

Cellulosic ethanol  
from agricultural residues

**THINK AHEAD,  
THINK SUNLIQUID®**



# Market ready and highly efficient SUNLIQUID® PROCESS FOR THE PRODUCTION OF CELLULOSIC ETHANOL



By developing sunliquid® technology, Clariant has cleared the way for cellulosic biofuels. Its process converts lignocellulosic agricultural residues, such as cereal straw, into cellulosic ethanol or other biobased chemicals in a way that is highly efficient, extremely economic, energy-neutral and sustainable.

### sunliquid® opens up new feedstocks

Until now, agricultural residues have held little attraction as a feedstock for the production of biofuels, since the stable structure of this lignocellulosic material is difficult to break down by conventional methods. As a result, the sugars contained in straw have remained largely unused until today.

Thanks to Clariant's sunliquid® process, this will change. Its key technology is based on feedstock-specific biocatalysts, which efficiently provide access to the sugars contented in the straw, an integrated enzyme production, simultaneous C5 and C6 fermentation and an energy-saving ethanol separation method. This gives rise to an efficient, extremely economic and therefore competitive process for the production of cellulosic ethanol.



### SINCE 2009

- sunliquid® pilot plant
- Capacity: 1 ton of cellulosic ethanol per annum
- Location: Clariant Biotech & Renewables Center, Munich



### SINCE JULY 2012

- sunliquid® demonstration plant
- Capacity: 1,000 tons of cellulosic ethanol per annum
- Location: Straubing-Sand, Bavaria



### FROM 2013

- Licencing of sunliquid® technology
- Realisation of industrial sunliquid® plants
- Capacity: 50,000 to 150,000 tons of cellulosic ethanol per annum

### Cellulosic ethanol – biofuel of the future

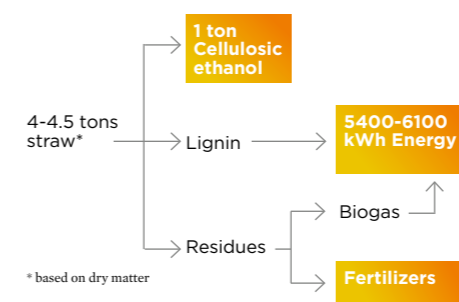
The efficient sunliquid® technology is key for an economic and sustainable process. The facts:

- The **production costs** are comparable with those of first-generation bioethanol – currently the world's most important biofuel.
- The **flexibility** of the sunliquid® process allows all lignocellulosic feedstocks to be converted – from wheat and corn stover to sugarcane bagasse or energy crops, such as miscanthus and switchgrass.

- The **ethanol yield** lies between 75% and 95% of the theoretical maximum.
- The entire **process energy** is generated from accumulated residues – mainly lignin. No fossil-based energy sources are used.
- The **greenhouse gas balance** is almost carbon neutral. Greenhouse gas emissions are reduced by 95% compared with fossil-based fuels.

- **No “food versus fuel” debate** – the sunliquid® process converts agricultural residues which are not suitable for either food or animal feed. Feedstocks are available from existing agricultural production, meaning that no valuable arable land has to be converted.

### sunliquid® efficiency in figures



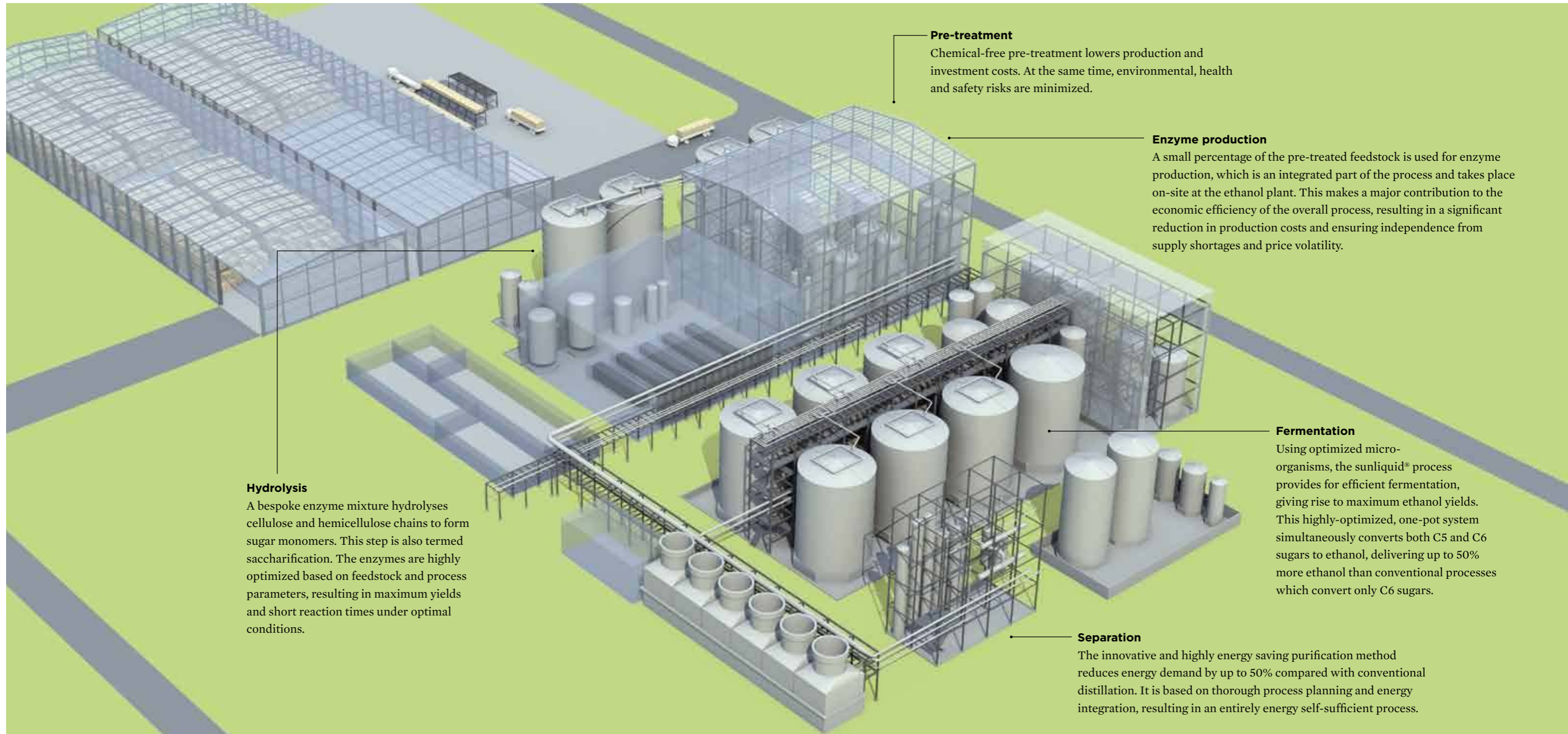
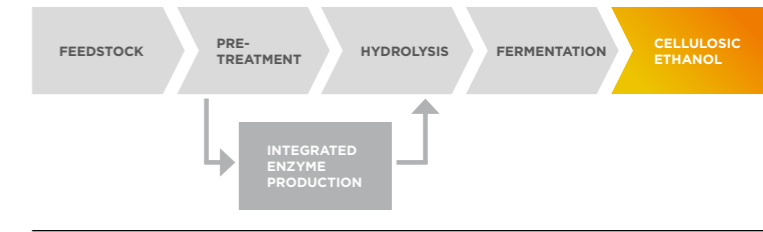
### Production costs

- Minimum enzyme costs
- No energy costs
- Biomass is the main driver for production costs
- Production costs are competitive to 1st generation bioethanol

# Complete turnkey process FOR UP TO 150,000 TONS OF CELLULOSIC ETHANOL PER YEAR

The sunliquid® process is now fully developed, being designed for industrial plants with a production capacity of 50,000 to 150,000 tons of cellulosic ethanol per year. Clariant provides the know-how and technology for all unit operations on a turnkey basis, coupled with the expertise required for successful implementation.

SUNLIQUID® - COMPETITIVE AND SUSTAINABLE CELLULOSIC ETHANOL



**Pre-treatment**

Chemical-free pre-treatment lowers production and investment costs. At the same time, environmental, health and safety risks are minimized.

**Enzyme production**

A small percentage of the pre-treated feedstock is used for enzyme production, which is an integrated part of the process and takes place on-site at the ethanol plant. This makes a major contribution to the economic efficiency of the overall process, resulting in a significant reduction in production costs and ensuring independence from supply shortages and price volatility.

**Fermentation**

Using optimized micro-organisms, the sunliquid® process provides for efficient fermentation, giving rise to maximum ethanol yields. This highly-optimized, one-pot system simultaneously converts both C5 and C6 sugars to ethanol, delivering up to 50% more ethanol than conventional processes which convert only C6 sugars.

**Separation**

The innovative and highly energy saving purification method reduces energy demand by up to 50% compared with conventional distillation. It is based on thorough process planning and energy integration, resulting in an entirely energy self-sufficient process.

**Hydrolysis**

A bespoke enzyme mixture hydrolyses cellulose and hemicellulose chains to form sugar monomers. This step is also termed saccharification. The enzymes are highly optimized based on feedstock and process parameters, resulting in maximum yields and short reaction times under optimal conditions.



# Licences and services EVERYTHING YOU NEED – FROM A SINGLE SOURCE

The sunliquid® process opens up new opportunities on the booming global market for second-generation biofuels. The potential is enormous – in the EU alone, around 25% of the demand for petrol could, according to various studies, be met by sustainably produced cellulosic ethanol as early as 2020. Clariant has already begun to issue licences for construction of commercial sunliquid® plants, as well as providing all the technology needed for their successful implementation.

Based on our expertise in the fields of biocatalysis, strain and enzyme optimisation, the customised plant concept is rounded off by a regular supply of starter cultures for enzyme production and yeast propagation, as well as all other components needed for cost-effective operation of the plant.



**COMPREHENSIVE BIOTECH KNOWHOW** The sunliquid® process owes its efficiency to the high specificity of the enzymes. These are individually optimised by Clariant experts at the Biotech & Renewables Center, in line with the relevant feedstock and processing conditions. To achieve this, use is made of the sunliquid® pilot plant, coupled with the most advanced screening and genetic engineering methods which allow up to one million biocatalyst variants to be analysed simultaneously.

**Clariant services for customised sunliquid® plants**  
Regardless of whether cereal straw or corn stover, bagasse or special energy crops are used to produce cellulosic ethanol or manufacture bio-based chemicals, Clariant adapts its flexible sunliquid® process to meet the relevant requirements and develop a suitable plant concept geared to the customer's specific needs.



**VALIDATION ON INDUSTRIAL SCALE** Since July 2012, Clariant has been validating both its technology and its biocatalysts on an industrial scale at the demonstration plant constructed in Straubing-Sand. In the case of wheat straw, validation has already been successfully completed and all other feedstocks are now to be tested here too.

**Bundled know-how – the sunliquid® licence package**  
The sunliquid® licence package provides Clariant customers with a complete turnkey process. The package includes:

- An integrated process technology package – for all unit operations in the ethanol production chain
- Starter cultures for process-integrated, on-site production of feedstock and process specific enzymes
- Starter cultures for process-optimised fermentation organisms to convert C5 and C6 sugars into ethanol
- Clariant materials for the adsorption-based separation process



**FULL-SCALE SERVICES AND TRAINING** Qualified personnel are needed to operate sunliquid® production plants. Clariant therefore offers customers full-scale staff training courses at its demonstration plant in Straubing – ensuring successful ethanol production from the first day onwards.

- sunliquid® key facts**
- High sugar yield through feedstock and process specific enzymes
  - Process-integrated enzyme production
  - Simultaneous C5 and C6 fermentation
  - Energy-saving separation technology

## CONTACT

You would like to learn more about sunliquid®? If so, we look forward to talking to you. You can reach us at:

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