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Advanced Biofuel Demonstration Competition Feasibility Study

Annex 3: Advanced biofuel demonstration projects: case studies

Submitted by:

Arup URS Consortium

In partnership with:

E4tech (UK) Ltd and Ricardo-AEA

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Reviewer List

Name	Role
Lucy Nattrass	Project Manager

Signoff List

Name	Role
Caroline Toplis	Client Package Order Manager

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1. Introduction

As outlined in the main report, seven biofuel projects that were to some extent publically funded were selected for further research. The following projects were selected based on the current status and stage of development (TRL), and in combination represent a cross-section of characteristics relevant to this feasibility study, such as technology, feedstock, project type and range of funding mechanisms. Funding awards for demonstrator projects have been found to range from €10 million to €59 and have been complemented by additional funding from other programmes, or national governments (e.g. GoBiGas).

The type of project supported by funding schemes and included in this selection involved;

- Construction of demonstration plants,
- Production at existing demonstration facilities; and
- Expansion of existing plant from pilot to demonstration or demonstration to commercial scale.

Demonstration projects are found to involve industry partners from throughout the supply chain, including feedstock producers. There is still, however a strong academic or research organisation presence in the projects examined even at later stage demonstration projects (e.g. KACELLE) but some of the projects examined were purely industry led (e.g. Project Alpha and Vanerco).

Not all of the project timelines are clear because many projects have been started in parallel or as follow-on from related, earlier stage projects. Where timescales were unclear, the project consortium has been contacted for further information or clarification. In addition, determining the exact grant received – or overall project cost where a number of public sources of funding have contributed to a project (or multiple related projects) has been difficult to ascertain. Again this information was requested of consortium members – but was not always provided.

2. BEST

Location:	Crescentino, Italy
Funding award:	€28.4M, NER300, payments based on biofuel production
Duration:	Funding award announced 2012 Payments for the first five years from start up 2013 – 2018
Other public support:	€8.59M funding for PROESA™ technology in the FP7 funded BIOLYFE project. Project length 3 years (from Jan 2010). Integrated pilot scale unit which was able to treat selected feedstock (1 tonne per day biomass input). Italian Ministry for Economic Development, through Industria 2015 programme (amount unknown).
Total investment:	Unknown >€200M has been invested in PROESA™ technology

Consortium:	BioAg Alliance: Novozymes and Monsanto Other partners are involved in research projects led by the alliance
Project type:	Demonstration plant: design, construct and operate
Conversion technology:	Enzymatic hydrolysis and fermentation
Capacity	To reach 75 Ml/yr
Feedstock:	Giant cane (arundo donax), wheat straw and rice straw
Technology:	Beta Renewables' PROESA™
Outputs/Fuel:	Ethanol and lignin
Other details:	The demonstration plant represents a scale-up factor of 10 times previous operations. Lignin will be used to power the plant[1].

2.1. Development timeline for the PROESA™ technology

Construction of the demonstration plant began in April 2011, production started January 2013, and the plant completed commissioning and was fully inaugurated in October 2013 (30 months).

Date	Technology development	Project development
2006	PROESA™ technology development and testing	Technology selection
2007		
2008		
2009	Laboratory scale testing	
2010		Planning permission requested Procurement of critical items
2011		Permits obtained Breaking ground
2012	Completion of mechanical work	
2013	Start-up	

3. GoBiGas, Sweden

Location:	Göteborg, Sweden

[1] A presentation of the facility and processes is available at: http://www.novozymes.tv/video/8756366/a-new-era-begins.

Funding award:	€58.8M NER300, payments based on biofuel production
Duration:	Funding award announced 2012 Payments for the first five years from start up 2016 – 2021
Other public support:	€24M Swedish Energy Agency (Phase 1: demonstration plant)
Total investment:	Not published
Consortium:	E.ON and Göteborg Energi
Project type:	Scale-up of operations from demonstration to commercial scale From 20 MW_{bioSNG} to 80 – 100 MW_{bioSNG}
Conversion technology:	Thermal gasification and methanation
Capacity	80 – 100 MW_{bioSNG}
Feedstock:	Forest residues
Technology:	Repotec's indirect gasification
Outputs/Fuel:	BioSNG
Other details:	The project represents phase 2 of an on-going project, phase 1 started in 2007 and involved the design and construction of a 2 – 4 MW_{bioSNG} pilot plant at Chalmers University of Technology, followed by a 20MW_{bioSNG} demonstration plant.

3.1. Development timeline for the GoBiGas Project

The timeframe from project inception to construction of the demonstration plant is approximately 6 years, the construction and commissioning phase was reported to be 2-3 years, and commercial operation (via scale up), due in 3 years.

Date	**Project development milestones**
2005	Initial concept: Sweden's first biomethane plant
2006	Feasibility study complete
2007	In-depth technologies review complete
2007	Göteborg Energi fund the building of an indirect gasifier at an existing boiler based in the Chalmers university of Technology for research and testing purposes
2009 - 2010	GoBiGas staff evaluate technology on-site
2011	Demonstration plant construction begins
2013	Demonstration plant operational
2013	Scale up begins

2016	Commercial scale production expected to begin

4. EuroBioRef

Location:	Sarpsborg, Norway
Funding award:	€23M FP7, grant funding
Duration	Project schedule 2010 - 2014
Other public support:	€7.8M Innovation Norway, for the construction of BALI™ demonstration plant (45%) €2.4M Biomass2Products, Norwegian Research Council (2009 - 2013) €1.2M New Norwegian Biorefinery - Norwegian Research Council (2012-2015) €0.17M NorZymeD - Norwegian Research Council
Total investment:	€36.9M
Consortium:	28 project partners from 14 countries across the value chain: 1. Centre National De La Recherche Scientifique, France (Coordinator) 2. Arkema France Sa/Ceca, France 3. Borregaard Ind. Ltd., Norway 4. Novozymes A/S, Denmark 5. Center For Renewable Energy Sources, Greece 6. Haldor Topsøe A/S, Denmark 7. Certh, Centre For Research & Technology Hellas / Institute For Solid Fuels Technology & Applications, Greece 8. Process Design Center Gmbh, Germany 9. Quantis, Switzerland 10. European Biomass Industry Association, Belgium 11. Danish Technological Institute, Centre For Renewable Energy And Transport, Denmark 12. Technische Universität Dortmund, Germany 13. Merck Kgaa, Germany 14. Faculdade De Engenharia Da Universidade Do Porto, Portugal 15. CIRCC, University Of Bari, Italy 16. Wsk "Pzl-Rzeszow" S.A, Poland 17. Ośrodek Badawczo-Rozwojowy Przemysłu Rafineryjnego Spółka Akcyjna, Poland 18. Sintef Materials And Chemistry, Norway 19. Société Agricole De Befandriana-Sud & Partners Sarl, Madagascar

	20. Umicore, Ag & Co Kg, Germany 21. Nykomb Synergetics Ab, Sweden 22. Alma Consulting Group, France 23. Orgachim Jsc, Bulgaria 24. Imperial College Of Science, UK 25. Novance, France 26. University Of Warmia And Mazury In Olsztyn, Poland 27. Technische Universität Hamburg – Harburg, Germany 28. Bkw Biokraftwerke Fürstenwalde Gmbh, Germany
Project type:	Demonstration of biomass crop production, conceptual process design and pilot scale separation and conversion processes
Conversion technology:	Biorefinery concept based on sulphite pre-treatment
Capacity	Greater than 50 kg dry biomass per hour The production capacity has not been published
Feedstock:	Residual materials from agriculture and forestry, and energy crops. Including Lesquerella, Lunaria, Jatropha, Castor and Safflower from agriculture and Willow, Switchgrass, Miscanthus, Black Locust, Cardoon and Giant Reed from forestry.
Technology:	BALI technology The technology is in use at the Borregaard refinery and has been subjected to testing since 2007.
Outputs/Fuel:	Aviation biofuels, chemicals and polymers
Other details:	The aim of the EuroBioRef project is to demonstrate the production and use of biomass suited to European regions, and the production of aviation biofuels and other marketable products including chemicals, polymers, and materials. In addition, the project has a number of performance goals, including a 30% improvement in cost-efficiency through improved reaction and separation, reduced capital investments, feedstock flexibility, reduced production time, energy use, and waste. The decision on whether to scale-up the project to commercial level is expected in 2014.

5. KACELLE

Location:	Kalundborg, Denmark
Funding award:	€9.1M FP7, grant funding
Duration:	KACELLE project duration 2009 – 2013 (other funding sources

	saw the initial stages of KACELLE started under other projects).
Other public support:	€6.5M under FP5 for Co-Production of Bio-fuels €10.3M from the Danish Energy Technology Development and Demonstration Programme, for design and construction of the Kalundborg demonstration plant
Total investment:	€54M (demonstration plant)
Consortium:	Inbicon (DONG Energy subsidiary), Statoil, Royal DSM, University of Copenhagen, University of Minho and the German Biomass Research Centre.
Project type:	Demonstration plant
Conversion technology:	Hydrothermal pre-treatment and enzymatic hydrolysis and fermentation
Capacity	5 Ml/yr
Feedstock:	Straw
Technology:	Inbicon's IBUS concept (Integrated Biomass Utilization System)
Outputs/Fuel:	Ethanol and lignin pellets
Other details:	Follows on from a 4 year FP5 funded project which involved Elsam A/S, Sicco K/S and The Centre for Plant Fibre (Denmark), and TMO (UK). The initial project developed IBUS producing bioethanol from wheat and wheat straw. The success of this project and pilot-scale demonstration activities led to the Energy Technology Development and Demonstration Programme (EUDP) part-funded construction of a fully integrated demonstration plant, the Kalundborg plant, which has been in operation since 2009. The aim of KACELLE project is to demonstrate and further optimise the Kalundborg plant, in order to commercialise the patented technology. It is anticipated that this demonstration plant will help to make the technology available in the market and attractive to investors in four to five years. The KACELLE project has delivered process optimisations and opex and capex savings. Next steps for this project involve a focus on commercialisation of the technology and consortium members are already involved in several full scale projects around the world (China, Brazil, Europe, Malaysia and US) on different feedstocks (wheat straw, corn stover, bagasse and EFB). Dong Energy are also involved in a number of projects with different partners focusing on the next generations of the technology - producing chemicals and creating more value of the

	lignin.

5.1. Development timeline for the Kalundborg plant

Having been developed under an FP5 project, the demonstration plant moved from design to operation in 2 – 3 years, and is expected to operate for four years.

Date	Action
2002 – 2006	FP5 funded project "Co-Production of biofuels" developed IBUS technologies
2007	EUDP-1 design and engineering funding announced
Spring 2008	EUDP-2 award for demonstration plant announced
Summer 2008	Construction of the demonstration plant
End 2009	Ethanol production begins
2009 - 2013	KACELLE project focusses on operation and optimisation of the demonstration plant, and the potential for up-scaling the technology and processes

6. Bioliq

Location:	Karlsruhe, Germany
Funding award:	€11M European Regional Development Fund & German Federal Ministry for Nutrition, Agriculture and Consumer Protection (BMELV) (split not known)
Duration:	Award for the set-up of the Bioliq synthesis stage announced in 2009 with the project on-going.
Other public support:	Multiple funding sources for a range of linked precursor and parallel projects; €1M EU's Regional Competition and Employment Fund (EFRE) via the Baden-Württemberg Ministry of Economics. €26M awarded to the Karlsruhe Institute of Technology (KIT) by the Federal Republic of Germany and the Baden-Württemberg Ministry of Economics for the construction of the pilot plant.
Total investment:	€60M overall for plant construction Note the pilot plant has been developed in a number of stages, including fast pyrolysis, gasification, and liquid synthesis
Consortium:	Karlsruhe Institute of Technology (KIT), Chemieanlagenbau Chemnitz GmbH, Air Liquide Global E&C Solutions, Crygenics Lurgi Zimmer, MUT Advanced Heating, and Mischanlagentechnik

	GmbH
Project type:	Set-up of the Bioliq synthesis stage plant
Conversion technology:	Flash pyrolysis, high-pressure entrained-flow gasification, and liquid synthesis
Capacity	Not published
Feedstock:	Straw and wood waste
Technology:	Bioliq
Outputs/Fuel:	DME that is then converted into hydrocarbons with petrol and diesel characteristics; bio-diesel and bio-petrol (not further specified)
Other details:	The pilot plant has been constructed in phases, which has allowed for build and equipment testing, and enabled KIT to secure additional funding for the next stages of development. The Bioliq project has been on-going since 2005 when plans for the plant first started: • First construction phase was commissioned in 2008 – 2009. • First test fuel outputs in 2010 at a capacity of ½ tonne of straw converted per hour. • In 2010, further funding was secured for the next phase of construction (Bioliq II) • March 2011, construction work started on the final build phases, with the plant fully commissioned and operational by July 2013. • Further projects are focussed on optimising the processes involved and making them suitable for large industrial-scale production.

7. Chemtex Project Alpha

Location:	North Carolina, USA
Funding award:	$99M Biorefinery Assistance Programme, loan guarantee
Duration:	Loan guarantee announced August 2012, construction expected to start 2014
Other public support:	$4M US Federal Governments Biomass Crop Assistance Program Award to develop 4,000 acres of miscanthus and switchgrass in North Carolina.
Total investment:	$200M

Consortium:	Chemtex, The Biofuels Center of North Carolina, Novozymes, BB&T and partners in the Pork Industry
Project type:	Construction of commercial plant
Conversion technology:	Enzymatic hydrolysis and fermentation
Capacity	Est. 91 Ml/yr
Feedstock:	Non-food biomass
Technology:	PROESA Technology
Outputs/Fuel:	Ethanol
Other details:	Project Alpha is expected to create approximately 65 direct and 250 indirect jobs during operation of the plant.

7.1. Development timeline for Chemtex's project alpha

The time from project inception to the start of construction is estimated at approximately 8 years, including 2 years from the announcement of the loan guarantee to construction.

Date	Action
2006 – 2008	Technology selection and proof of unit operation in laboratories
2009	Technology tests at laboratory scale
2012	Loan guarantee announced
2014	Construction expected to start

8. VANERCO

Location:	Québec, Canada
Funding award:	$734,500 NextGen Biofuel Fund, loan If the project meets project milestones and future approvals, the full loan amount from the NextGen Biofuels Fund could increase to more than $39M
Duration:	Announced in 2013, loans are typically paid back over 10 years
Other public support:	$27M through the Ministry of Natural Resources and Wildlife and Investissement Québec
Total investment:	Est. $97.5M
Consortium:	Enerkem and Greenfield
Project type:	Construction of a 1st of a kind commercial plant (TRL 8)
Conversion technology:	Gasification and catalytic synthesis to alcohols
Capacity	Est. 38 Ml/yr

Feedstock:	Non-recyclable waste (institutional, commercial, industrial, and construction and demolition)
Technology:	Enerkem
Outputs/Fuel:	Ethanol