The sunliquid® process - cellulosic ethanol from agricultural residues
Introduction to Clariant and the Biotech & Renewable Center
Clariant – Key Facts

- World leader in colors, surface effects and performance chemicals
- Annual sales of CHF 6.0 billion in 2012
- Headquartered in Muttenz near Basel, Switzerland
- World-wide operations with more than 100 group companies
- Approximately 21,200 employees
- Products and services of 7 Business Units are based on innovative specialty chemicals
- Clariant acquired Süd-Chemie in 2011 and as of July 2012 Süd-Chemie is officially integrated into Clariant
Clariant has a worldwide presence

- Clariant is represented in over 70 countries
- Focused investments in high-growth countries,
- Global production and safety standards
Clariant’s Products and Services are delivered through 7 business units

**Additives**
- Additives for plastics, coatings, adhesives, incl. flame retardants, waxes etc.

**Catalysis & Energy**
- Catalysts for chemical, refining and autos
- Lithium Battery materials

**Functional Materials**
- Adsorbents, solutions for protective packaging and water treatment

**Industrial & consumer specialties**
- Application solutions for consumer care and industrial markets

**Masterbatches**
- Color and additives concentrates/technical composites for plastics

**Oil & Mining Services**
- Chemical solutions serving refining and mining industries

**Pigments**
- Organic pigments, pigment preparations, and specialty dyes for coatings etc.
Clariant’s dedicated Biotech and Renewable R&D site complements its green strategy

Green strategy

- **Renewable feedstock** as the basis for development of sustainable biofuels and green chemicals
- **Biotechnology** as part of a strong technology platform for renewables

Key facts

- Located in **Munich** and **Straubing** (Bavaria)
- Start in 2006, currently >75 employees
- Lab and office space: 3,300 m²
- Demonstration plant: 2,500 m²
Biotech & Renewable Center is developing industrial processes for bio-based products

**Biotechnology**
- Isolation and optimization of biocatalysts & microorganisms

**Screening**
- Detection and selection of biocatalysts

**Pilot plant**
- Process development
- **Upscaling**
- Since 2009

**Industrial processes**
- Synergies between technology platforms (incl. chemical catalysts)
- New products
Milestones to industrial deployment

2006

Strategic move into Biotech & Renewables

2007

Biotech R&D center established in Munich

2008

Start-up of pilot plant for cellulosic ethanol

2009

Acquisition of Süd-Chemie by Clariant

2010

Start-up of demo plant in Straubing, Germany

2011

Industrial scale – sunliquid tech license

2012

2013
The sunliquid® technology
SUSTAINABLE AND ECONOMIC CELLULOSIC ETHANOL
sunliquid® - An ideal platform for the production of sustainable solutions at large scale

- Designed Micro-organisms
- Technology
- Enzymes
- Technology
- Green Chemicals
- e.g., Organic acids
- 2G Sugars
- Fermentation
- Cellulosic Ethanol
- Biofuels
- e.g., Ethylene Oxide
- Green Ethylene
Biomass resources alternatives – What’s in a hectare of wheat?

- 6-7 t grain
  - = 4.0–4.5 t sugars as starch

- 4-5 t straw
  - = 3.0–3.5 t sugars as lignocellulose
sunliquid® offers a competitive path to cellulosic ethanol

Key features and advantages

- Integrated enzyme production
- Fermentation of C6 and C5 sugars into ethanol
- Feedstock and process specific enzymes
- Energy saving ethanol separation technology
Transformation from agricultural residues to pure ethanol

1 hectare wheat → 4-5 tons of straw → 1 ton of ethanol
There are several key challenges in the production of cellulosic ethanol

Challenges

High process yields

Low operating costs

Low investment costs

Sustainable process
sunliquid® offers solutions to the key challenges in the production of cellulosic ethanol

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sunliquid® offers solutions to the key challenges in the production of cellulosic ethanol

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Using its world-leading screening expertise, Clariant has developed feedstock-specific enzymes

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<td>▪ Ultra high-throughput screening</td>
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<tr>
<td>▪ Optimization of enzymes and microorganisms</td>
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<td>▪ Evaluation of up to 100,000 samples per day</td>
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<td>▪ Large spectrum of assay formats possible</td>
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<td>▪ Optimized feedstock-specific enzymes already developed for various feedstock, including</td>
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  ✓ Corn stover                                                             |
  ✓ Sugarcane bagasse                                                       |
  ✓ Wheat straw                                                             |
sunliquid® offers solutions to the key challenges in the production of cellulosic ethanol

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sunliquid® technology enables to convert all types of sugars to cellulosic ethanol

- Proprietary fermentation microorganism developed by Clariant
- Simultaneous conversion of all sugars to ethanol
- One-pot-reaction, patented process
- Energy independence by using Lignin as integrated on-site an energy source
sunliquid® offers solutions to the key challenges in the production of cellulosic ethanol

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The integrated enzyme production significantly lowers the enzyme costs per gallon of Ethanol

Advantages of integrated enzyme production

**Low substrate cost**
- Enzymes are produced on lignocellulosic substrate

**No additional utilities**
- Enzyme production is process and plant integrated

**No formulation and logistics**
- Enzymes are produced directly where needed

**Feedstock and process-specific enzymes**
- No ‘one-size-fits-all’ solution

**Independent from enzyme suppliers**
- No additional margins due to pricing strategy

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Enzyme cost comparison
USD/gallon Ethanol
With an integrated enzyme production, sunliquid® is independent from enzyme suppliers

sunliquid®: Process-integrated enzyme production

Alternative: External off-site, on-site or hub-solution:
sunliquid® offers solutions to the key challenges in the production of cellulosic ethanol

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sunliquid® reduces the energy consumption in the downstream processing

Highlights

- Proprietary ethanol separation process with very low energy consumption
- Based on Clariant-technology
- Patented process and material
- Well-integrated in the sunliquid®-process
sunliquid® offers solutions to the key challenges in the production of cellulosic ethanol

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sunliquid® offers a high-performance process package

Key features of the sunliquid® process

- **Production costs** get competitive to 1G biofuels
- Process works flexible for **different renewable feedstocks**
- **High process yield** of 250-320 liter EtOH per ton of biomass
- **Energy neutral for EtOH production** – No additional fossil energy needed
- **Nearly carbon neutral** – GHG reductions of **about 95%** compared to fossil fuels
- **No “food vs. fuel” controversy**, no land use change concerns
Pilot plant operational since 2009
The demonstration plant for cellulosic ethanol in Straubing is on-stream

Key facts

Dimensions: 60m x 30m x 15m
Feedstock: ~ 4,500 t/a wheat straw
Output: 1,000 t/a (335,000 gal/year)
Location: Straubing-Sand, competence center for renewable feedstock
Inaugurated: July 20th, 2012
Images from inside the demonstration plant

Lignocellulosic biomass

Pre-treatment

Hydrolysis

Fermentation
Site Plot Plan as proposed for commercial scale plant during engineering study

**Enzyme Production**
A small percentage of the pre-treated feedstock is used for enzyme production. This step is integrated as part of the process and takes place on-site at the ethanol plant. This contributes to the economic efficiency of the overall process as well as a significant reduction in production costs and ensuring independence from supply shortages and price volatility.

**Feedstock Handling & Pretreatment**
After delivery, the feedstock undergoes mechanical and thermal pretreatment. This helps in opening up the stable lignocellulosic structure and prepare the plant material for enzymatic treatment.

**Hydrolysis**
A biological enzyme reacts with hydrolysis cellulases and hemicellulases chains to form sugar monomers. This step is also termed saccharification. The enzymes are highly optimised based on feedstock and process parameters, ensuring maximum yields and short reaction times under optimal conditions.

**Product - Cellulosic Ethanol**
This results in fuel-grade ethanol offering a purity level of 99.9%—while at the same time reducing CO₂ emissions by 92% compared to fossil gasoline.

**Energy Generation**
The sunliquid process is energy self-sufficient, no additional fossil energy being required. All energy needed for the process is generated from the residual lignin.

**Separation**
The upstream and proprietary precipitation method uses up to 95% less energy compared with conventional distillation. It is based on Clariant technology and material and was specifically designed to ensure high-energy efficiency throughout the whole process.

**Segmentation**
Using optimised micro-organisms, the sunliquid process produces for efficient fermentation, giving rise to maximum ethanol yields. This highly optimised step process simultaneously converts both C6 and C5 sugars to ethanol, delivering up to 8% more ethanol than conventional processes which convert only C6 sugars.
Clariant’s licensing model for commercialization of the sunliquid® process

**sunliquid® license agreement**
- Integrated process technology package including all steps along the ethanol production chain

**sunliquid® supply agreement**
- Starter cultures for process integrated enzyme production (delivery for each new propagation to maintain best performance)
- Starter cultures for the proprietary fermentation organism which converts C5 and C6 to ethanol (delivery for each new propagation to maintain best performance)
- Proprietary ethanol separation (material delivered by Clariant to maintain high product purification)
Timeline for industrial commercialization by 2013

- **Platform technology** able to provide cellulosic sugars, ethanol, and C2 chemicals
- **Pilot plant** has been operational for over 4 years since 2009
- **Demonstration plant** is on-stream and operating
- **Technology validation** at demonstration plant level
- Identification of **potential commercialization partners**
- **Technology package ready** for industrial-scale by 2013
For further information please contact

Dr. Ing. Paolo Corvo
Business Development Manager Biofuels Europe
Biotech & Renewable Center

Phone: +49 173 7357 015
E-mail: paolo.corvo@clariant.com

Clariant Produkte (DE) GmbH
Staffelseestraße 6
81477 Munich
Germany