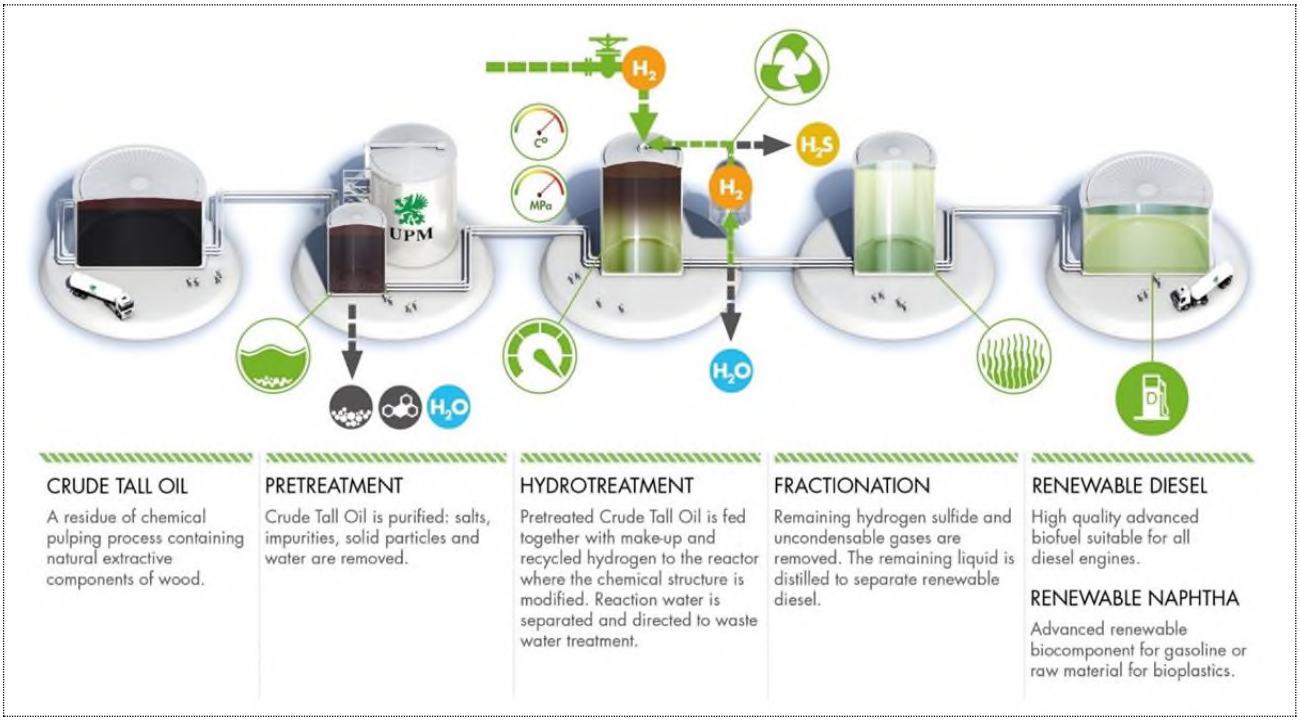
The biorefinery started in commercial scale in January 2015, reached break-even at the end of 2015, and improved profitability further in 2016. During 2017, production efficiency has increased significantly, and energy consumption reduced by 25%. UPM Biofuels was rewarded as the Bioenergy Industry Leader at the 2017 Platts Global Energy Awards.

Currently, UPM Biofuels is evaluating growth opportunitiesfor a possible second biorefinery in Mussalo, Kotka, in south-eastern Finland with a planned capacity of 500 000 tons.

UPM Lappeenranta Biorefinery produces 120 million litres of wood-based advanced biofuels annually.

Stakeholders involved:	The Biorefinery has been developed mainly by UPM in collaboration with numerous technology providers, industrial partners, fuel distributors and research institutions. In addition, UPM has engaged with local, national and EU policy makers on issues related to advanced biofuels markets.
Financing Support:	UPM invested EUR 179 million to build the biorefinery without subsidies.
Contribution to Sustainable Development Goals:	UPM Lappeenranta Biorefinery enables significant reduction in transport emissions, provides a safe and environmentally sound option for consumers for the logistics needs, improves the climate and air. UPM Biorefinery is also an excellent example of innovation in the forest industry, as it uses a residue of pulp production, does not increase harvesting of forest but provides an environmentally friendly option for transport. As the Biorefinery is located in South-Eastern Finland, it also boosts regional economy and provides jobs and well-being in the small city of Lappeenranta.

	Yearly greenhouse gas emissions savings achieved by production of UPM BioVerno equals to removing 120.000 cars from roads. In addition, tailpipe emissions, such as NOx and particles, are reduced significantly. In 2015, UPM Biofuels was chosen as an example case for goal number 13 for Climate Change by the United Nations (UN) Global Compact.
Contribution to European targets on GHG emission reduction in transports:	The greenhouse gas emissions are reduced significantly, over 80% compared to fossil diesel. UPM BioVerno low-ILUC advanced biofuels are categorised as the most sustainable advanced biofuel that have a mandatory blending mandate.
Employment:	The biorefinery benefits the local economy by offering work for 250 people directly and indirectly, reducing oil imports, increasing domestic area raw material, technology, equipment and labor.
Replicability and scale-up potential:	UPM Lappeenranta Biorefinery has reached its original goals. Currently, UPM Biofuels is evaluating growth opportunities for a possible second biorefinery in Mussalo, Kotka, in South-Eastern Finland. The UPM Kotka Biorefinery would produce approximately 500,000 tonnes of advanced biofuels made from sustainable raw materials for use in the road transport, marine and aviation sectors. The biorefinery's products could also be used for replacing fossil raw materials in the chemical industry.
Success factors:	The key success factor of the novel drop-in fuel is sustainability: feedstock is non-food origin with no direct or indirect land use change, and the greenhouse gas emission reduction is significant. UPM Biofuels welcomes the RED2 agreement as it creates an obligatory advanced biofuel blending mandate in all EU Member States and provides long term security and enables the further roll-out of advanced biofuels in the EU. UPM Lappeenranta Biorefinery has shown that investments in advanced biofuels industry are viable and showcases the power of innovation.
Constraints:	EU and national policies on biofuels will play an important role in the final assessment of new investments. UPM calls for ambitious implementation of RED2 in order for Member States to achieve their Paris agreement goals.



UPM Lappeenranta Biorefinery production process

Info provided by:	Marko Janhunen, Director, Public Affairs, UPM marko.janhunen@upm.com
More information:	www.upmbiofuels.com The story of UPM BioVerno -video: https://www.youtube.com/watch?v=0gd-miAoIIo&feature=youtu.be Links to other UPM Biofuels videos: http://www.upmbiofuels.com/whats-new/videos/Pages/default.aspx UPM Biofuels WHITEPAPER: http://www.upmbiofuels.com/whats-new/other-publications/Documents/Publications/upm-biofuels-argus-conference-2017-advanced-biofuels-provide-solution-to-reduce-transport-emissions.pdf Articles in Biofuels International Magazine – Latest one is "From sewing spools to renewable diesel" in March/April 2018 issue, pages 22-23: http://www.upmbiofuels.com/whats-new/other-publications/Pages/Default.aspx UPM Biofuels photos: http://www.upmbiofuels.com/whats-new/other-publications/Documents/Publications/upm-biofuels-argus-conference-2017-advanced-biofuels-provide-solution-to-reduce-transport-emissions.pdf

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Success Stories of Advanced Biofuels for Transport

PRIMOVE ENGINEERING PVT. LTD.
AGROGAS (2G BIOCNG)

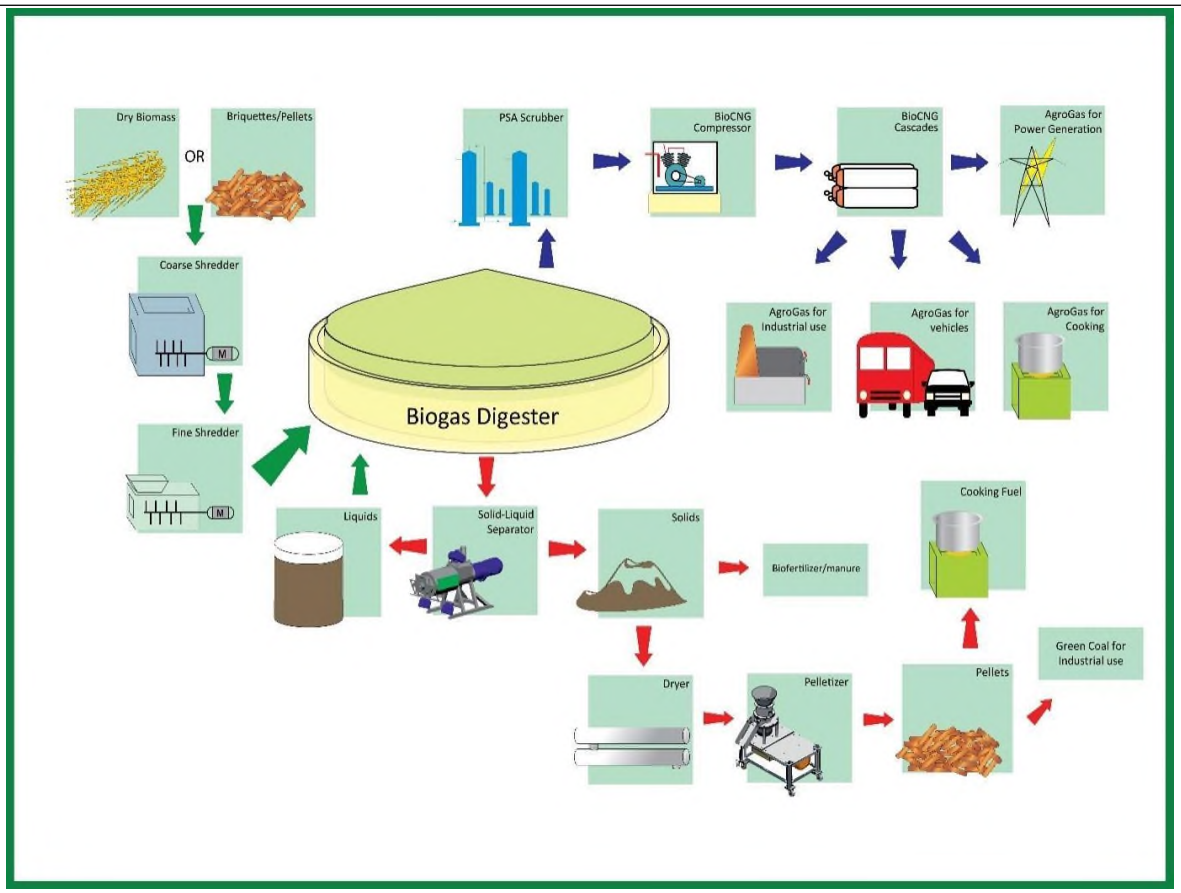
Year of plant start-up:	2016
Location:	Gat No. 271, Village Pirangut, District: Pune, State: Maharashtra, Country: India
Technology:	Anaerobic digestion to produce 2nd generation (2G) BioCNG from agro residue
Plant capacity	AgroGas (2G BioCNG) of 100 kg/d i.e. 35 t/y max. Capacity
Operational experience achieved	Approx. 5,600 hours; Operated daily since 14.08.2016 till date i.e. about 700+ days considering 350 days/annum. Total accumulated fuel produced > 30 ton
Total Capital Expenditure	₹ 1,150 Lakhs[1], being first such pilot scale technology demonstration unit
Principle feedstocks:	Domestically available Agro residue with 10% moisture (rice straw/maize straw/sugarcane trash/cotton straw/soya trash/coconut frond/organic solid waste/bamboo/napier grass etc.)
Feedstock Capacity	280 t/y, supply of feedstock is secured through various biomass aggregator sources identified
Products/markets:	Product: AgroGas (2G BioCNG) By Product: Digestate (bio-manure) 642kg/d i.e. > 250 ton till date Markets: AgroGas (2G BioCNG) fuel for vehicle filling and Digestate as manure for farm fields
Technology Readiness Level (TRL):	Technology is completely ready TRL 8 – system complete and qualified

[1] 1 Lakh INR = 100,000 INR = 1300 EUR

DESCRIPTION

Primove is a Pune based Technology Company working in the domain of gaseous fuels and energy. Produced exclusively from agricultural waste and plant material, AgroGas i.e. 2nd Generation BioCNG, also known as 'Fuel of the Future' is a much-needed, airtight invention from the labs of Primove. Patented and tested, AgroGas (2nd Generation BioCNG) is delivering a 3-fold socio-environmental impact – reducing carbon footprint, conserving fossil fuels and giving a sustainable entrepreneurial opportunity to the farmers thereby undoing the wrongs of fossil fuels. Primove has been the only company which has the technology today for processing any kind of agricultural biomass without any pre-treatment to produce second generation (2G) BioCNG that can be directly fed in vehicles. Primove has set up first 2G BioCNG plant in India at Pirangut in Pune which was inaugurated in August 2016 at the hands of Hon. Shri. Nitin Gadkari, Minister of Road, Transport and Highways and Hon. Shri. Manohar Parrikar, the then defense Minister.

If we initiate 5000 such 2nd Generation BioCNG plants across the country, then fuel import cost of ₹ 7 lakh crore[2] could be reduced to almost ₹ 3 lakh crore. If such plants are initiated in every village, then it can provide employment to at least 500 people from that community. In addition to this, AgroGas can prove to be a good import substitute as it is cost effective and pollution free. Our goal is to take the innovation of AgroGas plants throughout the length and breadth of India to ensure higher fuel substitution, more livelihood opportunities to the farmers and above all, reduction of carbon footprint, thereby lending a hand to the nation's goals of fighting the effects of pollution at a global level.



Process Flow Diagram

[2] 1 lakh crore INR = 10,000,000 INR

AgroGas being dispensed in Car

Stakeholders involved:	▪ Farmers providing agro residue, Briquette manufacturers, Customers who fill AgroGas in their vehicles (users), ▪ Farmers utilizing digestate/manure in their farm fields, ▪ State Pollution Control Board (PCB) granting NOC for the plant, ▪ Petroleum and Explosives Safety Organization (PESO) granting approval and licenses to operate the plant
Financing Support:	Primove's pilot project has not availed any subsidy but Ministry of New and Renewable Energy (MNRE) has provision to grant a subsidy of ₹ 400 Crore for such plants generating 12,000 m^3/d Biogas
Contribution to Sustainable Development Goals:	Advantages offered by the project are as follows: Small and marginal farmers who shall be able to sell their agro waste, which otherwise was being burnt thereby polluting the air, benefit from the project. This is an additional source of income for the farmers.

	This project falls under the sustainable development goal of the World Bank and facilitates affordable, reliable, sustainable and renewable energy from biomass. The project is Carbon Neutral as it is an inexhaustible and clean energy. The project comes under the "Swachh Bharat Abhiyaan" of Hon. Prime Minister of India. India has committed in the Paris Climate accord to reduce the greenhouse gas emission by production of energy from bio source instead of fossil fuel. The AgroGas (2G BioCNG) project is supporting the vision of the Government of India in the matter. Production of AgroGas (2G BioCNG) on a large scale could potentially replace imported LNG/CNG, commercial LPG and all transportation fuels and thus save valuable foreign exchange. Project will generate employment in rural area and supplement the agriculture income of farmers. In line with all advantages mentioned above, the project contributes to following SDGs: Reliable, sustainable and modern energy for all (SDG7), regional development (SDG8) and promotion of sustainable industrialization (SDG9), sustainable consumption and production patterns (SDG 12), and GHG emission reduction (SDG13)
Contribution to GHG emission reduction in transports:	The AgroGas (2G BioCNG) unit at Pirangut, Pune is the first and the only such plant to have received approvals and licenses for its operation (under Form E&F for compression and filling of Compressed Bio Gas and under Form G for dispensing of Compressed Bio Gas under Gas Cylinders Rules, 2016) which utilizes agro residue to produce BioCNG for automobile filling. The produced AgroGas (2G BioCNG) complies with purity specifications stipulated under IS 16087:2016 published by Bureau of Indian Standards (BIS) thus maintaining purity of methane > 90%. Use of BioCNG arrests harmful tailpipe emissions. AgroGas technology has the potential to meet India's new climate plan – also known as its Intended Nationally Determined Contribution (INDC) announced at the COP21 i.e. reduction of emissions intensity per unit GDP by 33 to 35 percent by 2030 below 2005 level. The organic carbon rich digestate goes back to farm fields to increase fertility of soil and give better farm yield. The existing project has the potential to power 13 cars (8 kg/fill) or 25 auto rickshaws (4 kg/fill) or a combination of above to thus reduce GHG emissions by these vehicles.

Employment:	The plant employs 6 operators, 1 supervisor and 1 engineer.
Replicability and scale-up potential:	The AgroGas (2G BioCNG) has the potential to be scaled up to produce 5 Ton per Day (TPD), 10 TPD, 25 TPD, 50 TPD or even more of BioCNG per day depending on land & raw material (agro residue) availability and the potential to sell AgroGas. The technology can be adapted for implementation at an international level.
Success factors:	▪ Biomass aggregation systems should be in place and a clear mandate from Central and State Govt. for centralized purchase of agricultural residue and prohibition on burning the biomass residue ▪ Sales avenues and facilitation by way of fertilizer companies buying digestate recovered from Biogas digester (which is a rich source of organic carbon) ▪ Free and fair open market policy for sales of BioCNG by the manufacturers of BioCNG in line with Parallel Marketer policy available for commercial LPG ▪ Due concessions under Income Tax act (at par with facilities available to new CGD and NG operators). Exemption of profits for certain years for IT under 80JJ(a) of Income Tax act ▪ Initiative by Govt. Oil Companies for setting up BioCNG plants and making available retail sales outlets for BioCNG sales throughout the country
Constraints:	Technically there's no constraint for AgroGas project. It is one of the most beautiful technologies which gives good business, contributes to clean environment and is yet sustainable.
Info provided by:	Rajesh Date, Director / Santosh Gondhalekar, Director, Primove Engineering Private Limited, Pune
More information:	www.primove.in

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Success Stories of Advanced Biofuels for Transport

IOC: BIOMETHANATION OF ORGANIC WASTE

Year of plant start-up:	2018-19
Location:	India
Technology:	Waste to Energy Conversion of various organic wastes such as food waste, municipal solid waste and crop residues to biogas
Plant capacity	5 Ton biomass/day
Operational experience achieved	4500 hr; total accumulated volume of fuel produced
Total Capital Expenditure	0.4 Million USD
Principle feedstocks:	Food waste, municipal solid waste and crop residues
Feedstock Capacity	1500 T/y
Products/markets:	Transport fuel, electricity, fertilizers
Technology Readiness Level (TRL):	TRL 8 – system complete and qualified

DESCRIPTION

Biomethanation also called as anaerobic digestion is a process of environmentally benign disposal of various organic wastes such as food waste, municipal solid waste and crop residue. In this process, organic waste is converted into biogas in presence of microorganisms under anaerobic conditions. Biogas mainly consists of methane, carbon dioxide and small amount of other impurities. Biomethanation plant also gives a byproduct called organic manure which is used as soil conditioner. Biomethanation plants benefit the environment by reduction of GHG, pathogen control and odor reduction.

Applications of biogas:

- Cooking in place of LPG
- Electrical power generation using gas engines
- For lighting purposes in gas fired lanterns
- Bio-CNG as transport fuel in automobiles
- For space heating applications

Details of IOC's biomethanation technology:

It is a two-stage anaerobic process

- Primary digester: organic fraction present in waste gets extracted into liquid form
- Second stage: organic matter is converted into biogas in the presence of indigenously developed inoculum

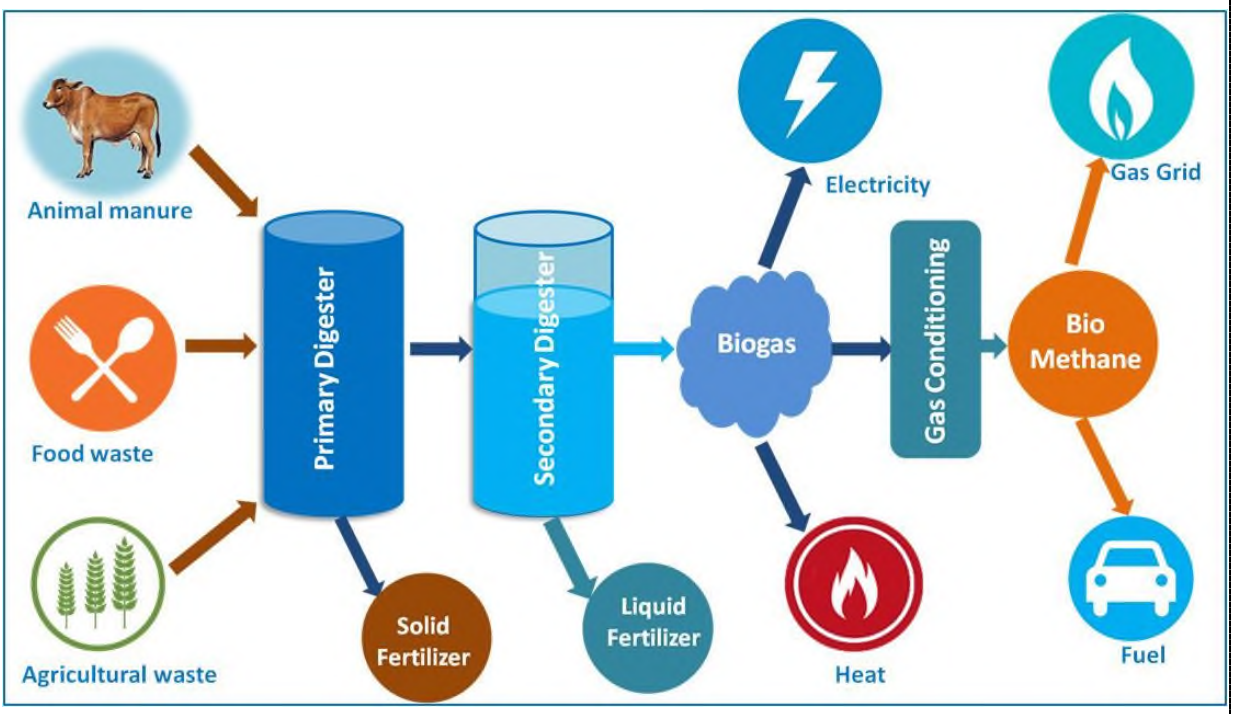
Benefits of IOC's Technology

- Higher methane content (>80%) in the biogas: Leading to better heating value and burning efficiency
- Better control on seasonal variations in gas generation rate
- Well studied and validated process backed up by sound technical inputs
- Compact and cost effective plant engineering and design

The following is the typical yield and composition of biogas generated in 500 kg/day biomethanation plant

Feedstock load kg/day	500
Expected biogas production Nm3/day	30
Expected bio-manure kg/day	50
Biogas Composition (vol%)	
CH4	80-85
CO2	11-13
N2	3-5

Developed technology has been evaluated at IOC R&D Centre in a small 50 kg/day, 250 Kg/day and 5 T/day biomethanation plant. Towards supporting Government of India's initiative on Swachh Bharat Abhiyaan, a 5 TPD biomethanation plant is being set up in FY 2018-19 in Municipal Corporation of Faridabad based on IOC's biomethanation technology. It is also envisaged to convert generated biogas into bio-CNG in the proposed plant.



Block-Diagram of Bio-methanation of Organic Waste

Stakeholders involved:	Finance: Indian Oil Feedstock: Local Civil bodies
Financing Support:	Finance: Indian Oil
Contribution to Sustainable Development Goals:	Through utilization of waste this project enables local production of energy in the form of BioCNG, Electricity, cooking gas etc. It also helps in keeping the environmental clean and provides organic fertilizers for crops.
Contribution to GHG emission reduction in transports:	This technology for controlled disposal of household and industrial waste, crop waste and kitchen waste etc) will significantly reduce the un-intentional release of CH_4 to environment.
Employment:	10
Replicability and scale-up potential:	A further several plants are in the pipeline in the country
Success factors:	It is important to have a supportive legislative and financial landscape for successful projects to replicate. Technology neutral policy and

	broad decarbonisation targets will support deployment of new facilities, as it will create a stable marketplace and create confidence for investors to finance more projects.
Constraints:	Technology neutral policy is not global today, but the language is changing to include new technologies such as gas fermentation of waste emissions. There are some countries today, where there isn't a level playing field for incentives (tax credits or mandates). In such cases, where new approaches such as recycled carbon fuels are ineligible, this is a constraint.

Info provided by:	Dr S K Puri, CGM (Bioenergy), IOCL, R&D Centre, Faridabad-121007, India
More information:	WWW.IOCL.COM

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Success Stories of Advanced Biofuels for Transport

THE DBT-ICT 2G-ETHANOL TECHNOLOGY

Year of plant start-up:	March 2016
Location:	Kashipur, Uttrakhand, India
Technology:	DBT-ICT 2G Ethanol Technology is a feedstock agnostic process which uses a two-step fractionation of biomass into separate streams of glucose, xylose and lignin. Glucose and xylose are co-fermented to ethanol and lignin can be burnt into boiler for steam/power generation. The technology is Zero-Liquid Discharge where >95% of water is recycled.
Plant capacity	10 tons biomass per day for production of 3000 L ethanol
Operational experience achieved	Continuous flow plant operated up to 7 days non-stop with feedstocks including bagasse, rice straw, cotton stalk and wheat straw, with alcohol yield in the range of 240-300 L/ton biomass. A total of 5000 hours of operating.
Total Capital Expenditure	USD 6 million
Principle feed-stocks:	DBT-ICT Technology is feedstock agnostic. However, as per the biomass availability survey in Bathinda region, Rice Straw and Cotton Stalk will be used as raw material in Bathinda plant.
Feedstock Capacity	450 tons biomass processing per day
Products/markets:	Technology capable of producing ethanol, silica (with rice straw), inorganic mineral fertilizer, and, food-grade Carbon Dioxide
Technology Readiness Level (TRL):	TRL 8 – system complete and qualified Front End Engineering done for 450 ton/day rice straw plant being erected at Bathinda, Punjab, India. Unit to start operating in Jan 2020.

DESCRIPTION

The DBT-ICT 2G-Ethanol Technology has been validated and demonstrated at a scale of 10 ton biomass/day at India Glycols Ltd. site at Kashipur, Uttrakhand, India. The technology and plant design are feedstock flexible i.e. any biomass feedstock from hard wood chips and cotton stalk to soft bagasse and rice straw can be processed. The

technology employs continuous processing from biomass size reduction to fermentation; and converts biomass feed to alcohol within 24 hours compared to other technologies that take anywhere from 3 to 5 days. The plant design with a low footprint also has unique features such as advanced reactor design and separation technologies with slurry-flow rapid reaction regime operations.

Achievements: The technology has several novel features and achievements that marks it apart from other globally promoted technologies.

- Two-Step alkali soda-nitric acid fractionation
- Slurry flow systems with recycle and reuse of water, alkali and acid
- Feedstock agnostic technology i.e. any biomass feedstock from hard wood chips and cotton stalk to soft bagasse and rice straw can be processed
- Lowest enzyme dosage on account of enzyme reuse over weeks
- No fancy metallurgy and hence low capital expenditure
- Low cost of production with recycling of enzymes, chemicals and water.
- Low consumption of power and water
- Demonstration plant ran smooth from the first run without any problems related to solid handling and other issues that plague other technologies

Challenges addressed: Scalable technology to a wide range from 100 ton biomass/day to 500 ton/day the technology can find decentralized deployment in Indian agricultural heartland not only providing biofuel options for India but positively impacting farm revenues for farmers, creation of jobs, net reduction in import of crude oil, and reductions in carbon emissions thereby fuelling India's green economic growth engine.

Based on the data generated at the 10 TPD plant, basic and detained engineering has been carried out for a 450 ton/day rice straw processing plant to produce 100 KL/day fuel grade ethanol. This plant shall come up and start operations in Jan 2020.

The 10 ton biomass/day Lignocellulosic ethanol plant at India Glycols Ltd., site at Kashipur, Uttrakhand, India built with the DBT-ICT 2G-Ethanol Technology

Stakeholders involved:	1. India Glycols Ltd. (technology user) 2. L&T Hydrocarbon Engineering (engineering partner for building commercial scale plants) 3. Hindustan Petroleum Corporation Ltd. (technology user building 100KL ethanol/day plant to start operation Jan 2020) Respective sites: 1. Kashipur, Uttrakhand, India 2. Mumbai, India 3. Bathinda, Punjab, India Respective Financing: 1. Self + Ministry of S&T 2. Self 3. Self + Federal VGF Respective Project Developers: 1. Vidyan Biocommerce Pvt Ltd, Mumbai, India 2. L&T Hydrocarbon Engineering, Mumbai, India 3. Technip FMC, Delhi, India
Financing Support:	The 10 ton/day demonstration plant received 50% soft loan from BIRAC, a venture funding enterprise under Department of Biotechnology of Government of India. According to the National Biofuel Policy 2018, the Government of India has targeted ethanol blending of 10% by 2020. To achieve this target and to reduce the dependency on fossil fuels, several OMC are putting up ethanol biorefinery plants in India. At the present a VGF of 40% of capital cost with a cap of 20 million USD has been offered to new cellulosic ethanol plants. A marked-up price for 2G-Ethanol is on the anvil. Gasoline blending companies have been obligated to buy whatever ethanol industry can offer at regulated price (marked up for 2G-Ethanol).
Contribution to Sustainable Development Goals:	The availability of agri-residues in India is approximately 250-300 million tons. The Government of India, through the National Biofuel Policy 2018 has set a mandate to blend ethanol in gasoline at more than 10%, depending on the ability to produce ethanol from the surplus agricultural biomass/residues. Use of these surplus agricultural residues and other renewable sources of energy can lead to partial or full replacement of petro-derived fuels with renewable fuels ensuring energy security for the country. This technology when commercialized would lead to the following sustainable development goals (SDG)

	▪ Reduced emission of carbon, ▪ Conversion of renewable carbon to value-adds ▪ Net reduction in import of crude oil ▪ Revenue generation for farmers ▪ Prevention of wasteful and hazardous burning of agro-residues on farms
Contribution to European targets on GHG emission reduction in transports:	Not applicable
Employment:	The 10 tpd/day plant employs 10 people. The commercial plant shall employ approximately 500 people. Set in rural background a lot many indirect jobs shall be created engaged in biomass collection, storage and transport.
Replicability and scale-up potential:	The 10 ton biomass/day plant was scaled up in one go from a 1 ton biomass/day plant. The scale up went without any hitch and the plant could be operated end-to-end from size reduction to fermentation (all continuous flow systems) in week 1. The technology has now been scaled up to 450 on biomass/day plant and complete engineering has been carried out. Engineering companies are confident that the plant shall run without issues anywhere in the processes.
Success factors:	It is important to have support from government bodies for rapid translation of the developed technologies to pilot/demonstration scales and successful commercialization as well as replication of the developed technologies.
Constraints:	The major constraint for the technology is setting up the initial few plants which would involve high CAPEX. It is estimated that with the development and improvement in technologies the cost of subsequent plants/ biorefineries, would be reduced. With the DBT-ICT Technology the scale up or sale down are not technology challenges

Features of the DBT-ICT 2G-Ethanol/Sugars Technology

Info provided by:	DBT-ICT Centre for Energy Biosciences, Institute of Chemical Technology, Mumbai, India
More information:	www.ictmumbai.edu.in [Website/pages for the success story] [Links to articles, fact sheets, posters, pictures/videos…]

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Success Stories of Advanced Biofuels for Transport

DBT IOC CENTRE FOR ADVANCE BIO-ENERGY RESEARCH: CARBON DIOXIDE TO HIGH VALUE LIPIDS

Year of plant start-up:	2018
Location:	IndianOil R&D Centre, Faridabad, India
Technology:	Carbon dioxide to high value lipids
Plant capacity	100 litre reactor
Operational experience achieved	Around 100 hours of operation since start-up
Total Capital Expenditure	0.5 Million US dollars
Principle feedstocks:	Carbon dioxide
Feedstock Capacity	10 kg/day of CO_2
Products/markets:	Omega 3 fatty acids, Biodiesel
Technology Readiness Level (TRL):	**TRL 7** – system prototype demonstration in operational environment

DESCRIPTION

DBT-IOC Centre for Advanced Bio-Energy Research at IndianOil R&D (IOC R&D) has developed a novel 3rd Generation Bio-fuel technology by integrating the LanzaTech USA anaerobic gas fermentation technology to convert carbon dioxide into acetic acid and IOC (R&D) aerobic fermentation technology to convert acetic acid to lipids (algal oil) including highly valuable Omega 3-fatty acids (DHAs). The lipids are then transesterified to esters followed by separation of Omega 3-fatty acids (DHAs) esters as high value product & remaining lipid esters are used as biodiesel fuel. This makes the overall process economically feasible. DHA esters are essential components of nutrient formulation for children, adults and shall help in combating childhood malnutrition. The DBT-IOC centre has put up world's first pilot facility at IOC R&D, Faridabad at 100 lt reactor scale to sequestrate about 10 kg/day of CO2. The US & Japan patents have been granted for IOC R&D process. IndianOil & LanzaTech received Game Changer Company of the year award by Petrofed in 2015 for this novel integrated process. The projected market for Omega 3 fatty acid esters by 2025 is about 60,000 Tons per annum (~ US $ 57 billion). Commercial grade DHA esters price ranges from US $500- $ 1200 per Kg depending upon the purity grade of DHA. Currently most of the production of Omega 3 fatty acid esters is from fish oil which uses huge quantities of wild fish as feed, contributing to an overfishing crisis and threatening global food security.

Carbon dioxide to high value lipids Pilot Facility, IndianOil R&D Centre, Faridabad, India

Stakeholders involved:	Indian Oil Corporation Limited LanzaTech USA Department of Biotechnology, Government of India
Financing Support:	Indian Oil Corporation Limited Department of Biotechnology, Government of India
Contribution to Sustainable Development Goals:	The process has demonstrated the tremendous potential of CO_2 sequestration /carbon recycling. This technology shall create a platform that can produce sustainable food and fuels economically and at commercial scale. This disruptive technology shall not only reduce carbon emissions but also produce very high value products like DHA as well as Biodiesel.
Contribution to European targets on GHG emission reduction in transports:	The facility in India is first such pilot facility in the world. Upon successful pilot trials. IOC have plans to put up commercial plant at suitable refinery/ 2G ethanol plants where pure CO_2 is available from the MEG/2G ethanol fermentation units and hydrogen from refineries .There are lot of MEG plant in Europe & several 2G ethanol plants are coming up in Europe where this technology has application.
Employment:	The plant employs ~ 10 engineers & Operators.
Replicability and scale-up potential:	Several commercial plants are in pipeline in India & abroad upon successful pilot plant trials
Success factors:	The Government of India has unveiled a new National Biofuel Policy (2018) that incentivises biofuel generation through multiple measures. Major

	steps include encouragement of biofuel generation from excess crop production and setting apart Rs 5000 crores viability gap funding (VGF) to establish second generation ethanol refineries. For providing specific fiscal incentives, the policy categorises biofuels into several groups: 1G (First Generation), 2G, 3G, and bio-CNG. This policy shall provide major boost in commercialising the technology.
Constraints:	Currently technology is at pilot scale only. Process validation being carried out for commercial viability.

Info provided by:	Dr S K Puri, Chief General Manager, Indian Oil R&D Centre, Faridabad
More information:	www.iocl.com

Success Stories of Advanced Biofuels for Transport

BEIJING SHOUGANG LANZATECH NEW ENERGY SCIENCE & TECHNOLOGY CO., LTD.: GAS FERMENTATION

Year of plant start-up:	2018
Location:	Caofeidian, Hebei Province, China
Technology:	Gas fermentation to ethanol
Plant capacity	45k MTA (Metric Tons Annually)
Operational experience achieved	Over 1 year of operation since start up; more than 28,000 tons of fuel ethanol produced
Total Capital Expenditure	350 million RMB[1]
Principle feedstocks:	Steel mill off gas
Feedstock Capacity	Design flowrate 59,000 kg/hr
Products/markets:	Transport fuel, Jet fuel feedstock (ATJ-SPK), biomass for animal feed and biogas for use at steel mill.
Technology Readiness Level (TRL):	TRL 8 – system complete and qualified

DESCRIPTION

LanzaTech's technology has been demonstrated at five industrial sites with over 850,000 hours of operation using steel mill waste gases (BlueScope Steel, NZ; Shougang Steel, CN; BaoSteel, CN; China Steel, TW) and approximately 30,000 hours using syngas from industrial MSW gasification (Sekisui, JPN). Operations were conducted as series of campaigns, each frequently over 2,000 hours in duration. In addition to customer-owned pilot/demonstration units, LanzaTech operates an R&D and piloting facility in Soperton, GA known as LanzaTech Freedom Pines Biorefinery.

With the success of its pilot and demo programs, LanzaTech started construction on the first generation commercial facility in China in 2016. On May 3, 2018, LanzaTech initiated operations at this facility with its Joint Venture partner, Shougang Group. The 45,000-ton ethanol/annum facility located at the Jingtang Steel Mill outside Beijing is currently producing ethanol and optimization efforts are underway.

[1] 1 RMB (Chinese Yuan) = 0.13 EUR

LanzaTech Commercial Facility with Shougang, China

Stakeholders involved:	Joint Venture Partners: LanzaTech; Shougang Group, Tangmin; Site: Jingtang Steel Mill, Financing: Shougang Group, Shougang Funds; Tangmin Group; Shanghai Dehui
Financing Support:	The project has received multiple grants from municipal, provincial governments for carbon reduction and circular economy.
Contribution to Sustainable Development Goals:	Through utilization of waste emissions this project enables local production of low carbon fuels, that displace need for fresh fossil inputs; it creates new green employment at the steel mill and by avoiding combustion of gases at site, the processes reduces criteria pollutants which would impact local communities. Using wastes and residues in this way, promotes sustainable consumption patterns and provides a new avenue for low carbon fuels. With this in mind, the project contributes to the following SDGs: GHG emission reduction (SDG13), sustainable consumption and production patterns (SDG 12), reliable, sustainable and modern energy for all (SDG7), regional development (SDG8) and promotion of sustainable industrialization (SDG9).

Contribution to European targets on GHG emission reduction in transports:	The facility in China is a first generation commercial facility converting industrial off gases to ethanol. This project is a landmark facility that will show European Steel mills the opportunities of carbon recycling, through production of low carbon fuel as ethanol or jet fuel, supporting decarbonisation goals. Optimization of the technology will be implemented at LanzaTech's Steelanol project in Belgium with ArcelorMittal. This will be the first project globally to demonstrate utilzation of blast furnace (BF) gas in a live fermentation. This is particularly important as more than 80% of the carbon rich gases available at steel mills is BF gas, highlighting the first commercial application of using this gas stream globally. This project will have the GHG reduction potential of taking 80,000 cars off the road each year.
Employment:	The plant employs ~ 130 engineers & operators.
Replicability and scale-up potential:	A further three plants are in the pipeline in the USA, South Africa, Europe and India.
Success factors:	It is important to have a supportive legislative and financial landscape for successful projects to replicate. Technology neutral policy and broad decarbonisation targets will support deployment of new facilities, as it will create a stable marketplace and create confidence for investors to finance more projects.
Constraints:	Technology neutral policy is not global today, but the language is changing to include new technologies such as gas fermentation of waste emissions. There are some countries today, where there isn't a level playing field for incentives (tax credits or mandates). In such cases, where new approaches such as recycled carbon fuels are ineligible, this is a constraint.

Info provided by:	Freya Burton, LanzaTech
More information:	www.lanzatech.com

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Success Stories of Advanced Biofuels for Transport

2G ETHANOL TECHNOLOGY DEVELOPMENT

Year of plant start-up:	2012
Location:	Indian Oil R&D Centre, Faridabad, India
Technology:	2G Ethanol technology from Agricultural wastes
Plant capacity	250 kg/day
Operational experience achieved	6 years
Total Capital Expenditure	1.5 Million US dollars
Principle feedstocks:	Agricultural residues like Rice straw, Wheat straw, Bagasse
Feedstock Capacity	10-12 kg/hr biomass
Products/markets:	Ethanol
Technology Readiness Level (TRL):	**TRL 7** – system prototype demonstration in operational environment

DESCRIPTION

Department of Biotechnology, Ministry of Science and Technology, New Delhi and the Research and Development Centre, Indian Oil Corporation Limited, Sector-13, Faridabad, Haryana established Bioenergy Research Centre (DBT-IOC Centre) for the development of 2G ethanol and other value added chemicals. For this purpose a pool worth Rupees 53 Crores[1] was created with the contribution of 51% by DBT and 49% by IOC. The centre started functioning from May 2012. Besides this, the centre roped in various institutes like NREL, USA and the Lund University, Sweden to develop 2G-Ethanol technology as both of these organisations are pioneer across the world in this area.

A group of researchers started working in the laboratory with almost no prior experience in this area. Within a year, with the help of NREL, USA a pilot plant having processing capacity of 250 kilograms per Day was commissioned indigenously. Thereafter, by exploiting this pilot plant facility, a large amount of database was

[1] 1 Crore INR = 10,000,000 INR = 130 kEUR

generated using various catalysts and agricultural residues like rice straw, wheat straw, bagasse, etc. The data was related to all the steps involved in the process of biomass to ethanol, i.e. pretreatment, enzymatic hydrolysis and fermentation followed by distillation and purification of ethanol was generated.

All sorts of studies were conducted like carbon mass balance; component based mass balance, life cycle assessment and life cycle costing using this pilot plant in a span of about 4 years. Thereafter, the process flow diagram of technology was firmed up in order to scale it to 10 tons per day processing unit. Basic Design Engineering package (BDEP) of the technology was firmed up with the help of process design and engineering cell of IOC. Now, mode of execution of the project, necessary approvals and the allocation of the funds is being finalized.

Simultaneously, vendor development work is underway for the fabrication and integration of the plant. It is anticipated that this demo-scale plant of 10 tons biomass per day processing capacity will be functional by the end of 2019 at panipat. Once the technology is demonstrated at 10 ton per day unit, it will be ready for deployment in the country.

In the nutshell, the project was conceived and processes are being scaled up indigenously which itself explains a very successful and exemplary success story of the efforts made by the Department of Biotechnology, Ministry of Science and Technology, New Delhi and the Research and Development Centre, Indian Oil Corporation Limited, Faridabad, Haryana.

Lignocelulosic Ethanol (2G) pilot plant facility at IndianOil R&D Centre, Faridabad

Stakeholders involved:	Indian Oil Corporation Limited Department of Biotechnology, Government of India
Financing Support:	Indian Oil Corporation Limited Department of Biotechnology, Government of India
Contribution to Sustainable Development Goals:	All sorts of studies were conducted like carbon mass balance; component-based mass balance and life cycle assessment.
Contribution to GHG emission reduction in transports:	This project will have the GHG reduction potential by blending ethanol with gasoline
Employment:	The plant employs 10 engineers, chemists, biotechnologists, project assistant
Replicability and scale-up potential:	Demo plant on indigenous technology is coming by 2019. Commercial plant on this technology plants has been planned in future in India.
Success factors:	The project was conceived and processes are being scaled up indigenously which itself explains a very successful and exemplary success story of the efforts made by the Department of Biotechnology, Ministry of Science and Technology, New Delhi and the Research and Development Centre, Indian Oil Corporation Limited, Faridabad, Haryana
Constraints:	High CAPEX, highly efficient enzyme for lower OPEX

Info provided by:	Dr S K Puri, Chief General Manager, Indian Oil R&D Centre, Faridabad
More information:	www.iocl.com

ARTFuels IEA Bioenergy European Commission

Success Stories of Advanced Biofuels for Transport

DBT-IOC: Indigenous Enzyme Technology development

Year of plant start-up:	2018
Location:	Faridabad, India
Technology:	Indigenous Enzyme Technology development
Plant capacity	5000 litre reactor
Operational experience achieved	Better results than the laboratory experiments, successfully tested the efficacy of the produced enzyme in the 1MT 2G ethanol Pilot Plant with acid pre-treated slurry.
Total Capital Expenditure	0.3 million Us dollars
Principle feedstocks:	Pre-treated Rice straw , bagasse , agriculture residue etc
Feedstock Capacity	-
Products/markets:	2G Bio-ethanol Plants/bio-refinery
Technology Readiness Level (TRL):	TRL 7 – system prototype demonstration in operational environment

DESCRIPTION

Cellulase enzyme is a major opex cost component in 2G ethanol process for conversion of biomass into ethanol. Currently the enzyme supply is proprietary to very few companies and the cost of enzyme per litre of ethanol production is very high. In view of this, DBT-IOC Centre for Advanced Bio-Energy Reseach, IOC R&D Centre Faridabad has developed its indigenous cellulase enzyme recipe for the sustainable supply of enzyme at low opex.

The cellulase enzyme preparation consists of multiple activities and hence more than 85000 mutants of fungal strains were profiled for different cellulolytic and hemicellulolytic activities like endo/exoglucanase, β-glucosidase, FPase etc. Based upon profile enzyme broths from potential strains were blended and analyzed for hydrolytic performance at different FPU/Protein concentrations. This has led to two strains that were selected for further activity improvement and process development. These strains had very high hydrolytic activity ranging from 1.5-2.5 FPU/ml on Avicel as substrate. Carbon sources such as commercial cellulose, pretreated biomass were used and found better for enzyme production. After optimization of carbon and nitrogen sources, cultural conditions, feeding strategies, etc the cellulase enzyme production has been improved significantly.

Enzymes has been produced at 5 Lit scale reactors using optimized media and carbon sources. Large numbers of experiments were performed for fine tuning and repeatability testing. Some fermentor parameters (pH, temp., DO, amount of feed) were again optimized at this scale. This indigenously developed cellulase enzyme is cost effective and its performance was analyzed on different pretreated biomass (acid pretreated rice straw, wheat straw, sugar cane bagasse) for fermentable sugar production. The process has been up scaled up successfully using commercial grade chemicals in series of 250L and 5000 L reactors. The enzyme broth produced commercially in 5000 L reactors has shown excellent productivity and activity. The broth also has efficient hydrolytic activity comparable to commercial enzymes.

The indigenously produced enzyme broth as such (without concentration and stabilization) has been evaluated in the 1MT/Day pilot plant and the indigenous enzyme has shown comparable hydrolysis efficiency to the commercial enzyme for rice straw biomass. The indigenously developed cellulase enzyme is cost effective by about 30%. This is first attempt in India to develop large scale enzyme production process.

Scaleup facilities from 5 litre to 5000 L reactors

Stakeholders involved:	2nd generation ethanol manufacturers, oil companies
Financing Support:	Indian Oil Corporation Limited Department of Biotechnology, Government of India
Contribution to Sustainable Development Goals:	This technology shall provide sustainable and economical supply of enzymes which are the major opex cost element in biomass to ethanol conversion process based upon which globally as well as in India a large number of plants are being committed.
Contribution to GHG emission reduction in transports:	Ethanol blending in gasoline has high GHG reduction potential
Employment:	The enzyme production is an involved process that requires manpower both skilled for analytical monitoring and semiskilled for plant operation. Hence, employment potential is there.
Replicability and scale-up potential:	The process has been up scaled up successfully using commercial grade chemicals in series of 250L and 5000 L reactors. The enzyme broth produced commercially in 5000 L reactors has shown excellent productivity and activity. Therefore, this process carries high scale up potential
Success factors:	The Government of India has unveiled a new National Biofuel Policy (2018) that incentivises biofuel generation through multiple measures. Major steps include encouragement of biofuel generation from excess crop production and setting apart Rs 5000 crores viability gap funding (VGF) to establish second generation ethanol refineries. For providing specific fiscal incentives, the policy categorises biofuels into several groups: 1G (First Generation), 2G, 3G, and bio-CNG. This policy shall provide major boost in commercialising the technology.
Constraints:	Currently technology has been demonstrated at 5000 L scale only. Process validation being carried out for commercial viability.

Info provided by:	Dr S K Puri, Chief General Manager, Indian Oil R&D Centre, Faridabad
More information:	www.iocl.com

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Success Stories of Advanced Biofuels for Transport

PRAJ'S ADVANCED BIOREFINERY

Year of plant start-up:	2016
Location:	Pune, Maharashtra, India
Technology:	Praj's 2nd generation Biomass to Bioethanol technology ("enfinity") and biomethanation of stillage to biogas and renewable CNG
Plant capacity	1 million litres per annum (MLPA)
Operational experience achieved	Plant commissioned in 2016 December. Operational for 2 campaigns of 3 months each.
Total Capital Expenditure	--
Principle feedstocks:	Principle feedstock: Rice straw, sugar cane bagasse, wheat straw, corn cobs, corn stover, cotton stalk, saw dust.
Feedstock Capacity	more than 4000 MT[1]/Year (bone dry basis) Feedstock supply arranged through local farmers and biomass suppliers from different parts of India.
Products/markets:	Present: Fuel ethanol, Bio-CNG, Bio-fertilizer and CO2. In pipeline: Bio-chemicals (Xylitol)
Technology Readiness Level (TRL):	TRL 9 – actual system proven in operational environment

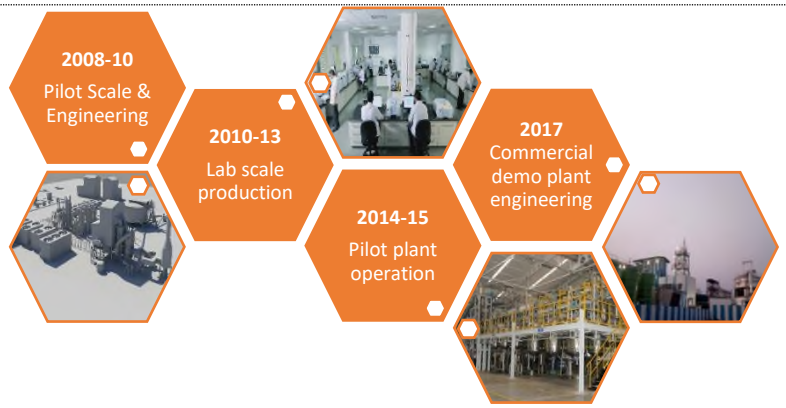
DESCRIPTION

From 1st generation to 2nd Generation ethanol technology, we thrive on challenges. We have over 750 references in 75 countries across the globe. Each of these plants carry our signature of technology innovation and integration, delivering lower water and energy footprint.

This knowledge helped us in developing the 2nd generation cellulosic ethanol technology "Enfinity".

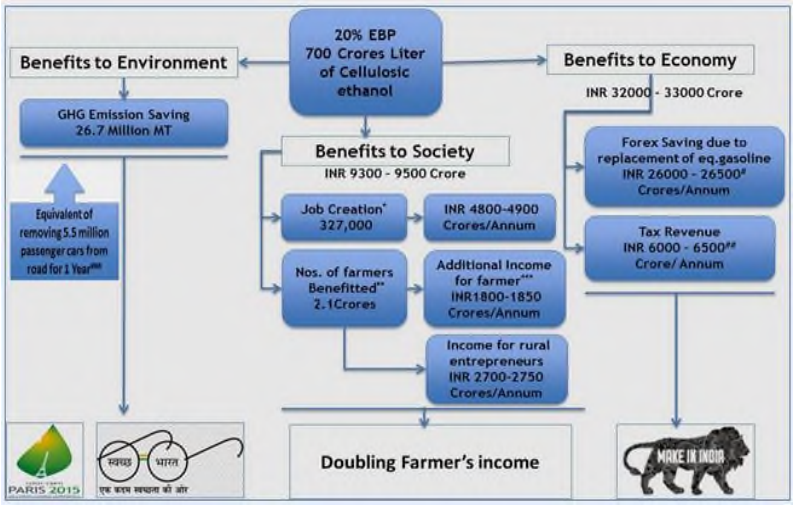
Praj's state of the art second generation ethanol pilot plant facility is operational since 2009. This facility has tested more than 450 MT of biomass such as corn cob, cane bagasse, corn stover, Empty fruit bunches (EFB), Rice straw, etc. Rigorous testing and 800,000 man-hours of technology development efforts enabled us to scale the "Enfinity" to 1 Mln litres per annum capacity.

[1] MT = Metric tons



Key milestones

Stakeholders involved:	Farmers and Village level entrepreneurs, Biomass suppliers, project developers, policymakers, Public sector units (IOCL, HPCL, BPCL MRPL); organizations, EPC and PMC (GoI- agencies)
Financing Support:	Invested 100% by PRAJ. The National Biofuel Policy of Government of India (GoI) supported the mission of 10% ethanol blending by 2022 and 20% by 2030 and procurement of cellulosic ethanol through Oil Marketing companies. There will be Viability Gap Funding from GoI to support commercial projects of 100 m^3/day capacity.
Contribution to Sustainable Development Goals:	**Promote sustainable agriculture :** Sustainability in agreeculture by using the agricultural crop residue to produce ethanol, which result into higher returns to farmers and resolve crop residue management issue. It also add fertility to soil by providing biofertilizer which is generated through process. **Ensure healthy lives and promote well-being for all at all ages :** Smoke produced due to burning of agricultural crop residue deteriorated the human health, by using residue in the process to produce bioethanol will avoid the burning of crop residue, resulting in improving air quality and human health. **Ensure sustainable consumption and production patterns :** It ensures the sustainable crop production and economical development of society. Crop residue generated is going to be consume by such projects. It assures crop production and its utilization pattern. Ethanol produced from such projects will also help to meet the demand of Ethanol Blending target (EBT) of the said state. **Take urgent action to combat climate change and its impacts**: Due to crop residue burning in the field air pollution has increased, by utilizing such biomass to produce bio ethanol and blending it in gasoline will reduce burning activity and will save climate. By adopting 20% EBP in India will save ~ 26 MMT GHG emission.

	Protect, restore and promote sustainable use of terrestrial ecosystems: Usage of crop residue in bioethanol production will lead to betterment of ecosystem by way of improving soil condition, restoring fertility by avoiding burning, by maintaining better and quality grain production, by blending ethanol in gasoline etc. **Ensure access to affordable, reliable, sustainable and modern energy for all:** Production of ethanol from crop residue and making it available for transport fuel ensures affordability reliability to society. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all, 
Contribution to European targets on GHG emission reduction in transports:	NA
Employment:	Nearly 3, 27,000 additional direct and indirect jobs will get created by adopting 20% ethanol blends in India.
Replicability and scale-up potential:	The PRAJ technology demonstration facility is now scalable to commercial scale.
Success factors:	National Biofuel Policies, commitment to reduce GHG emissions as per COP 21, improving farmers Income, create rural employment and reduce fossil fuel imports and forex saving.
Constraints:	Regulatory support mechanisms to support capital expenditure first few projects and premium for price products.

Pictures from the facility

Info provided by:	tusharpatil@praj.net
More information:	www.praj.net

ARTFuels IEA Bioenergy European Commission

Success Stories of Advanced Biofuels for Transport

RELIANCE CATALYTIC HYDROTHERMAL LIQUEFACTION

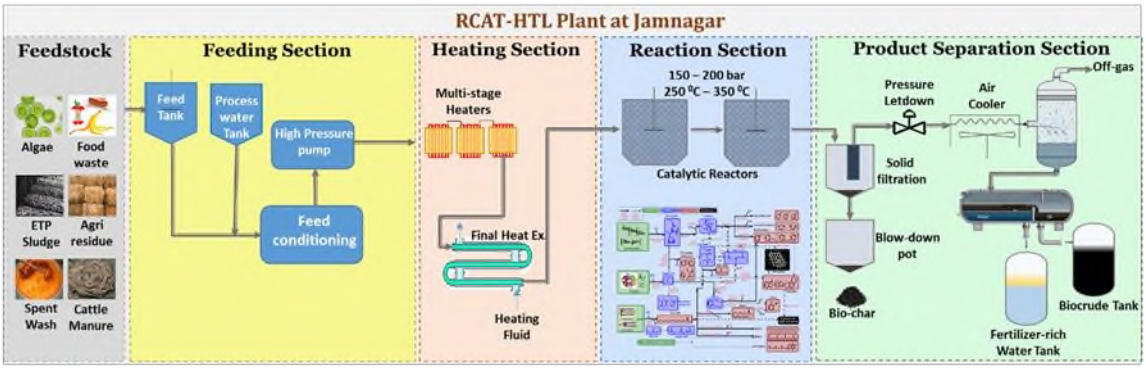
Year of plant start-up:	2016
Location:	Gagva, Jamnagar, India
Technology:	Reliance Catalytic Hydrothermal Liquefaction (RCAT-HTL)
Plant capacity	The plant has been upgraded for continuous run in 2018. Currently at 0.5 barrel per day of drop-in liquid biofuel.
Operational experience achieved	1100 hours
Total Capital Expenditure	USD 4.0 million
Principle feedstocks:	Algae, wet organic biomass, Bio-waste (Food waste, ETP Sludge, Agricultural Crop Residue etc.), ETP sludge, oily sludge from refinery and petrochemicals
Feedstock Capacity	2 ton per day (10-20% solids)
Products/markets:	Transport fuel
Technology Readiness Level (TRL):	TRL 8 for algae, food waste and ETP sludge

DESCRIPTION

Reliance Catalytic Hydrothermal liquefaction – 'RCAT-HTL', a catalytic thermochemical process developed by Reliance Industries Ltd. (RIL), converts biomass, biowaste and organic waste into energy-rich drop-in liquid biofuel and recovers fertilizer-rich water and biochar. This environmentally sustainable process overcomes the limitations of the existing technologies and offers a green solution to the hazard of wet waste and agro-residues disposal. RIL's RCAT-HTL is also more feed-flexible – it can handle both dry as well as wet bio-waste, organic waste, mixed waste by co-processing or independently.

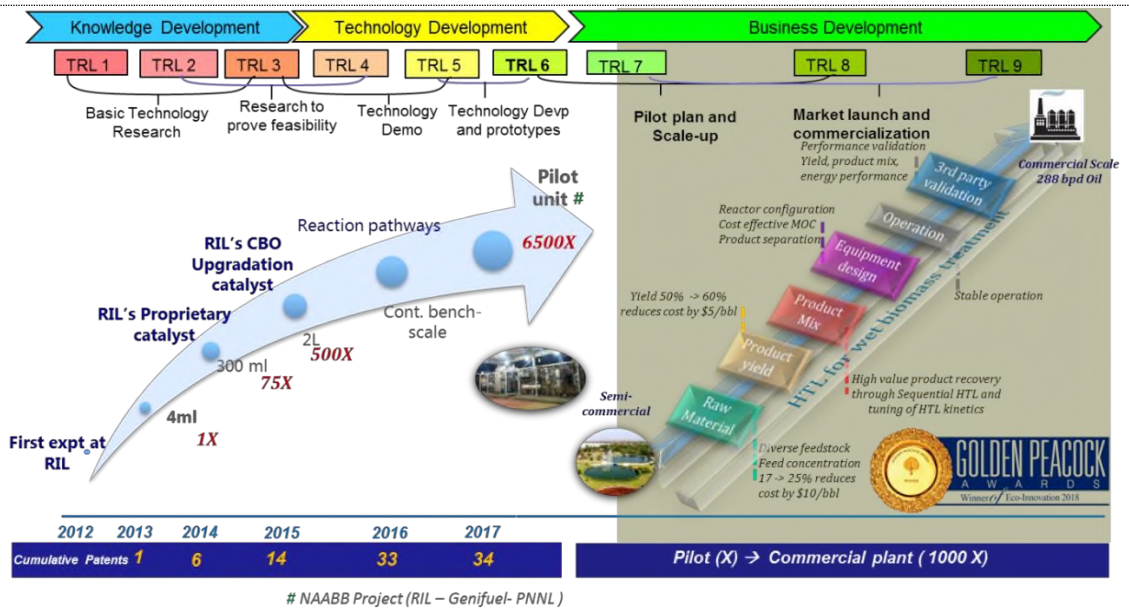
Research on RCAT-HTL process at RIL began as part of Algae to Oil (A2O) program in 2011, aimed to convert algae to biofuel. In due course, it has been realized that RCAT-HTL has a huge potential for processing not only algae but also various wet organic biomass and bio-waste to produce biofuel. Biggest advantage of RCAT-HTL over other thermo-chemical technologies is in case of wet waste. The process uses water in the wet waste as a reactant thereby avoiding the energy-intensive drying of wet biomass; and improving the overall energy recovery. By avoiding the drying, water which is otherwise lost is recovered along with the nutrients that are available in the wet feedstock.

Reliance's catalytic HTL (RCAT-HTL) process, not only improves the yield and quality of the energy-dense liquid biofuel but is also kinetically tunable to produce the desired bio-product mix, to suit the market demand. RIL has accomplished significant milestones in developing catalytic hydrothermal liquefaction within a short span. We have designed, engineered, commissioned and operated RCAT-HTL process at various scales in batch (Lab scale) and continuous (Bench and Pilot scale) mode of operation. With over 30 patents and concept to commissioning experience of running a pilot plant, RCAT-HTL is at an advanced Technology Readiness Level (TRL), towards commercialization of this climate friendly technology. Recently, Reliance received coveted 'Golden Peacock Eco-Innovation Award - 2018' for our RCAT-HTL technology. This coveted award is conferred by IOD (www.iodglobal.com)



Pilot plant of RCAT- HTL in operation at Jamnagar

Visit by Mr. Y.B. Ramakrishna, Chairman, Working Group on Biofuels (WGB), MoP&NG



NAABB Project (RIL – Genifuel- PNNL)

Stakeholders involved:	RIL manufacturing locations, Bulk food waste generators such as restaurants, malls, catering business, food processing industries, Urban municipalities, Farmers etc.
Financing Support:	The project is entirely financed by RIL
Contribution to Sustainable Development Goals:	Over 1.3 billion tons of food waste is generated per annum across the globe (UN FAO Report, 2011). India generates close to 68 Million tons of Municipal Solid Waste (MSW) and more than 190 million tons of agricultural crop residue. RCAT-HTL offers sustainable solution to the bio-waste disposal with resource recovery by converting these wastes to biocrude. RCAT-HTL strongly aligns with Government of India's Swachh Bharat mission to treat waste in sustainable manner and recovering resources. This will be RIL's significant contribution to Swachh Bharat mission. Life cycle assessment of RCAT- HTL shows exceptionally positive results. Offsetting fossil crude with renewable biocrude can achieve reduction in GHG emissions as much as 85%.
Contribution to European targets on GHG emission reduction in transports:	Disposing wastes at open dumps and landfill generates huge amounts of methane. Treating waste by RCAT-HTL reduces greenhouse gases and contributes to environmental benefit Reliance Industries has publicly declared its commitment towards reduction of greenhouse gases intensity of the energy mix by strengthening actions and investments in the areas of carbon capture and storage, renewable energy, and low GHG research and development. RIL's Commitment has been recaptured in RIL's sustainability Report 2015-16, where, it identifies reduction of GHG emissions intensity by increased use of clean energy as one of the primary targets.

	For every barrel of oil that RCAT- HTL produces, it saves about 0.5 tons CO_2e in GHG emissions by offsetting fossil crude with greener biofuel from waste. Consequently, treating just 10-15% of food waste available in India can help RIL achieve 50% reduction in its GHG emissions.
Employment:	Realizing the full potential of RCAT-HTL technology and by establishing several modular plants more than 50000 jobs can be generated
Replicability and scale-up potential:	RCAT-HTL plants are proposed to be of modular design. Capturing just 10% of untreated market of Food processing waste and Agri-residue will require 600 such modular plants with potential assets value of over $12 billion, and estimated to generate annual profits of $4-5 billion
Success factors:	RCAT-HTL is a sustainable technology that not only utilizes moisture present in the wet waste as reaction medium but also recovers clean water. With its rapid conversion capability, RCAT-HTL converts wet bio-waste to biocrude in few minutes. It is a very economical process with a short payback period. RIL's proprietary 3rd Gen catalyst provides higher biocrude yield and carbon recovery compared to conventional technologies. By tuning RCAT-HTL kinetics, a product mix of biofuel and bio-products can be achieved. In addition to these, Concept to Commissioning expertise developed by RIL will be of immense value in scaling up RCAT- HTL to a successful commercial technology
Constraints:	RIL has built and operated First-of-its kind RCAT-HTL plant with full-fledged automated operation. World is not yet conversant with RCAT-HTL Technology as it has not been listed in waste treatment/conversion technologies hierarchy. Additional efforts are required to make stakeholders acquainted with RCAT-HTL. Drop in fuels pricing is not incorporated in Biofuel policy. This necessitates more clarity on pricing from policy makers and government
Info provided by:	Ramesh Bhujade, Vice President-R&D, Reliance Industries Limited

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Success Stories of Advanced Biofuels for Transport

THE GOBIGAS PROJECT

Year of plant start-up:	2013
Location:	Sweden, Gothenburg
Technology:	Biomethane production via gasification of biomass
Plant capacity	20 MW biomethane
Operational experience achieved	More than 12 000 hours of gasification and 69 GWh of biomethane delivered to the natural gas grid until the plant was conserved in 2018
Total Capital Expenditure	1561 MSEK (150 MEUR)
Principle feedstocks:	Domestic feedstock was used including: wood pellets, wood chips based on residues from saw mills and logs of low quality, shredded bark, and recovered wood of class A1 (only test period)
Feedstock Capacity	30-35 MW_{th} based on lower heating value of the dry fuel.
Products/markets:	Vehicle gas (primary market) or biomethane for combustion (secondary market) and co-production of 5 MW district heating as a by-product.
Technology Readiness Level (TRL):	TRL 8

DESCRIPTION

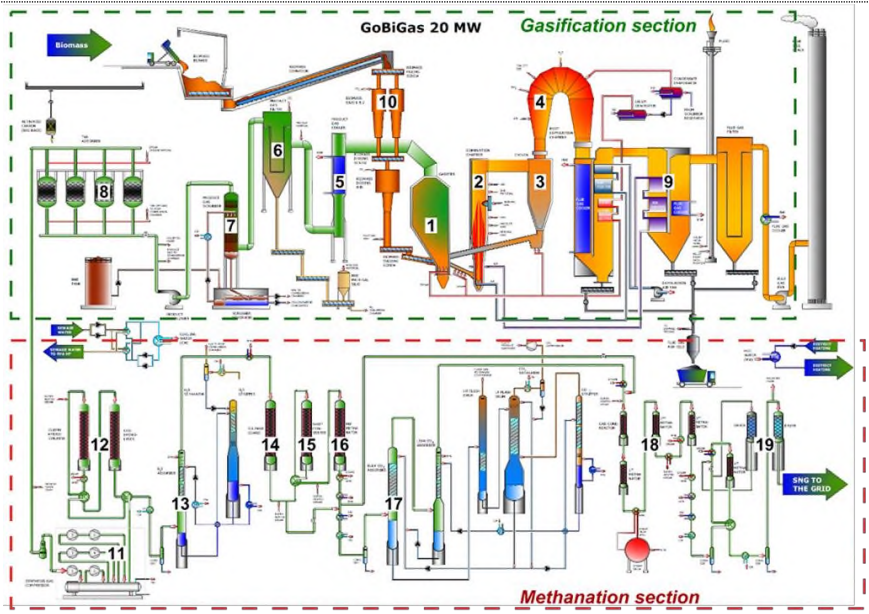
In the GoBiGas project, a first of its kind industrial scale biorefinery was built with the purpose to demonstrate and enable commercial production of biomethane from woody biomass *via* gasification. This report summarizes the experience, lessons learnt and conclusions from the pre-study, construction and operation of the GoBiGas plant with the aim of support development of commercial production plants of advanced biofuels.

The GoBiGas plant, with a production capacity of 20 MW biomethane delivered gas to the natural gas grid in Sweden and is located in Gothenburg, Sweden. The plant was built and operated by Göteborg Energi AB, with financial support of the Swedish Energy Agency. The project was initiated in 2005 as pre-project studies with the goal of having 120 MW bio-methane in production in 2020. The construction of the plant described here was started in 2010 and the commissioning of the plant was initiated in 2013. The purpose was to build a prototype unit to de-risk the scale-up to the full intended capacity. The prototype plant project was therefore focused on

how the technology would be commercialized through construction of a similar stand-alone plant with a production capacity of 100 MW or more and was not in itself an economic venture.

In parallel, work was initiated on the full-scale project that received a NER 300 grant support. However, due to market changes and general uncertainties on the development in biofuels in transport, the second project was stopped in 2016, and the motives to operate the costlier prototype plant was reduced such that the plant was decommissioned in 2018 and is now maintained in a conserved state. With more than 12,000 hours of operation the GoBiGas project (of which several uninterrupted operating periods of up to 1900 hours in 2016 to 2018, following a period of extended commissioning and initial operation involving experience build-up, technical and operational improvements) has demonstrated how the quality of the gas produced from a biomass gasifier can be controlled using a range of different feedstock including bark, wood pellets, wood chips and recovered wood of class A1. Results show that a biomass to grid-quality biomethane can be produced with this technology at an efficiency of up to 70% (based on the lower heating value of the dry ash free fuel) is possible and at a reduction factor for greenhouse gas emissions of over 80%. To reach such a high efficiency it is required to dry the feedstock which also benefits the stability of the process. Results also show that the gas quality fulfils the European standard for injection into the natural gas grid, hence showing that large scale production of biomethane delivered by injection to the natural gas grid is possible.

The project has demonstrated that the technology can be applied at a commercial scale with high performance using known technology. Future development should involve improved compatibility between different process steps as well improved economic feasibility of the production. With current process setup and using forest residues as feedstock, the production cost for at plant with 200 MW production capacity, estimated based on the economic data from GoBiGas, corresponds to about 600 SEK/MWh (approx. 60 €/MWh in 2017).

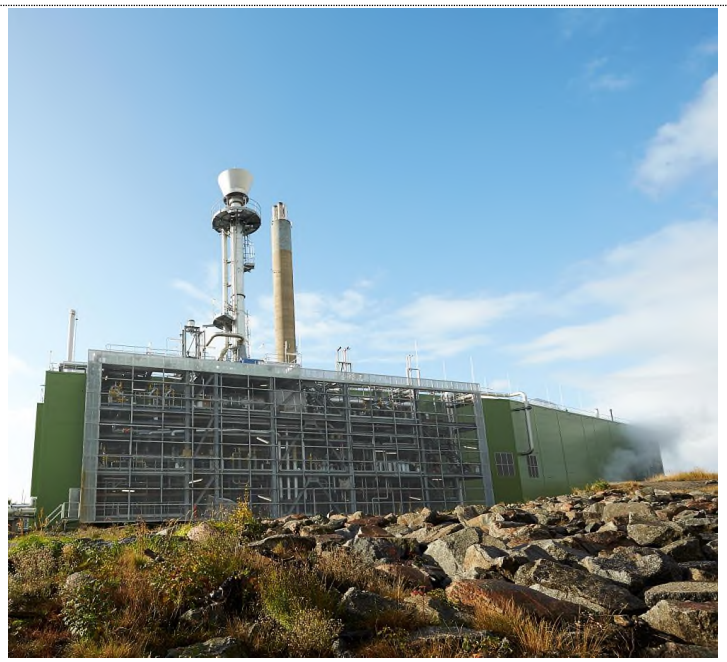


1. Gasifier
2. Combustor
3. Cyclone
4. Post Combustion Chamber
5. Product Gas Cooler
6. Product Gas Filter
7. RME-Scrubber
8. Adsorbent beds
9. Flue Gas Train
10. Lock hoppers
11. Compressor
12. Olefin hydrogenatio
13. H_2S Scrubber
14. Guard bed
15. Water Gas Shift Reactor
16. Pre-Methanation
17. CO_2 Scrubber
18. Methanation
19. Dryers

A Schematic overview of the GoBiGas-plant including a list of the major process steps

Stakeholders involved:	Göteborg Energi AB (local energy company owned by the city of Gothenburg) and the Swedish Energy Agency. Cooperation with the Swedish Gasification Centre, Chalmers University of Technology and Valmet AB (manufacturer of the gasifier) in the evaluation of the technology.
Financing Support:	222 MSEK (20 MEUR) from the Swedish Energy Agency. A NER 300 support of 59 million Euro was obtained for the second phase, which was however not realized
Contribution to Sustainable Development Goals:	SDG 7: Local lignocellulosic resources and wastes can be used to provide renewable biomethane for use in transport or as a fuel. SDG 8: The use of biomass for energy purposes generates job creation along a value chain stretching from urban to rural areas. SDG11: The production of biomethane reduces the carbon footprint of the city of Gothenburg, while the use of renewable CNG in cities reduces diesel tail-pipe emissions. SDG12: Renewable biomethane produced from lignocellulosic biomass or wastes can substitute fossil natural gas in a sustainable way. SDG 13: Greenhouse gas emission reduction factor > 80%. Scale-up and further improvements would make a higher figure possible. SDG 15: Swedish and EU policy safeguards the sustainable use of forest resources for energy purposes.
Contribution to European targets on GHG emission reduction in transports:	The project demonstrates that renewable biomethane can be product at above 80 % GHG reduction for use in e.g. transport. Follow-up projects at larger scale and in a variety of locations can contribute to reducing GHG emissions by substituting fossil gas at larger scale.
Employment:	To operate and maintain the plant, incl. management approx. 30 FTE has been required. During the engineering and construction phase, a high number of FTE has gone into the work temporarily.
Replicability and scale-up potential:	The focus of the project was to scale-up to enable commercial production at a capacity of 100 MW or larger in Gothenburg. The replication potential elsewhere is significant.
Success factors:	That an off-take market for biomethane exists that provides a premium value for this product relative to fossil natural gas.

Constraints:	The investment recovery period for project of this nature is long, 10-15 years. Policy interventions in support of such technologies are typically exceeding 10 years and are also changed within such periods, which in addition to market fluctuations does not give investors sufficient foresight and introduces risks.



Picture of the GoBiGas facility

Info provided by:	Anton Larssson, Göteborg Energi AB
More information:	https://www.goteborgenergi.se/Om_oss/Vad_vi_gor/Forskning___Utveckling/Gobigas https://onlinelibrary.wiley.com/doi/abs/10.1002/ese3.188

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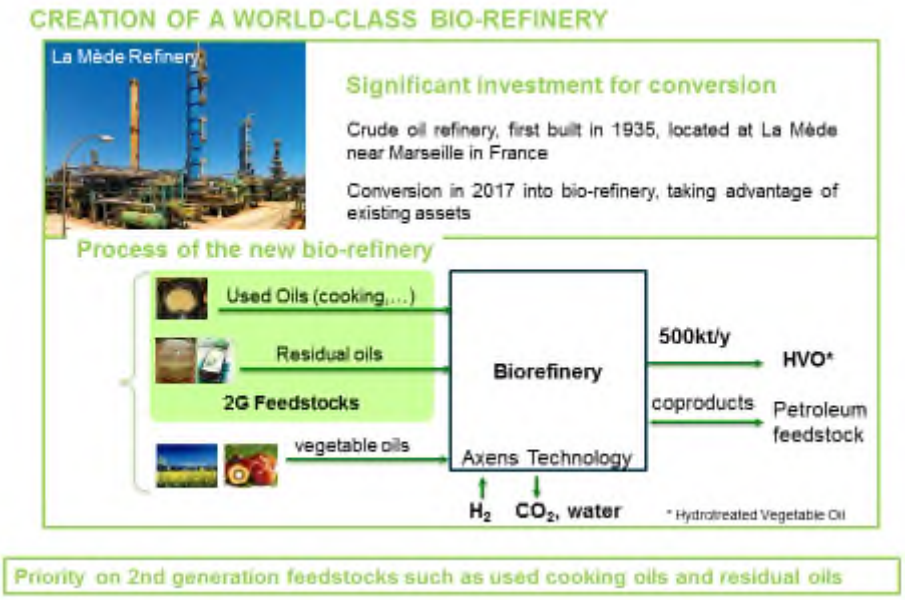
Success Stories of Advanced Biofuels for Transport

HVO REFINERY LA MÈDE

Year of plant start-up:	2018
Location:	La Mède, France
Technology:	Lipids hydrogenation process
Plant capacity	500 kT/y (HVO biodiesel)
Operational experience achieved	Not started-up yet
Total Capital Expenditure	275 M Euros
Principle feedstocks:	Lipids: mix of Vegetable Oils and residual lipids
Feedstock Capacity	650 kT/y based on a mix of Vegetable Oils and residual lipids, and for HVO biodiesel production
Products/markets:	Transport fuels
Technology Readiness Level (TRL):	between TRL 8 and 9 : new Axens process, first-ever to be used at industrial level TRL 8 – system complete and qualified TRL 9 – actual system proven in operational environment

DESCRIPTION

Retrofit of a former 150,000 bpd (barrels per day) crude oil refinery into a bio-refinery, aiming at supplying the regulated renewable transport fuel European market in drop-in HVO biodiesel and biojet, in a context where 1) FAME biodiesel faces incorporation rates limitations (ICE technology), 2) biojet must be drop-in and no first-generation biojet exists, the incorporation rates must increase to 10 % in energy content by 2020 (RED), 14 % by 2030 (RED II).



Overview of the process

Stakeholders involved:	Lipids producers (Ag and Waste industries)
Financing Support:	Primary support comes from the European Renewable Directive mandating incorporation of renewable energy in transport, mostly in the format of biofuels
Contribution to Sustainable Development Goals:	SDG 13: GHG emission reduction in transport SDG 7: reliable, sustainable, affordable energy for all SDG 8 and 15: local development
Contribution to European targets on GHG emission reduction in transports:	HVO biodiesel and HEFA bio jet will help attain RED and RED II objectives of GHG emission reduction in transport
Employment:	250 local jobs have been maintained on the industrial site by the retrofit
Replicability and scale-up potential:	First of a kind for the Axens lipid hydrogenation process, allowing further sales of this mature technology process across the world
Success factors:	Renewable regulations mandating the use of biofuels to reduce the transport carbon footprint must be in place Axens process operability and viability
Constraints:	Sustainable lipids availability

Info provided by:	Philippe Marchand
More information:	www.total.com

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Success Stories of Advanced Biofuels for Transport

SUNLIQUID LIGNOCELLULOSIC ETHANOL PLANT IN ROMANIA

Year of plant start-up:	2020
Location:	Podari, Dolj County (near Craiova), Romania
Technology:	Conversion of agricultural residues to cellulosic ethanol via enzymatic hydrolysis and fermentation
Plant capacity	50 kt/a of cellulosic ethanol
Operational experience achieved	Not yet in operation
Total Capital Expenditure	Over 100 M Euros
Principle feedstocks:	Domestically available agricultural residues like wheat and other cereal straw
Feedstock Capacity	Approx. 250,000 metric tons per year
Products/markets:	Cellulosic ethanol as transport fuel
Technology Readiness Level (TRL):	TRL 8 – sunliquid technology has been proven in pre-commercial plant in Straubing, Germany for over 6 years in operational environment

DESCRIPTION

After 6 years of operating Clariant's pre-commercial sunliquid® plant in Straubing, Germany and thorough process demonstration, in December 2017 Clariant announced the approval by the Board of Directors to invest in a new full-scale commercial plant for the production of cellulosic ethanol from agricultural residues using its sunliquid® technology in Romania.

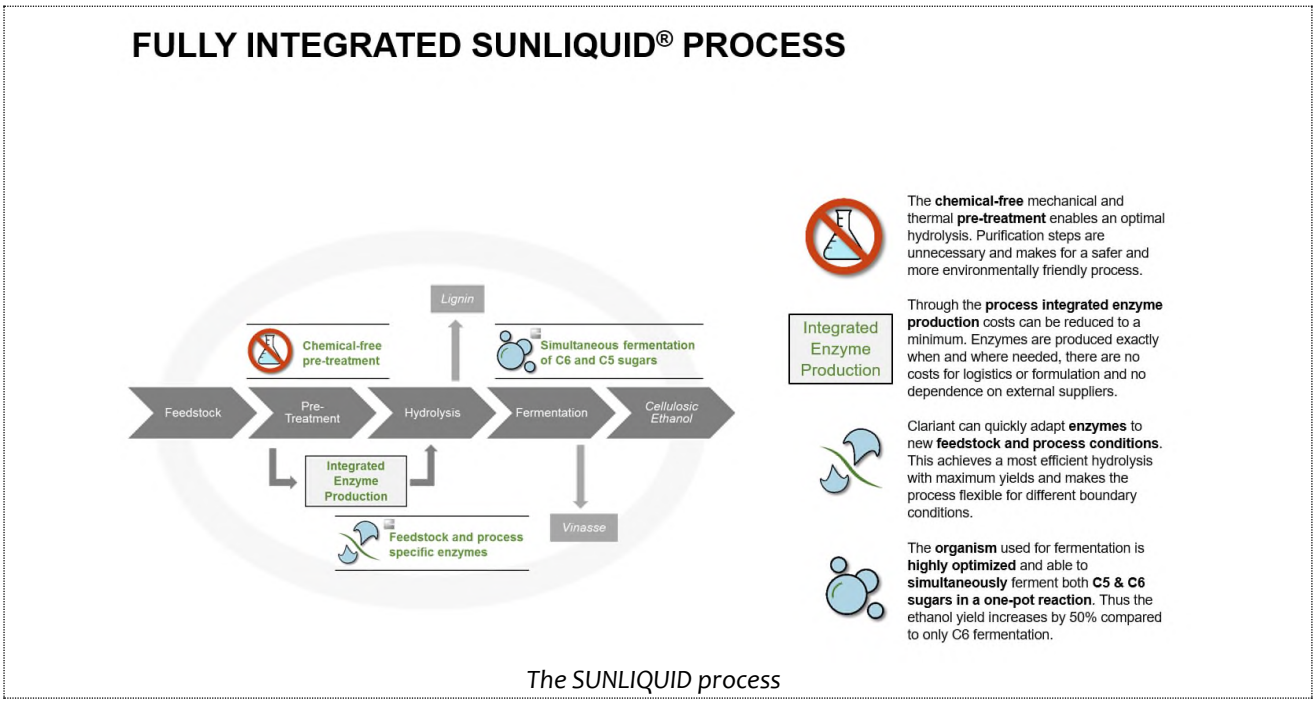
The new plant, with an annual production capacity of 50,000 tons, will be built in the southwestern part of Romania in the region of Craiova. The facility will be a flagship site, confirming competitiveness and sustainability of the sunliquid® technology at commercial scale thus supporting Clariant's sunliquid® licensing business strategy.

At full capacity, the new plant will process approximately 250,000 tons of wheat straw and other cereal straw annually, which will be sourced from local farmers. Co-products from the process will be used for the generation of renewable energy with the goal of making the plant independent from fossil energy sources. Therefore, the

resulting cellulosic ethanol is an almost carbon neutral advanced biofuel.

Construction of the plant will provide a whole range of benefits for the surrounding region of Craiova. It will allow local farmers to industrially market straw for the first time, which was previously practically unutilized agricultural residue.

During the construction phase of the new plant, several hundred construction workers will be employed from locally based companies wherever possible. After completion, the plant is expected to provide around 300 permanent jobs in supporting industries serving the site, and in the transportation and storage of the feedstock. The plant itself will employ a workforce of between 100 and 120. Clariant plans to recruit its workforce locally and provide training both in its own laboratories in Planegg near Munich and at the pre-commercial sunliquid® plant in Straubing, Bavaria.



The SUNLIQUID process

The plant in Romania in a nutshell

Stakeholders involved:	Clariant, EC FP7, BBI JU, farmers, local service providers
Financing Support:	EC FP7, BBI JU
Contribution to Sustainable Development Goals:	Sunliquid cellulosic ethanol GHG savings potential of 95% compared to fossil fuels, sustainable and domestic source of renewable energy in Romania, example of circular economy
Contribution to European targets on GHG emission reduction in transports:	Sunliquid cellulosic ethanol GHG savings potential of up to 95% compared to fossil fuels
Employment:	100-120 direct jobs associated to operation of plant 300 indirect jobs for supporting businesses like agriculture and logistics sector 800 jobs during construction phase
Replicability and scale-up potential:	Based on cellulosic feedstock availability in the EU
Success factors:	Feedstock availability, legislative support, proven technology, favourable infrastructure
Constraints:	Uncertainty in legislation and government support

Info provided by:	Paolo Corvo, Head of Sales & Marketing Biofuels & Derivatives, Clariant
More information:	www.sunliquid.com https://www.sunliquid-project-fp7.eu https://www.biofuelsdigest.com/bdigest/2018/09/16/looking-deeper-into-clariant-cellulosic-technology-part-1-of-2-a-visit-to-straubing-germany-and-an-integrated-pilot-plant/

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Success Stories of Advanced Biofuels for Transport

ALL-GAS: ALGAE BIOFUEL FOR VEHICLES

Year of plant start-up:	2014
Location:	Spain, Andalucia, Chiclana de la Frontera (Cadiz)
Technology:	Microalgae biofuel production for vehicles based on wastewater nutrients and biomethane upgrading to CNG
Plant capacity	2 Ha of algae cultures and biofuel production above 26,000 kg CH_4/year (enough to run 35 vehicles x 15 000 km/yr)
Operational experience achieved	Above 35,000h (non-stop operation since 2014 on various scales)
Total Capital Expenditure	ca. 4 M€
Principal feedstocks:	Nutrients contained in wastewater which are transformed in microalgae biomass
Feedstock Capacity	2000 m3/ d of wastewater that transform to between 100 to 140 ton biomass per hectare and year, or a total of 250 t/yr on the 2 ha.
Products/markets:	Main product: Compressed biomethane for fleet vehicles (> 90 % CH_4, meeting Automotive fuel specifications (EN 16723 – Part 2) . Co-products: 1. Residual biomass after anaerobic digestion rich in aminoacids, nitrogen and phosphorus (biofertilizer) 2. Reuse water (meeting standards of COMMISSION DIRECTIVE 98/15/EC of 27 February 1998 amending Council Directive 91/271/EEC with respect to N + P)
Technology Readiness Level (TRL):	TRL 9 – actual system proven in operational environment

DESCRIPTION

Thanks to EU Support since 2011, the FP7 All-gas project represents a true revolution in the circular economy, establishing a new paradigm by producing algae biofuel from wastewater with a positive energy balance, fuelling up to 20 vehicles per ha, and allowing sustainable water reuse as a by-product.

The project was born with the objective of demonstrating, on an industrial scale, the production of algae biofuel for vehicles. In addition, it uses urban wastewater as a source of nutrients for the culture and presents a circular economy model in which algae treat the wastewater without external energy supply, through photosynthesis.

In December 2017, the industrial plant in Chiclana (Spain) was inaugurated by EU Commissioner for Energy, Miguel Arias Cañete. An algae culture area of more than 2 hectares came into service making this plant the world's largest facility for the generation of biofuels from microalgae.

Currently, the project is capable of moving up to 40 cars with the biofuel obtained, with the effluents of 10,000 inhabitants (2000 m3/d). Compared with ordinary biofuels, such as bioethanol from sugar or biodiesel from palm-oil, All-gas produces 4 times more energy per hectare, generating at the same time reuse water - without the need to use agricultural land or fertile soil, freshwater or artificial fertilizer.

This technology allows to convert the wastewater from any small or medium-sized town with enough available land (1 football field for 5000 people) and sunlight into a sustainable biofuel. At the same time, the electrical energy needed to clean wastewater with conventional technology is saved.

Fleet vehicles and algae ponds of the FP 7 All-gas project in Chiclana(Cadiz)

Stakeholders involved:	EU Commission – DG ENER Chiclana Municipality and its Environmental Management Company, Chiclana Natural FCC Aqualia as the local operator or Wastewater Treatment Permitting Agencies (National Coastal Management Administration, Fisheries, Water and Environmental Depts. Of the Andalucia Regional Government) Universities of Cadiz and Almeria as supporting Research and Scientific Community
Financing Support:	EU FP 7 grant, co-financing by FCC Aqualia and Chiclana Natural as well as the consortium partners (BDI Bioenergy/AU, Fraunhofer-Umsicht/DE, Hygear/NL and University of Southampton/UK).
Contribution to Sustainable Development Goals:	**GHG emission reduction (SDG13):** Wastewater energy requirement is reduced 5-fold in comparison to conventional methods (from 0,5 kWh el/m3 to < 0,1 kWh/m3) **Sustainable consumption and production patterns (SDG 12):** Third generation biofuels can be produced onsite from waste. **Reliable, sustainable and modern energy for all (SDG7):** biomethane (EN 16723 – Part 2) for fleet vehicles can be produced with recycled nutrients contained in the wastewater, without need for freshwater, arable land or artificial fertilizers. **Ensure availability and sustainable management of water and sanitation for all (SDG6):** a new paradigm of wastewater treatment is developed, where a positive energy balance is achieved - biofuel is produced and electricity needs are minimal.
Contribution to European targets on GHG emission reduction in transports:	To achieve serious reductions in GHG emissions over the coming decades involves a combination of three broad changes: 1. Transforming the economy from running on carbon-dioxide-emitting fossil fuels to rely on renewable fuels; 2. Achieving substantial improvements in energy efficiency; 3. Implementing the large-scale capture and storage of carbon dioxide emissions. This project addresses all three of these targets: 1. Producing biofuels from algae, based on renewable, non-fossil CO_2 and sunlight 2. Harvesting resources such as wastewater and agricultural residues as nutrients and for energy generation to achieve a self-sufficient biofuel production system

	3. The net balance of CO_2 generated in this project is positive, as it is based almost entirely on renewable sources. The aim of the project is not only the production of quality biofuel from algae but also taking in account a sustainability approach: biofuel feedstock is grown with environmentally safe and biodiversity-friendly practices, sequestering carbon from the biomass to give a positive carbon balance of the overall system. This project fulfils the main European policy goals: 1. Reducing greenhouse gas emissions 2. Boosting the decarbonisation of transport fuels 3. Diversifying fuel supply sources and developing long term replacements for fossil oil 4. Diversifying income and employment in rural areas
Employment:	During lifespan of the project more than 10 direct jobs were created among researchers and engineers in process development. In addition, during the construction and implementation of the infrastructure, around 15 to 20 indirect jobs were created among builders and suppliers. In the long run through replication, the municipalities that implement the new solution will employ personnel in a new activity of biofuel production and distribution
Replicability and scale-up potential:	Replicability of FP project is very high since it needs mainly wastewater and non-arable land for its application. The land requirements of the process (kg CH_4/ha year) will depend on the climatological conditions, in the Mediterranean region an algae harvest around 100 t / ha is possible, yielding up to 15 000 kg Ch_4/yr.
Success factors:	1. Need for wastewater treatment: extension, upgrading or replacement of existing facilities - or waste nutrients from manure and animal farming 2. Available Land 3. Fleet of municipal cars to be converted to CNG, or easy access to gas network with L quality.
Constraints:	1. Climatic conditions affect the performance of the process 2. Land availability and nutrient supply (wastewater, manure) 3. Permits related to the operation of CNG facilities

Schematic Performance of Algae biofuel production

Info provided by:	Zouhayr Arbib, Zouhayr.arbib@fcc.es
More information:	http://www.all-gas.eu/en/ https://www.youtube.com/watch?v=4ZSjeXj0O88 https://www.youtube.com/watch?v=9a5p4crkxq4

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Success Stories of Advanced Biofuels for Transport

BFSJ: PRODUCTION OF FULLY SYNTHETIC PARAFFINIC JET FUEL FROM WOOD AND OTHER BIOMASS

Year of plant start-up:	Under construction
Location:	Sweden
Technology:	Hydrolysis of wood biomass to alcohols followed by chemical synthesis to jet fuel
Plant capacity	10,000 t/y
Operational experience achieved	N/A - not yet in operation
Total Capital Expenditure	Estimated € 44,000,000
Principle feedstocks:	Wood waste; domestic
Feedstock Capacity	40,000 t/y wood waste
Products/markets:	Fuel for aviation, road transport, heavy duty machinery
Technology Readiness Level (TRL):	TRL 8

DESCRIPTION

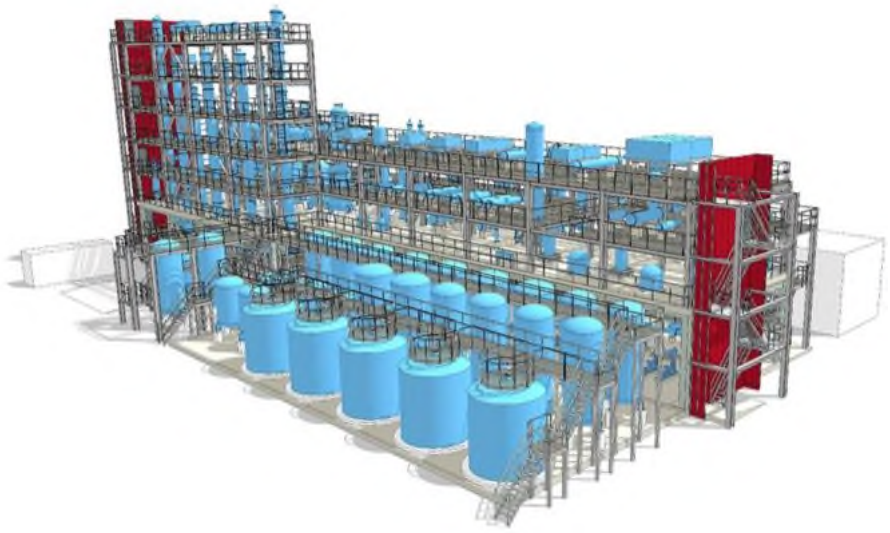
The BFSJ project uses the Alcohol To Jet (ATJ) pathway, as an alternative to the technologies available today, for the production of drop-in aviation fuels. The alcohols are produced from wood waste and other biomass. Such drop-in aviation fuels can be a 100 % replacement for standard aviation fuel. Funding for the project is provided under the EU FP7 programme.

A pre-commercial industrial scale plant is being constructed. The plant uses Swedish Biofuels technology to convert biomass to aviation fuel via alcohols. The capacity of the plant is to be 10,000 tonnes per year, of which half is aviation fuel with the rest being ground transportation fuels. The aviation fuel produced will be compatible, without blending, with in-service and envisaged jet engines for both civil and military applications. It will consume a variety of sustainable raw materials, focusing on wood residues. The ground transportation fuels, both gasoline and diesel varieties, will be drop-in compatible with existing fuels.

During the course of the project, it became clear that production technology should be adapted to be more flexible, so that it could be built either as a standalone facility, the original concept, or as a "bolt-on" facility taking

output from existing alcohol production plants as an intermediate product. The technology has been successfully modified to account for such a possibility. This has the added benefit of increasing the replicability and scale-up potential of the technology.

Currently the project is in the phase of site selection.



Demonstration plant

Stakeholders involved:	Large parts of the biomass to aviation fuel supply chain are represented by the BFSJ consortium members: forestry by SCA, end user by Lufthansa, producer by Swedish Biofuels, market developer by SkyNRG, equipment manufacturer by Remeksi Keskus, analysis by E4Tech and policymakers by the Institute of European Studies at the University of Brussels.
Financing Support:	Financing support has been given by the European Commission – FP7 Programme: BFSJ 612763.
Contribution to Sustainable Development Goals:	SDG13: Direct action to reduce carbon dioxide emissions by converting aviation fuel use to fossil free fuel. SDG12: Assist in rendering the rapidly expanding global air travel sector sustainable through the use of sustainable fossil free fuel. SDG7: Increases access to liquid fuels for those countries without their own supply of fuel. SDG15: Increase the productivity of land through the use of sustainable wood waste as raw material for the production of jet fuel. SDG8: Promotes regional development for the husbandry of forests and regional production of aviation fuel.
Contribution to European targets on GHG emission	The process converting wood waste to fuel cuts carbon dioxide emissions from the use of the fuel by 65 % or more. Greater emissions savings can be achieved

reduction in transports:	by using renewable sources of electricity and diesel fuel in the production process and logistics.
Employment:	20 jobs per processing plant More jobs for forest husbandry and logistics in direct proportion to the quantity
Replicability and scale-up potential:	The technology uses standard chemical engineering processing equipment and can be replicated and scaled as desired.
Success factors:	Successful replication depends on the will to reduce carbon dioxide emissions, replacing fossil aviation fuel with fossil free alternative. Typically, this can take the form of a mandate for renewable fuel in transport together with appropriate targets. Given the lower cost of fossil jet fuel compared to bio jet, some price support is required.
Constraints:	The usual showstopper for the majority of alternative fuel technologies is availability of the corresponding sustainable biomass. However, the technology developed by Swedish Biofuels expects to overcome this problem as, in principle, any locally grown and waste biomass can be used as a feedstock to the process.

Info provided by:	Professor Angelica Hull
More information:	

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Success Stories of Advanced Biofuels for Transport

FAST PYROLYSIS BIO-OIL PRODUCTION PLANT EMPYRO

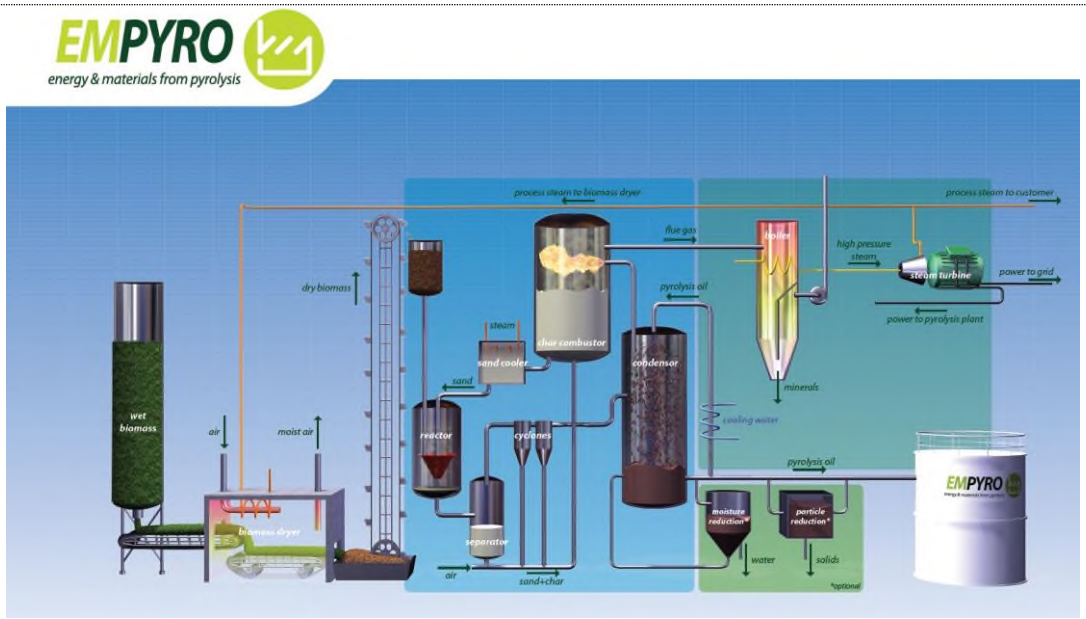
Year of plant start-up:	2015
Location:	Netherlands
Technology:	Fast Pyrolysis
Plant capacity	24.000 tons/year of FPBO (Fast Pyrolysis Bio-Oil)
Operational experience achieved	Since start-up over 30.5 million litres (36 kton) of FPBO have been produced as of mid-2018. Currently in operation 24/7 and producing at design capacity. All FPBO that was produced has been used by our customer (to replace natural gas).
Total Capital Expenditure	25 million EUR
Principle feedstocks:	Wood residue (from local Dutch suppliers). Other cellulosic biomass types under investigation.
Feedstock Capacity	36.000 tons/year (dry matter)
Products/markets:	Main use currently: Replacing natural gas as heating fuel to produce high-temperature steam in the boiler of an industrial client. Side use: FPBO produced at Empyro was provided to researchers in over 20 countries so far. Their research ranges from the production of fungible biofuels for automotive and aviation to bio-based chemicals. In the pipeline: • Production of renewable transport fuels from FPBO both via the co-refining route (this will be done with the FPBO from a new plant under construction for Pyrocell in Sweden, starting in 2021), as well as via the standalone upgrading route by hydrodeoxygenation. • Use of FPBO as a renewable substitute for fossil-based chemicals such as bitumen, phenols and creosote in the process industry. By-products: Steam (6.5 MW net) and power (0.5 MW net) bringing the overall efficiency to 85-90%.
Technology Readiness Level (TRL):	TRL 9

DESCRIPTION

The commercial production of fast pyrolysis bio-oil started at the opening of Empyro in May 2015. Since then (by mid-2018) more than 30 million litres (36 kton) of FPBO has been produced and delivered to our client Friesland Campina, who applied all the delivered FPBO in their steam boiler to replace natural gas. The excess energy that the Empyro plant produces has all been sold to AkzoNobel in the form of steam and to the grid in the form of power.

The history of Empyro starts in the late eighties at BTG Biomass Technology Group, when the concept of fast pyrolysis with a rotating cone reactor was invented. Since then BTG worked on the further development and scale-up of this technology and finally in 2008 BTG Bioliquids was founded as an independent company to commercialise the technology. A year later the separate company Empyro was founded with the aim of building and operating the first commercial fast pyrolysis plant in the Netherlands. It took five years to get everything ready for construction, including financial closure, biomass and FPBO delivery contracts, permits, detailed engineering, etc. Then in 2014 the construction started, resulting in start-up of the plant in 2015, in time and on budget. The skid-based modular construction approach by Zeton made it possible to assemble the plant on site in only eight days. After a ramp-up period in the first couple of years ('teething troubles') Empyro is now producing at its design capacity.

In January 2019 Empyro was acquired by Twence, a local waste processing company, which further demonstrates that the plant operates successfully. In April and July of 2019, two plants similar to Empyro (same size) were sold to clients in Finland (GFN) and Sweden (Pyrocell), respectively, showing the excellent replicability of the concept. Both plants are currently under construction. The plant in Finland is scheduled for start-up in 2020, the plant in Sweden in 2021. FPBO produced by Pyrocell will be co-processed by Preem in its refinery to produce advanced biofuels.



Process flow scheme showing Empyro's fast pyrolysis process using our modified rotating cone technology.

Stakeholders involved:	FrieslandCampina, AkzoNobel, BTG, Zeton, European project partners, Twence, TechnipFMC.
Financing Support:	To demonstrate biomass pyrolysis technology on commercial scale the Empyro project was financially supported by the European Commission under the Seventh Framework Programme (Grant Agreement 239357), by the Dutch government through the cross-sectoral programme Biobased Economy of the topsectors Energy and Chemistry, and by the Province of Overijssel via the Overijssel Energy Fund.
Contribution to Sustainable Development Goals:	Empyro contributes to multiple sustainable development goals. Most notably to SDG13 on climate change, as it results in a GHG reduction >90% across the entire value chain. By using FPBO the Borculo site of FrieslandCampina (FC) saves 10 million m3 of natural gas per year and reduced its GHG emissions by 15%. The fact that our biomass is sustainably sourced ('Better Biomass' certification) means that this fuel and the low carbon footprint products of FC support the SDGs 12 and 15 on sustainable consumption and production and on sustainable use of terrestrial ecosystems. BTG Bioliquids works hard to make this sustainable resource available for all (SDG 7), by supporting e.g. the development of residential FPBO boilers, as well as by developing FPBO-based advanced biofuels. Lastly the close cooperation between BTG, BTG Bioliquids, FC, AkzoNobel and Zeton in the east of the Netherlands pushed the development of the region (SDG 8), as was recognized by the local government in their support for Empyro.
Contribution to European targets on GHG emission reduction in transports:	Advanced biofuels are made from sustainable biomass residues and offer GHG reduction of over 60% compared to fossil fuels. Large volumes of advanced biofuels can be made from FPBO by direct upgrading or even by co-refining it in existing oil refineries.
Employment:	Empyro process operators, process engineer, plant manager, truck drivers (oil and biomass), financial controller, maintenance, cleaning, etc. yields about 20 FTE direct jobs, excluding the further supply chain (biomass preparation and oil application). Additional jobs are created now the construction of new FPBO plants takes off. Construction of one Empyro-type plant yields 100 full-time jobs in the Netherlands, plus additional jobs on site for the construction and subsequent operation.
Replicability and scale-up potential:	The replicability and scale-up potential of this technology is outstanding, also because our fast pyrolysis technology is flexible in terms of feedstock. Our model is to deliver dozens of Empyro plants all over the world. These will be built at the source of the biomass residue such as sawmills, sugar cane mills, sunflower oil production plants etc. The FPBO produced by multiple of these Empyro sized units will be shipped to a central (bio-)refinery in order to benefit from economy of scale. That way advanced biofuels can be produced in large volumes and at a competitive price.

Success factors:	The coming years FPBO is to become a commodity in the use for renewable energy applications and by co-refining for advanced biofuels. Important factors to achieve this are mandates by the government (like in the RED2), and/or creating incentives by either subsidising sustainable resources or imposing a taxation on the use of fossil resources (i.e. high CO_2 price). For practical implementation of new FPBO production plants the integration of heat with existing industry is beneficial for both financial viability and sustainability. When it comes to the production of advanced biofuels from FPBO by co-refining a practical accounting method such as a mass-balance approach is important to make this route possible for refiners, given the huge complexity of their existing installations.
Constraints:	The main constraint at this point in time is the fact that the production costs of FPBO are still higher than those of most fossil fuels. In comparison to renewable alternatives FPBO is very cost-effective, but oil and gas products are typically still cheaper. That is why government incentives are key to the success of FPBO-based fuels and products. Examples of such incentives are the fossil carbon taxes that are employed by Finland and Sweden.

The Empyro fast pyrolysis plant

Info provided by:	Ruud Meulenbroek and Tijs Lammens, BTG BioLiquids
More information:	https://www.btg-btl.com/en https://www.nonfossilfuture.today/ More pictures, articles and videos can be found in our mediakit online at: *https://btg-btl.box.com/v/mediakit*

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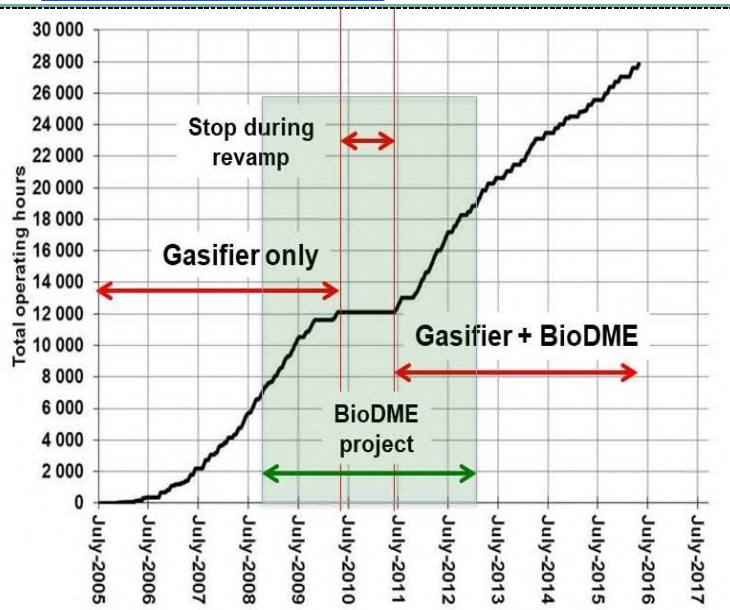
Success Stories of Advanced Biofuels for Transport

CHEMREC/HALDOR TOPSOE/VOLVO BIO-DME PROJECT

Year of plant start- up:	Chemrec gasifier without downstream BioDME plant in operation from September 2005. Plant Start-up Nov 2011 within Bio-DME project Oct 2008 – Dec 2012 Extended Bio-DME project Jan 2013 – Aug 2014 Continued Bio-DME plant operation until 2016
Location:	Sweden, Norrbotten, Piteå
Technology:	Chemrec Black Liquor Gasification (BLG) Technology for production of renewable Syngas, Green Liquor and Steam for chemical recovery to the pulping process. Haldor Topsoe novel once through MeOH technology followed by Methanol to DME conversion technology. In included conversion of renewable Syngas from the gasification unit to (raw) Bio-MeOH and directly converting raw Bio-MeOH to Bio-DME. VOLVO novel DME Engine- and Vehicle Technologies for 10 Euro 5 HD trucks verified in field test.
Plant capacity	4 ton DME/d * 300 d/y *50 % = 600 ton DME/y
Operational experience achieved	The Bio-DME project accumulated approx. 7000 hours of plant operation, with approx. 400 ton BioDME produced and approx. 800,000 km field test mileage within the BioDME time period. Total, including Extended Bio-DME project and Continued Bio-DME plant operation until 2016, accumulated approx.16 000 hours of plant operation, approx. 1050-ton BioDME produced and approx. 1 600 000 km field test mileage. See Figure 1.

	 *Accumulated operating hours 2005 to 2016 including the BioDME period 2008 to 2012*
Total Capital Expenditure	Total approx. EUR 75 million of which approx. EUR 30 million (2008-2011) for the syngas cleaning, MeOH and DME synthesis (the BioDME project) in addition to approx. EUR 45 million for the BLG plant (2001-2012).
Principle feedstocks:	Kaft Black Liquor from Smurfit Kappa Kraftliner pulp mill in Piteå, Sweden. An overall comment to the Chemrec concept: The Chemrec gasifier is fed with the black liquor generated as an energy rich byproduct in the pulp mill and which today is fired in the so-called recovery boiler, a central major part of the pulping process. Energy from the combustion provide steam and power for the pulp mill operation. When the black liquor is gasified and converted to a product as described in in the BioDME project and energy thus withdrawn from the pulp mill operation, the energy needed for steam and power generation is instead fed to the plant in the form of forest residue to a high-pressure boiler. See link to FILM provided under "More information" below.
Feedstock Capacity	20 ton black liquor (BL) per d *300 d/y * 50 % = 3 000 ton BL/y secured through participation of local pulp mill in the BioDME project. 20 ton BL/day corresponds to about 3 MWth.
Products/markets:	BioDME main market as transport fuel for HD trucks, buses and off-road machinery and additional industrial market through blending of 20 % BioDME into LPG. BioMeOH by-product supplied as blend stock for RME production and chemical feedstock.
Technology Readiness Level (TRL):	TRL 8 – system complete and qualified

DESCRIPTION

Application of the novel Chemrec Technology for energy- and chemical recovery from **Black Liquor** (BL) converts pulp mills to Biorefineries.

1. Chemrec Black Liquor Gasification (BLG) Technology.

Atmospheric Air-blown gasification:

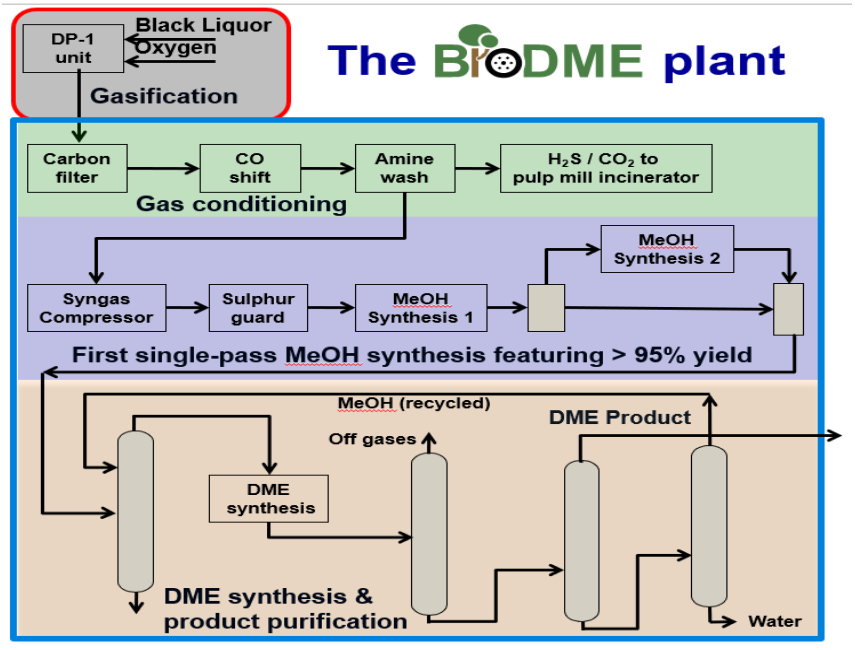
- Frövi, Sweden: 12 MWth operated about 4000 h between 1991 and 1994
- New Bern, USA: First commercial plant at Weyerhaeuser pulp mill in NC, USA. 45 MWth / 47 000 h of operation between 1995 and 2008

Pressurized, Oxygen-blown gasification

- Karlstad, Sweden: Pilot plant 1.5 MWth / 15 bar / about 1000 h of operation
- Piteå, Sweden: Development plant 3 MWth / 30 bar / about 27 000 h of operation (The BioDME gasifier unit DP-1 is per figure below). See *Figure 2 and 3.*

2. Haldor Topsoe methanol and DME technology

Novel once-through MeOH technology combined with conversion of raw (non-purified) methanol to fuel grade DME. See *figure below.*



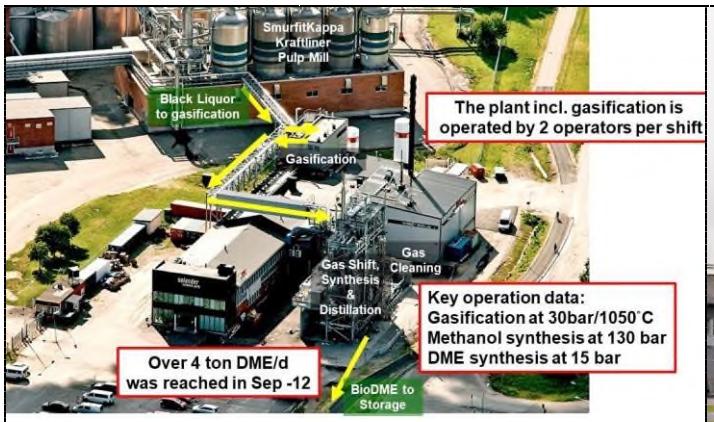
Main blocks and key process sub-units in the BioDME project. The black rectangle on top illustrates the original Chemrec gasification plant

3. VOLVO novel DME Engine- and Vehicle Technologies

10 Euro 5 HD trucks verified in field test. Vehicles operated in commercial services both in north and south Sweden. 4 tank station in operation and DME shipped from Piteå in a standard LPG tank car cleaned for the DME service. See Figure 4.

The Bio-DME project lasted from Oct 2008 – Dec 2012 and was prolonged with a national project during the period Jan 2013 – Aug 2014. After Aug 2014, LTU (Luleå University of Technology) coordinated a continued research and development program called the Biosyngas Program. Continued operation of the BioDME plant was part of that program which ended in May 2016.

During the full period Dec 2011 to May 2016 the BioDME plant produced in total 1054 tonnes of BioDME. The Volvo DMe fueled trucks run in total about 1 600 000 km during that period.



View of the plant site with some key processes and data indicated.

A DME fuelled timber truck operation in the Piteå area

Stakeholders involved:	BioDME project consortium with 17 partners incl. Technology providers, Forest owners and Forest industry, Fuel distributer, University, regional and local Government, Swedish Energy Agency.
Financing Support:	Direct support through grants from EU and Swedish Energy Agency. Indirect support through Swedish CO_2 tax exemption.
Contribution to Sustainable Development Goals:	Through utilization of Black Liquor Gasification (BLG) in chemical pulp mills, 100 % renewable feedstock from the forest is converted to sustainable renewable transportation fuels, replacing fossil fuels. In areas with significant forest and forest industries implementation of the Chemrec BLG and Topsoe synthesis Technologies represent a considerable contribution to the following SDGs: GHG emission reduction (SDG13), sustainable consumption and production patterns (SDG 12), reliable, sustainable and modern energy for all (SDG7), Sustainable use of terrestrial ecosystems (SDG15), regional development (SDG8).
Contribution to European targets on GHG emission reduction in transports:	Sweden produces around 25% of all forest-based pulp in the EU at around 20 different sites and the implementation of BLG and fuel synthesis at all Swedish pulp mills would replace approx. 25 % of current Swedish fuel consumption resulting in 6-million-ton fossil CO_2 emission savings. Implementing the BLG technology on all European chemical pulp mills would result in 4 times larger reduction of EU GHG emissions or approximately 24-million-ton fossil CO_2 emission savings.

Employment:	The Piteå plant employed 20 engineers & operators. The Chemrec and Topsoe development organizations employed additional 15 qualified staff and managers. Each implementation project would for the development and operation phases result in plant operating and maintenance staff of about 80 people. According to a Pöyry study the number of indirect jobs created as a consequence of establishing a full-sized plant described in this document would be 8-10 times larger.
Replicability and scale-up potential:	The BLG/Bio-DME Technology has high replication/scale-up potential at local/regional, national as well as international level. Identified potential 70-80 plants in Europe out of 300 plants globally.
Success factors:	The key condition required for the success story to be successfully replicated is the implementation on an EU and national level is long- term (at least 15 years) stable directives and regulations which impact project cash flow, such as incentives and taxes.
Constraints:	Current lack of long-term legislation is preventive for arranging debt financing and implementation of large-scale renewable transportation fuel projects.

Info provided by:	Ingvar Landälv /Jonas Rudberg
More information:	A good description of the BioDME concept can be viewed in a 3.5 minute film produced by Volvo: https://www.youtube.com/watch?v=cF1F7luFpnc "*Two years' experience of the BioDME project—A complete wood to wheel concept*" (can be ordered through Ingvar Landälv, ingvar@landalv.se or at the following link: https://onlinelibrary.wiley.com/doi/pdf/10.1002/ep.11993)

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Success Stories of Advanced Biofuels for Transport

LANTMÄNNEN AGROETANOL

Year of plant start-up:	2001, updated 2008
Location:	Norrköping, Sweden
Technology:	Lantmännen Agroetanol is one of the largest biorefineries in the Nordic region and part of Lantmännen. We mainly refine grain at our plant, but also other raw materials such as residuals from the food industry.
Plant capacity	**Ethanol:** Agroetanol has capacity for over 200,000 m3 ethanol annually. Part of it becomes biofuel and some of this volume is used in other applications. • Agro Cleanpower ED95: 90% CO_2 reduction makes Agro Cleanpower ED95 one of the world's most sustainable fuels. We supply Agro Cleanpower 95 as a ready-to-use fuel to bus operators and truck haulage companies. • Agro Cleanpower E85: Using E85 instead of petrol is by far the easiest way to reduce your carbon footprint – up to 70% carbon dioxide reduction with Agro Cleanpower E85. There are currently over 200,000 registered cars in Sweden that can run on E85, known as 'flex-fuel' cars and 1,700 public E85 pumps. • E10 for low-blend: Almost all petrol sold in Sweden now has 5% ethanol added. The blend should be increased to 10% (E10) in a few year time, just like it has been done in e.g. Belgium and Finland. Feed/Protein: Our refining process converts the starch portion of grain into ethanol. We separate the protein into stillage, which is used to produce DDGS, an animal protein feed. That means that we cycle back some of the raw material back to the farms and the food chain and finally the plant nutrients to the fields in the manure. Our protein feed has a high protein content, is GMO-free, has high climate performance and the raw materials are locally produced, avoiding the need for imports from far-away countries such as soy. This is positive for the EU, because there is a massive shortage of protein in the EU and a heavy-reliance on protein imports. • Agrow Feed 90: Our main product is Agrow Feed™ 90, a tasty protein feed containing 30-35% protein depending on seasonal variations. The product is dried and pelleted (6 mm). Carbon dioxide: the grain fermented in our biorefinery releases a carbon dioxide. Still, since carbon dioxide is part of the natural cycle, nothing is added to atmosphere. In our case, however, we capture it and deliver it directly via

	pipes to our next-door neighbour, AGA-Linde, who liquefy it into carbonic acid. In this way, we are not only the largest producer of ethanol and protein animal feed, but also the largest supplier of green CO2/carbonic acid in Sweden. That's enough bubbles to fill every carbonated beverage sold throughout the country. • Carbonic acid for foods: In addition to all the regular bottled carbonated beverages found in stores, carbonic acid is also often added directly to drinks in restaurants and bars. • Industrial applications for carbon dioxide: Carbon dioxide is also common as a refrigerant in the food industry, both in the packaging of goods and for transport. It is also used in fire extinguishers and in the paper pulp production process. Replacing all fossil carbon dioxide currently in use with clean, green carbon dioxide is an important part of the transition to a sustainable society.
Operational experience achieved	More than 3,700 million m3 ethanol produced.
Total Capital Expenditure	More than € 200 million.
Principle feedstocks:	We mainly refine grain (wheat) at our plant, but also other raw materials such residuals from the food industry and bread returns from food retailers.
Feedstock Capacity	About 80 ton/h. The raw materials are mainly domestic. The majority is wheat and other grains, but recycled products and industrial residues from the food industry are also used.
Products/markets:	Our refining process yields three main products – ethanol, protein and carbon dioxide. We process each of these into sustainable products such as transport fuel, animal feed and carbonic acid. Our ethanol for example reduces the GHG emissions by more than 90% compared to fossil fuels, making it one of the most sustainable fuels in the world. See the below image for a full overview of the by-products.
Technology Readiness Level (TRL):	TRL 9 – actual system proven in operational environment

DESCRIPTION

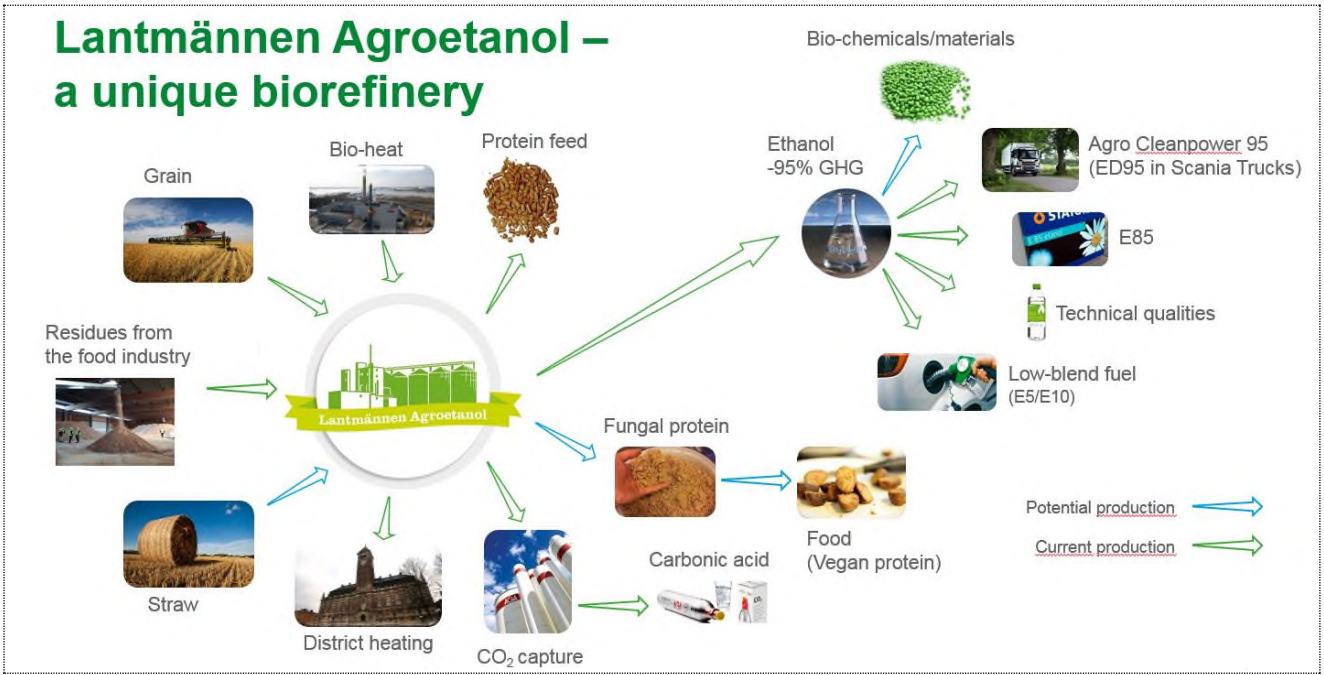
Lantmännen Agroetanol helps find solutions for a more sustainable society. We take care of nearly everything in our ingredients and create value at multiple levels. Our ethanol replaces fossil oil, whether in fuels, chemical products or in a future plastic.

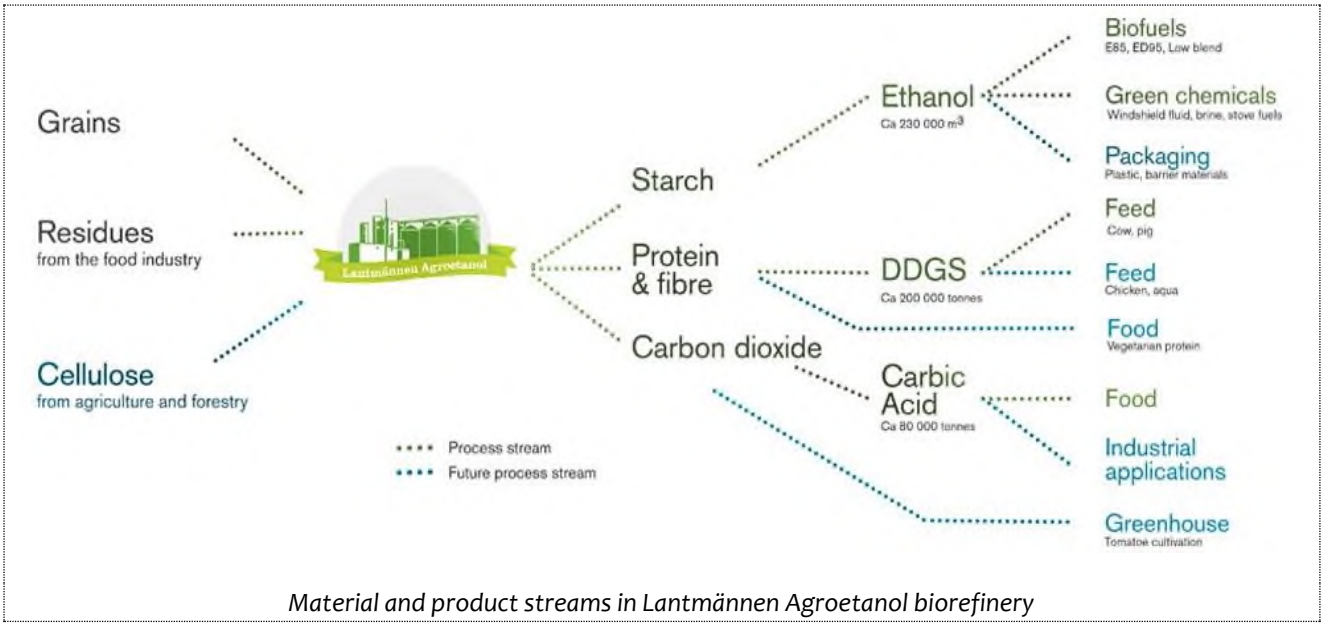
Since 2001, we have produced fuel ethanol at our plant in South-Eastern Sweden based on wheat and other grains as well as residues from the food industry. Thanks to efficient processes, the use of renewable process energy from adjacent biomass-fuelled CHP and important co-products in the form of protein-rich feed and biogas, the fuel ethanol produced reduces GHG emissions by more than 90% compared to fossil fuels.

Our feed products are high-grade protein to replace soya which otherwise would be imported, mainly from the

other side of the world. What we can offer instead is a viable protein locally grown and produced with only short transportation required as a result. Finally, the CO_2 formed during fermentation is captured and converted into clean and green carbonic acid to replace the fossil-produced version. Who would not prefer to drink mineral water with green bubbles rather than fossil fuel-produced?

Our innovation-driven organisation constantly seeks new solutions in order to lead the way into a green future. Free from all that is fossil fuel produced.





Material and product streams in Lantmännen Agroetanol biorefinery

Stakeholders involved:	Lantmännen Agroetanol is part of Lantmännen, an agricultural cooperative owned by 25,000 Swedish farmers, with operations throughout the entire value chain from farm to fork. Thus, it involves a range of actors and stakeholders in the agriculture sector. Agroetanol is part of Händelö Eco industrial park. Besides Agroetanol, E.ON, which has a combined heat and power plant delivering steam, electricity and heat from renewable raw materials is part of this, but also Svensk Biogas, a biomethane company and the city of Norrköping. Händelö Eco Industrial park is a part of the natural cycle of city, industry and agriculture.
Financing Support:	As an agriculture cooperative, we are owned by virtually all active farmers in Sweden. Our Agroetanol business has sales of around 1.7 billion Swedish kronor and approximately 90 employees. All investments have been 100% financed by Lantmännen. Blending mandates, especially GHG reduction quotas in European countries, and tax exemption for high blend biofuels.
Contribution to Sustainable Development Goals:	Our Agroetanol business contributes to a number of the UN's Sustainable Development Goals, namely: • **SDG 2: End hunger, achieve food security and improved nutrition and promote sustainable agriculture**. By producing vital by-products like protein through our biorefinery operation, a scarce resource in Europe, we are helping achieve food security for Europeans. • **SDG 7/ SDG 12/ 13: Ensure access to affordable, reliable, sustainable and modern energy for all. Ensure sustainable consumption and production patterns. Take urgent action to combat climate change and its impacts**. Our highly sustainable, crop-based bioethanol provides Europe with access to a green, available fuel which dramatically reduced CO_2 emissions compared to fossil fuels. • **SDG 8: Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all**. Our biorefinery is providing jobs for local people in Sweden, as well as supporting Europe's farmers who supply us with the grains, which in-turn provides them with stable income at a time when traditional farming costs lead to many farms closing across Europe.
Contribution to European targets on GHG emission reduction in transports:	In our biorefinery Lantmännen Agroetanol produces sustainable ethanol with over 90% GHG savings, we're not only contributing but beating the EU's GHG emission reductions targets for the Union as well as for transport. The fossil diesel in heavy goods vehicles have so far been difficult to replace at any scale, but ED95 in Scania trucks can be used to reduce the GHG emissions significantly.
Employment:	Approximately 130 jobs directly plus the farming sector and downstream industries which largely depend on our products. We estimate the total employment in the whole value-chain (field to ethanol) to approximately 500 jobs.

Replicability and scale-up potential:	The scale-up potential at local and regional level is low, medium at national level and high at international level. However, the international trend in biofuel policy is to disincentive all crop-based fuels independent of life cycle environmental performance. This leads to significant political risk pertaining to replicability and scale-up. Still, we are about to scale-up the use of food industry residues and continuously increase the GHG savings per liter of ethanol.
Success factors:	Policy-driven market demand for biofuels with substantial GHG emission potential will help the EU meet is climate objectives, helping to protect our environment.
Constraints:	For more biorefineries to exist and be economically viable, we need long-term policies from the European Union and the member states that provide investor certainty and allow for market development. What's more, we want to see more policy actions which encourage the transition from fossil-fuels to greener energy alternatives like bioethanol – this could mean providing fiscal incentives (e.g. double counting for biofuel crops) to help create a level-playing field for sustainable, renewable fuels against cheap, dirtier fossil fuels.

Info provided by:	Alarik Sandrup, Director Public and Regulatory Affairs
More information:	https://www.lantmannenagroetanol.se/en/ https://www.lantmannenagroetanol.se/en/produkter/etanol/ed95/ https://lantmannen.com/en/about-lantmannen/financial-information/interim-reports/

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