sunliquid®

CELLULOSIC ETHANOL FROM AGRICULTURAL RESIDUES

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Business Line Biofuels and Derivatives
24.10.2019

what is precious to you?

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Climate change: action necessary in the transport sector

TOO MUCH CARBON IN THE AIR

In 2015, the transport sector was responsible for

23%

of the GHG emissions worldwide

and

25.8%

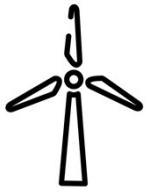
in the EU[1]

IMPLICATIONS ON THE ENVIRONMENT[2]

- Global temperature rising
- Melting of arctic ice & glaciers
- Sea level rising
- Ocean warming & acidification
- Areas below sea level becoming uninhabitable

TRANSPORT DECARBONISATION SOLUTIONS TO ACHIEVE CLIMATE AMBITIONS

Vehicle technology & efficiency



Energy infrastructure efficiency & development

Mode shift in transportation

Advanced biofuels: key role to decarbonize transport sector

[1] Source: International Energy Agency: https://www.iea.org/etp/tracking2017/transport/ and European Environment Agency: https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-greenhouse-gases/transport-emissions-of-greenhouse-gases-10#tab-related-briefings
[2] Source: NASA: https://climate.nasa.gov/evidence/

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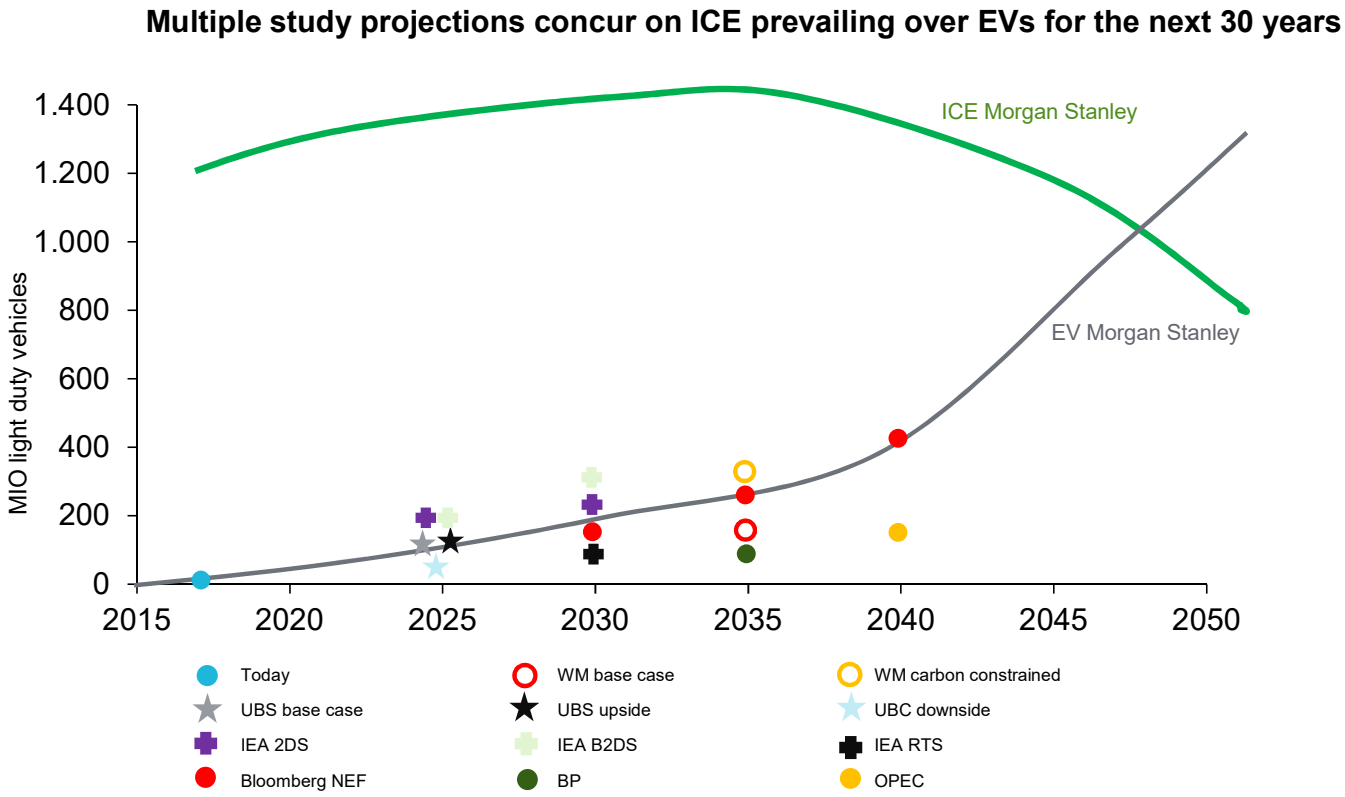
Decarbonizing transport requires multiple solutions



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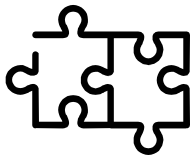
Advanced ethanol: numerous benefits to make an immediate impact on private mobility & beyond

Made from agricultural residues such as straw, non-food lignocellulosic materials & waste

Among the highest total life cycle GHG emissions
95% GHG[1] - 15 CO_2eq/MJ[2]

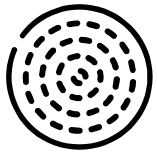
Readiness
Technology already deployed at commercial level: immediate low emission traffic



Unrivalled for use
Superior energy density also for long haul heavy duty road transport, aviation & marine

Low carbon-abatement costs
No need for large investments into infrastructure or engine adaption; immediate blend into gasoline

Contributes significantly to energy security
Domestically produced, increased energy independence & security; backbone for a long term fuel supply



Local sources & green jobs
Use of locally sourced feedstock & new revenue stream for farmers

New business opportunities from by-products
e.g. as energy source or fertilizer

[1] Cellulosic ethanol produced with sunliquid, % compared to gasoline without CO_2 CCU/S
[2] Source: https://www.biofuelsdigest.com/bdigest/2018/11/06/results-are-in-clariants-sunliquid-delivers-6x-lower-carbon-intensity-than-fossil-gasoline/ without CO_2 CCU/S

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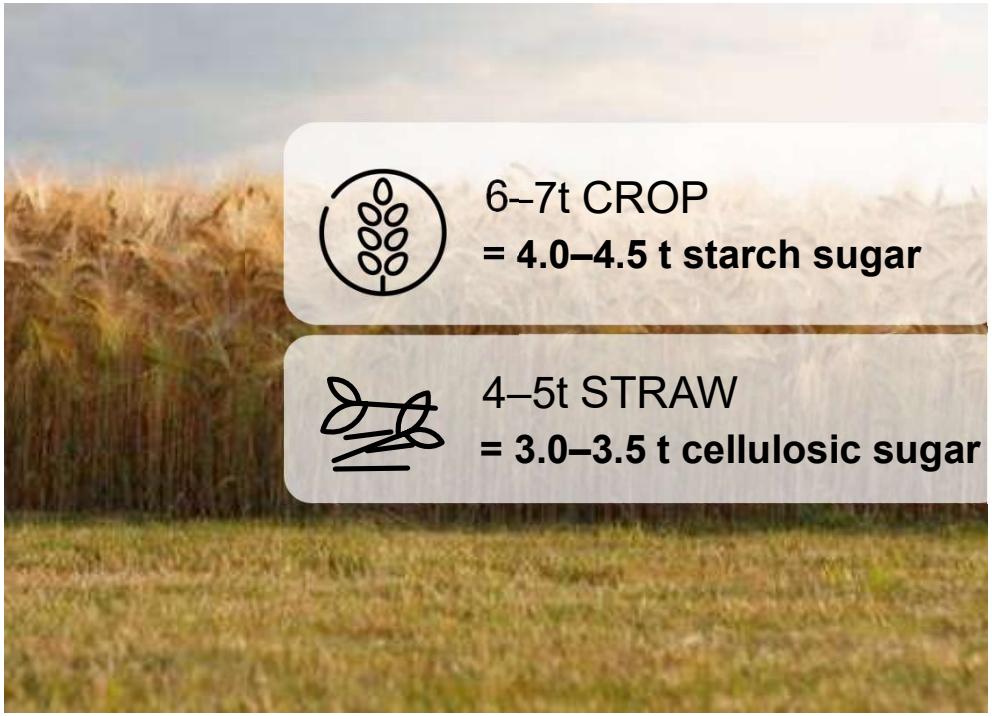
The potential of agricultural residues

What is inside one hectare of cropland?



FEASIBLE BIOMASS FEEDSTOCK TYPE

Key message: agricultural by-products are an abundant and underutilized resource

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Straw availability in Europe

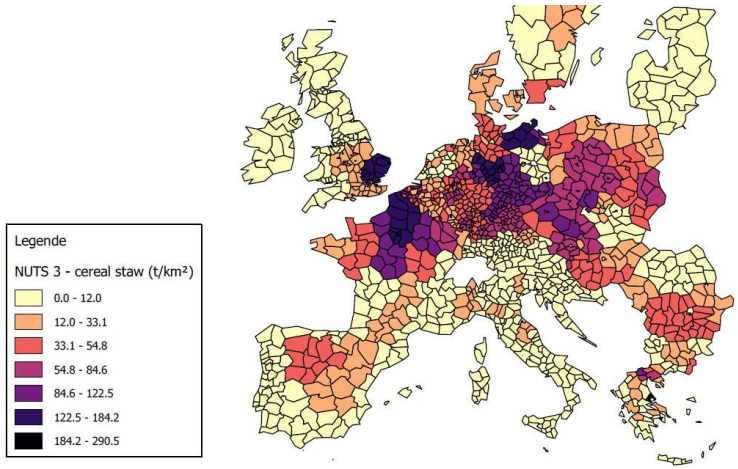
Europe has a gross straw production of around 500 million tons p.a.

International Council on Clean Transportation (ICCT)[1]

- Availability of agricultural by-products like straw in Europe in
  - 2013 at 122 millions tons
  - 2030 at 139 million tons

- By using innovative technologies, Europe could therefore already produce over 28 million tons (equivalent to about 35 million liters) of cellulosic ethanol

- Assuming an average fuel consumption and an average mileage of 15,000 kilometres per year, this could provide fuel for around 30 million vehicles per year.



Country	Wheat straw net availability in 1000 t
France	30582
Germany	19585
United Kingdom	11731
Poland	9158
Romania	8027
Italy	5711
Bulgaria	5054
Hungary	4197
Spain	4026
Denmark	3822
other EU28 countries	19382
Total	121279

[1]Source: Stephanie Searle, Chris Malins (ICCT): Availability of cellulosic residues and wastes in the EU, 2013, p. 2, available online at www.theicct.org, accessed on 20.08.2018.

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The sunliquid® technology – competitive path from feedstock to cellulosic ethanol

FEEDSTOCK | PRE-TREATMENT | HYDROLYSIS | FERMENTATION | CELLULOSIC ETHANOL

INTEGRATED ENZYME PRODUCTION

KEY ADVANTAGES and DIFFERENTIATORS

- Chemical free pre-treatment
- Process integrated enzyme production
- Simultaneous C_5/C_6 fermentation
- Fully integrated process

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Pretreatment

Background

Composition of lignocellulosic biomass makes it resistant against enzyme conversion leading to low yields and long conversion times. Therefore, a pretreatment step is essential to increase the reactivity of cellulose by disruption of its close association with hemicellulose and lignin.

State of the art

Several pretreatment technologies have been developed:

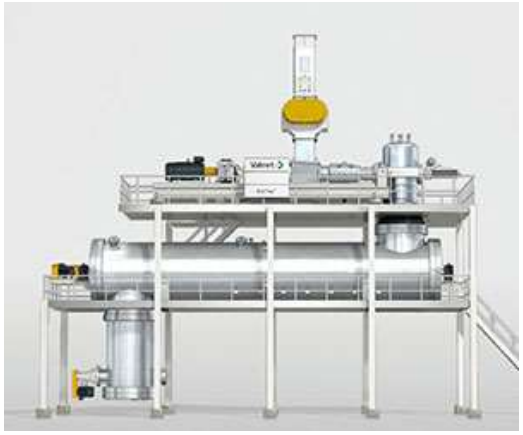
- Acid Pretreatment
- Organosolve
- Acid-Catalyzed Steam Pretreatment
- Ammonia Fiber Explosion (AFEX)
- Wet Oxidation

Drawback of these processes is that the high demand of chemicals (uneconomic) and the generation of inhibitors (e.g. Furfural) which have a negative effect on the growth of organisms, enzymatic hydrolysis, and fermentation.

Sunliquid process

Continuous and chemical free pretreatment process based on the steam explosion technology. Steam expands due to a sudden pressure drop and disrupts the cells of the biomass.

Typical conditions: high-pressure saturated steam at temperatures between 160 and 220ºC (6 to 25 bar) for 1–20 min



Source: Valmet

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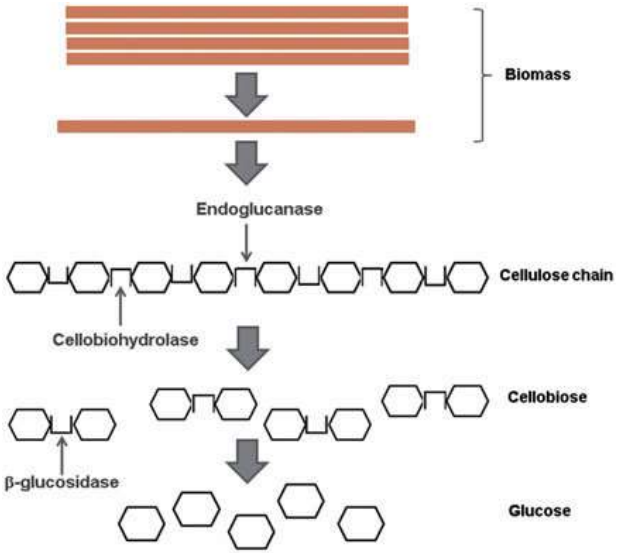
Hydrolysis

Several enzymes are interacting to breakdown the Biomass



Mixture and properties adapted to generate performance and specificity

- Selection of enzymes
- Single Enzymes (e.g. Activity, Temperature stability)
- Concentration of enzymes in the mixture

Clariant: **Feedstock and process specific enzyme mixtures**
Competitors: **Enzymes developed and produced on internal standard (e.g. acid pretreated corn stover)**

Gomez del Pulgar, Eva Maria & Saadeddin, Anas. (2013). The cellulolytic system of Thermobifida fusca. Critical reviews in microbiology. 40. 10.3109/1040841X.2013.776512.

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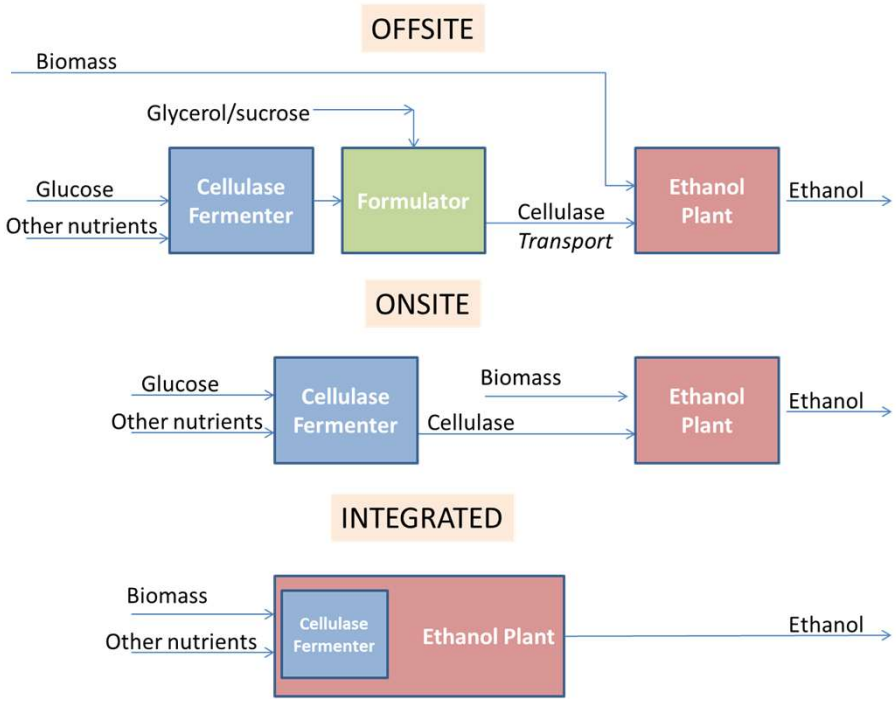
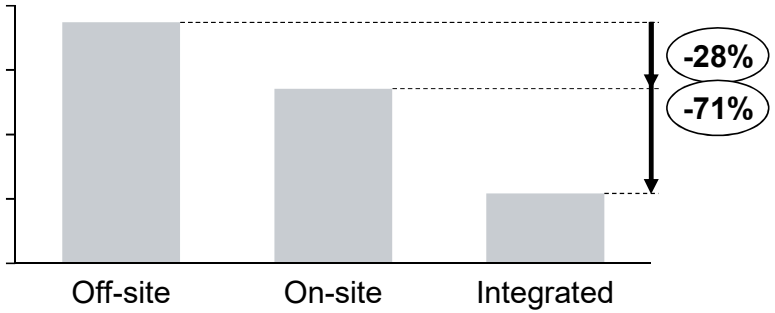
Integrated enzyme production



sunliquid®: integrated enzyme production

- Adopted production strain for producing high concentrations of enzymes using 2G sugars as carbon source
- Production strain can be adopted to different feedstocks
- Fermentation broth can be used as it is: no need of enzyme purification or concentration
- Less logistics complexity
- No dependence on availability and pricing of third party supplier

Cellulase costs



Source: E. Johnson: Integrated enzyme production costs lowers the cost of cellulosic ethanol, Biofuels. Bioprod. Bioref 10:164-174 (2016)

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High quality by-products: the underestimated value driver

LIGNIN
Good lignin quality (essential for optimizing boiler CAPEX & OPEX) thanks to chemical free pre-treatment & solid-liquid separation after hydrolysis

Lower impurities → lower sulphur and alkali metals by steam pre-treatment reduces SOx emission and flue gas treatment and improves operability and availability of boiler

High dry matter (60% dry matter) → improves energy recovery and combustion performance. No co-firing of fossil fuels required

Optimized lignin properties → impacts boiler CAPEX

sunliquid® lignin demonstrated with market leading vendors

VINASSE
Good vinasse quality enables application as organic fertilizer (preferred), or as biogas or combustion feedstock

Lower impurities → reducing sulphate

Dramatically reduces water treatment

Rich in nutrients → directly usable as valuable organic fertilizer

Organic fertilizer **field-tested and qualified in Germany**

As bio-fertilizer field test

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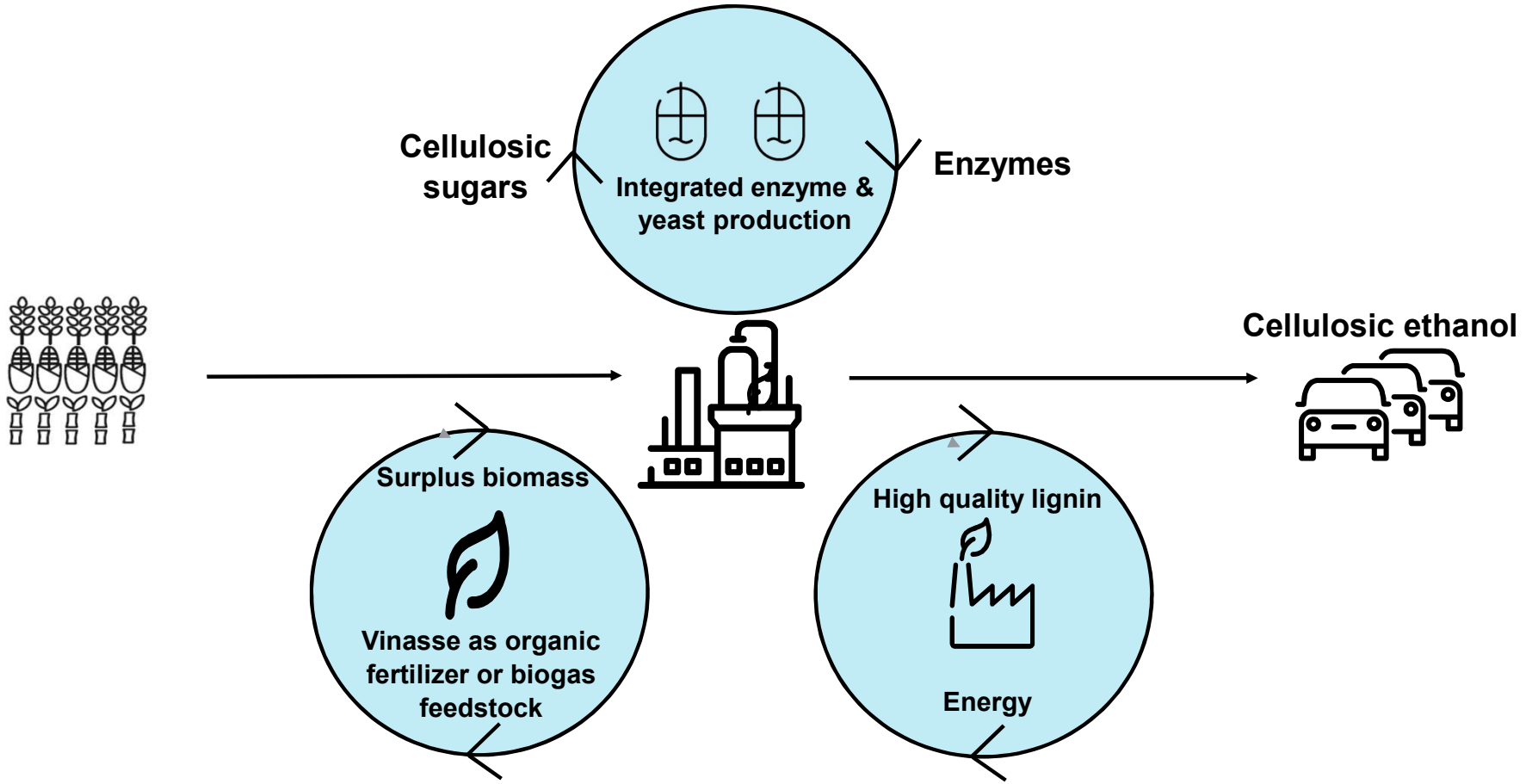
Clariant's sunliquid® integrated solution



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Climate and energy targets led to support policies for renewable energy deployment

NATIONAL ENERGY AND CLIMATE POLICY
is based on EU legislation

EU RENEWABLE ENERGY DIRECTIVE RED II

Supporting **ADVANCED BIOFUELS DEPLOYMENT**

European legislation

Part of the European Commission's »Clean energy for all Europeans – unlocking Europe's growth potential« package (Nov. 2016)

Revision of the »Renewable Energy Directive (RED II)« with focus on highly sustainable solutions in the transport sector (incl. mandate for advanced biofuels)

Legislation focus on 2G in other countries

E10 mandate by 2020 (~ 13m tons/year) with strong support from the government on non-food based biofuel and 2G ethanol demo/commercial plants

National Biofuel Policy approved/ mandated implementation of E10 by 2022; 12 2G ethanol plants mandated by the Ministry of Petroleum & Natural Gas by 2022 to be built by Indian oil companies

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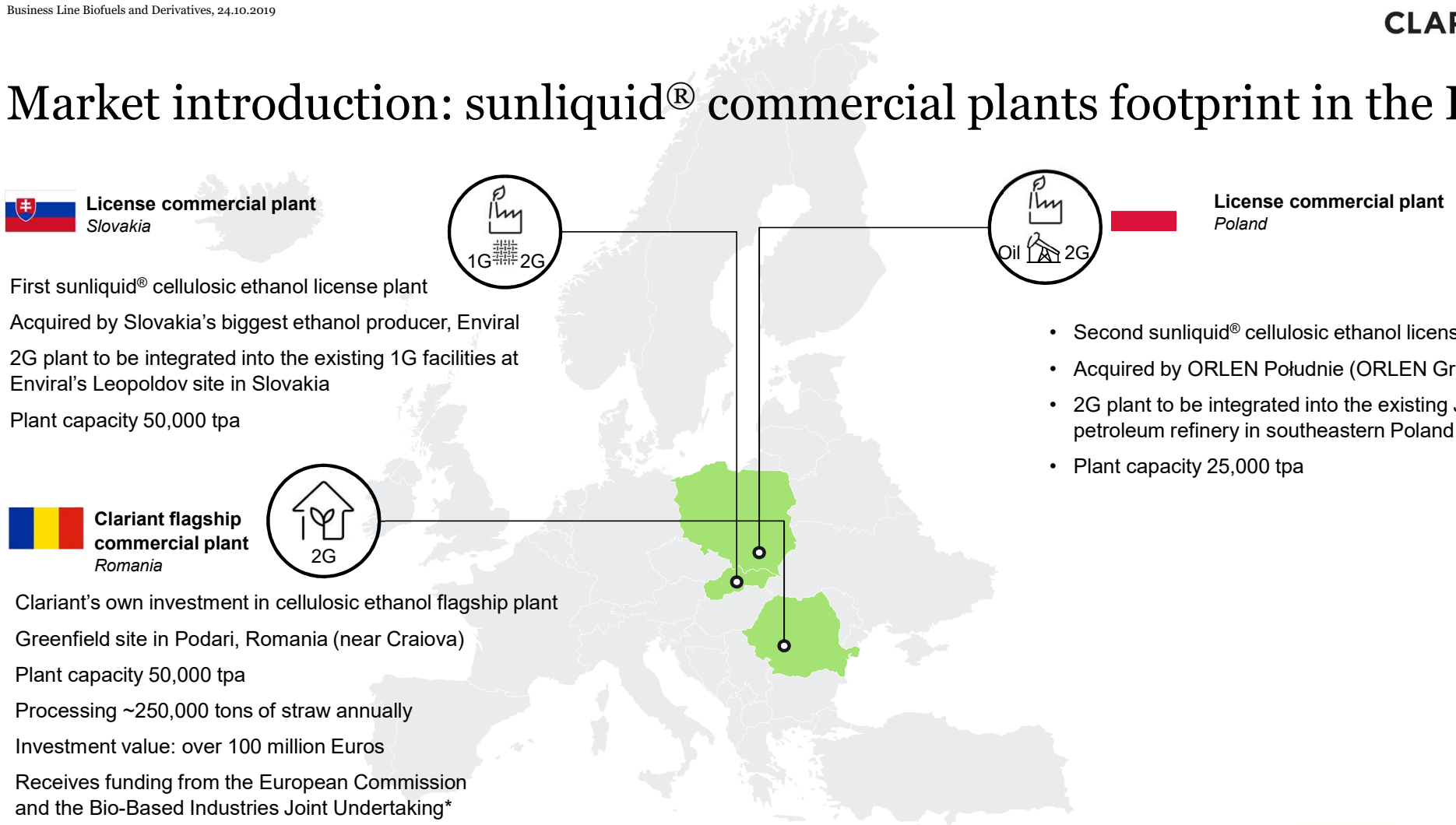
Market introduction: sunliquid® commercial plants footprint in the EU



License commercial plant
Slovakia

- First sunliquid® cellulosic ethanol license plant
- Acquired by Slovakia's biggest ethanol producer, Enviral
- 2G plant to be integrated into the existing 1G facilities at Enviral's Leopoldov site in Slovakia
- Plant capacity 50,000 tpa

License commercial plant
Poland

- Second sunliquid® cellulosic ethanol license plant
- Acquired by ORLEN Południe (ORLEN Group member)
- 2G plant to be integrated into the existing Jedlicze petroleum refinery in southeastern Poland
- Plant capacity 25,000 tpa

Clariant flagship commercial plant
Romania

- Clariant's own investment in cellulosic ethanol flagship plant
- Greenfield site in Podari, Romania (near Craiova)
- Plant capacity 50,000 tpa
- Processing ~250,000 tons of straw annually
- Investment value: over 100 million Euros
- Receives funding from the European Commission and the Bio-Based Industries Joint Undertaking*

* The project receives funding from the European Union's Seventh Framework Program for research, technological development and demonstration under Grant Agreement no. 322386 (FP7 SUNLIQUID) and from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under Grant Agreement no. 709606 (BBI LIGNOFLAG)

Horizon 2020 European Union Funding for Research & Innovation
BIO-BASED INDUSTRIES Public-Private Partnership
Bio-based Industries Consortium

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sunliquid® ethanol commercially deployed

Application as car fuel

- Gasoline-ethanol blend containing 20% cellulosic ethanol from Clariant's pre-commercial plant was tested in Mercedes' fleet
- The test showed an attractive environmental profile
- Today's vehicles can already use E20 blends

Haltermann making solutions

Mercedes-Benz

Application as truck fuel

- Partnership with Scania for the ethanol-powered trucks used at the Clariant Suzano Brazil plant
- The Ecotrucks started using second-generation ethanol produced from sugarcane bagasse using Clariant's sunliquid® technology

SCANIA

Application as cleaning agent

- sunliquid® cellulosic ethanol from straw replaces 100% of conventional ethanol in Frosch® Multisurface-Cleaner (by Werner & Mertz)
- World's first cleaning solution with cellulosic ethanol
- Selling in the local market with very positive feedback

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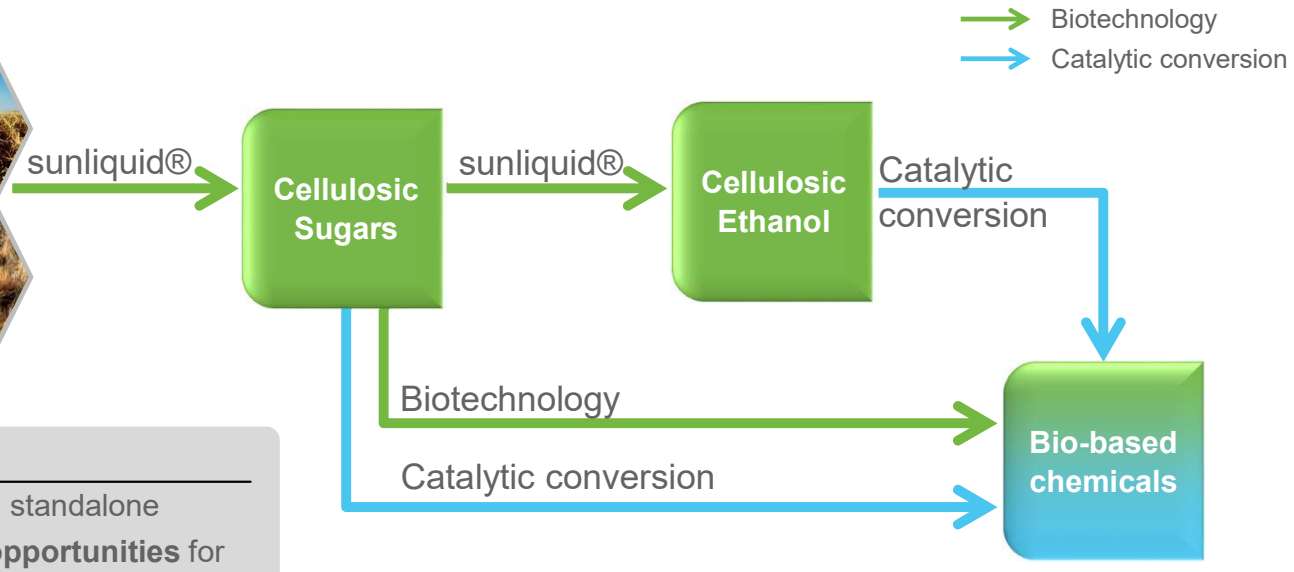
But that is not all...sunliquid® is the ideal technology platform for highly sustainable bio-based products



sunliquid®

- **Sugar platform** standalone
- **Development opportunities** for biobased products
- **Extensive know-how** in biocatalysis, strain optimization and heterogenous catalysis

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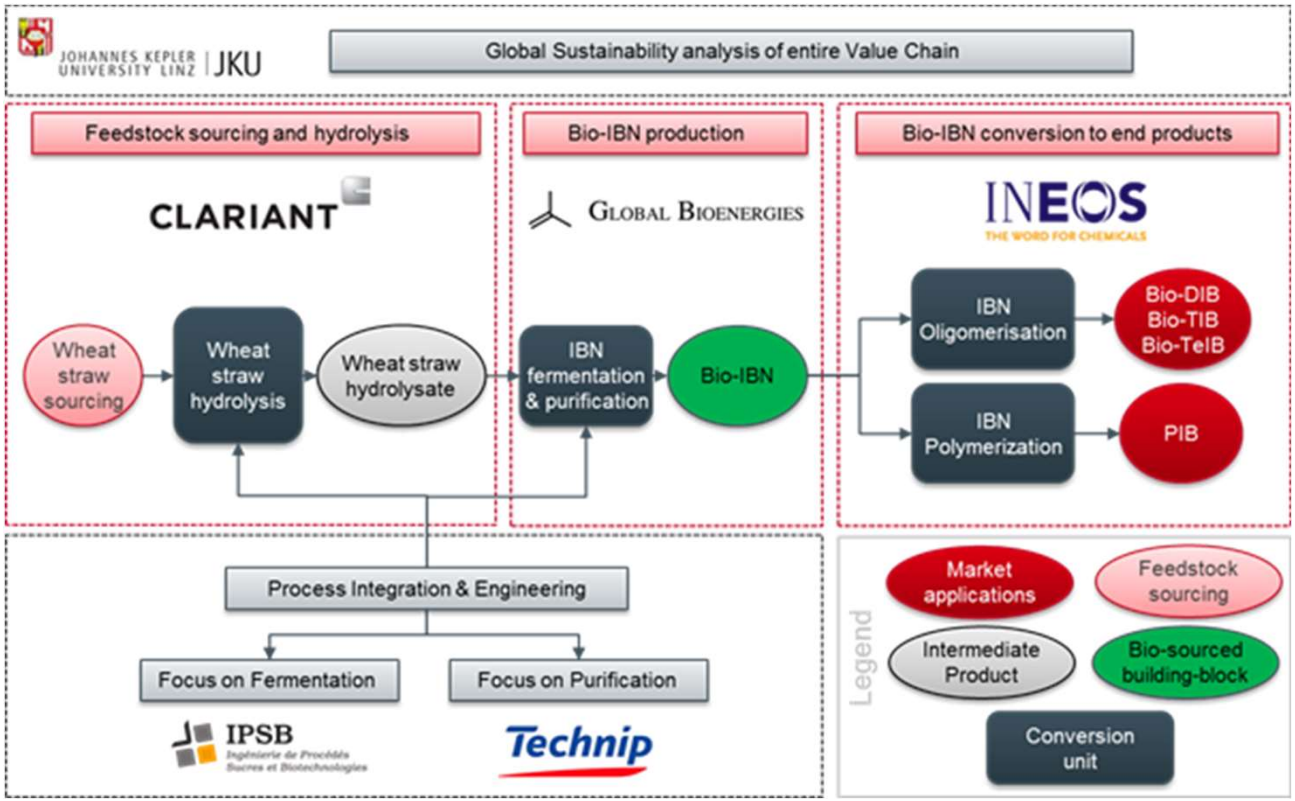
EU Funded Project: H2020 OPTISOCHEM



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Questions?

The project receives funding from the European Union's Seventh Framework Program for research, technological development and demonstration under Grant Agreement no. 322386 (SUNLIQUID) and from the Bio-Based Industries Joint Undertaking under the European Union's Horizon 2020 research and innovation program under Grant Agreement no. 709606 (LIGNOFLAG) and under Grant Agreement no. 744330 (OPTISOCHEM) .