GLOBAL BIOENERGIES

Direct fermentation to renewable isobutene, a platform to fuels and chemicals

October 2018

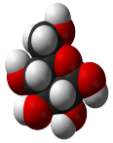
Synthetic biology at the heart of new value chains

Agro-industries | GLOBAL BIOENERGIES | Petrochemistry

Sugar beet and cane

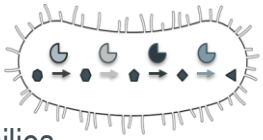
Cereals

Industrial sugars



Breakthrough innovation:

- First artificial metabolic pathway created by way of synthetic biology



Intellectual property:

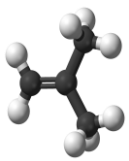
- Exclusive rights on 32 patent families
- 38 patents already granted

1 Fermentation

Breakthrough technology: direct fermentation to a gas

2 Purification

Combination of proven petrochemical modules



Isobutene

Drop-in gasoline, LPG and jet fuel

Materials, specialty chemicals, Lubricants, cosmetics

Illustrations are not representative of current Global Bioenergies' installations

Mission

Develop processes converting 1st, 2nd, and 3rd generation feedstocks into renewable fuels and materials to secure supply and limit global warming

First target: isobutene, a key platform molecule today massively derived from oil

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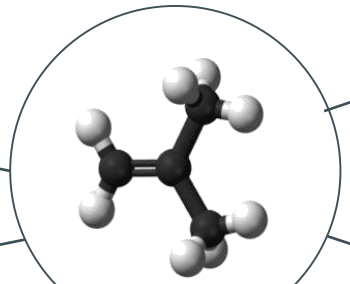
Direct fermentation to isobutene: Technology and upscaling

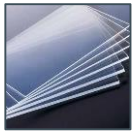
Isobutene: a platform molecule with large existing markets



Chemicals and cosmetics

Existing market $0.6bn

Organic glass



Existing market $0.8bn

Lubricant additives

Existing market $1.6bn

Butyl rubber

Existing market $2.0bn

Domestic gas

Potential market $15bn

Gasoline

Existing additives market $15bn

Potential as drop-in fuel $1000bn

Jet fuel

Existing $0bn

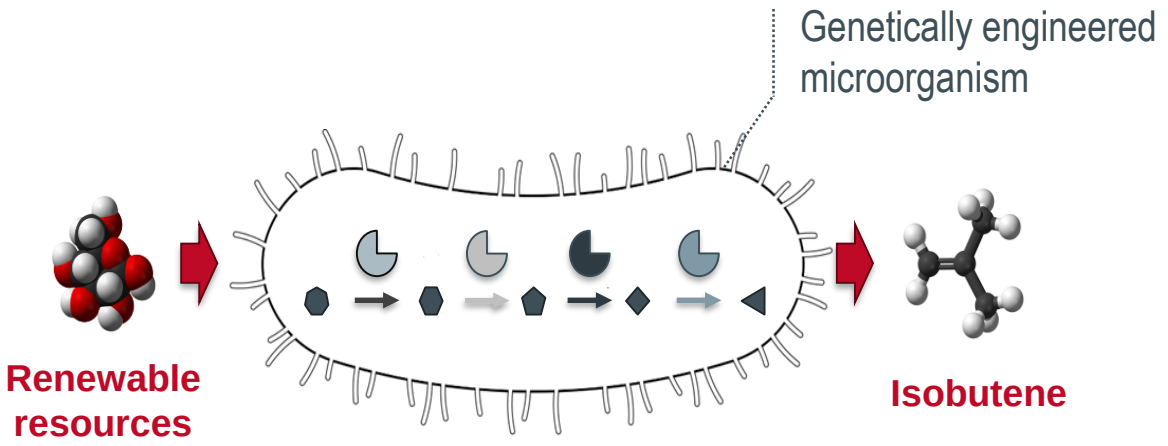
Potential $120bn

Materials 2.5 million tons/yr as of today

Fuels 12 million tons/yr as of today

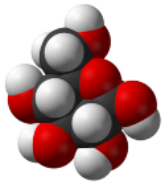
How can it be produced renewably?

- **Synthetic biology** has enabled Global Bioenergies to create "**Microbial factories**"



- This **breakthrough innovation:**
  - Opens up a new domain: the direct production of gaseous hydrocarbons
  - Is protected by 32 patent families
  - Similar approach applied to other programs on butadiene, propylene, isopropanol, …

A simple and robust industrial process



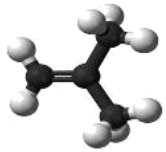
Renewable resources

1 Fermentation

Breakthrough technology: direct fermentation to a gas

2 Purification

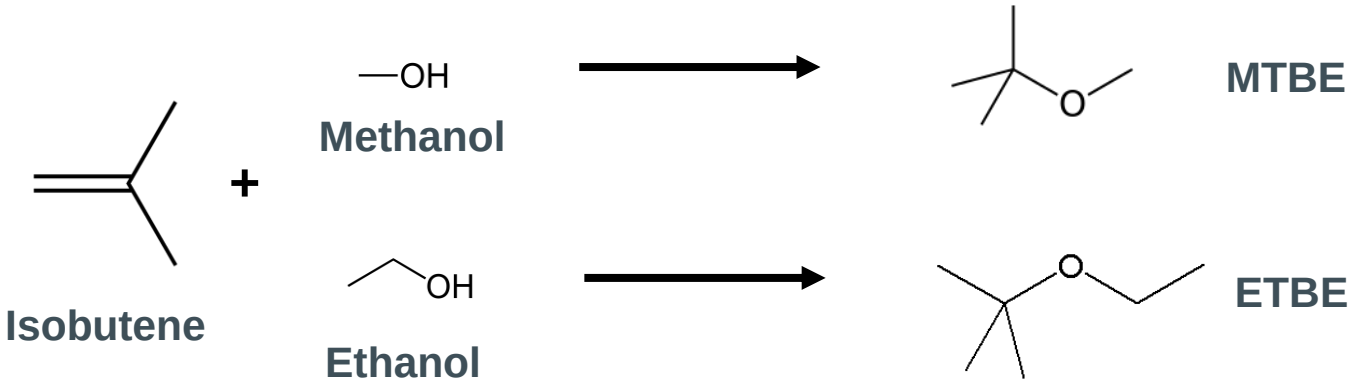
Combination of proven petrochemical modules



Isobutene

Illustrations are not representative of current Global Bioenergies' installations

Biobased MTBE, 100% bio-based ETBE

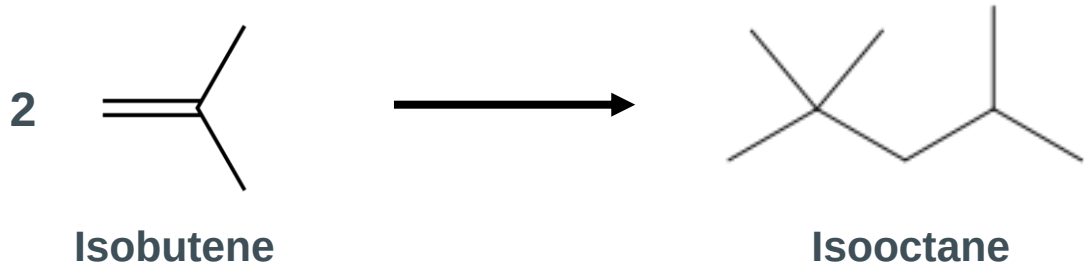


Advantages:

- MTBE counting for blending mandates
- ETBE with 2.7 times more biobased energy

- Biobased additives to avoid the blending wall

Isooctane, reference component for gasoline, bio-based



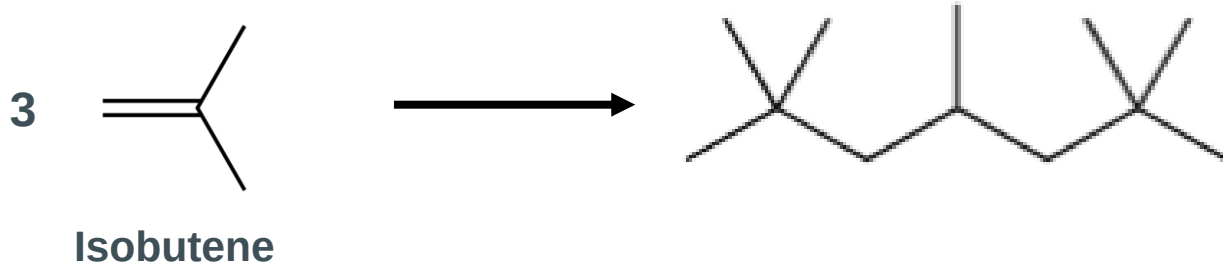
Advantages:

- The reference molecule for gasoline: octane number of 100
- High energy density (+64% vs ethanol)
- 100% drop-in, no infrastructure adaptation needed
- Sugars can be sourced from cellulose: 2nd generation and without blending wall

- **Partnership with Audi (e-benzin)**

Audi

Isododecane, a jet fuel component



- Isododecane is an isoparaffinic synthetic paraffin (i-SPK) thus has excellent cold-flow properties

Approaching commercial maturity using 1st generation resources

2009 | 2012 | 2014 | 2017 | 2020

R&D

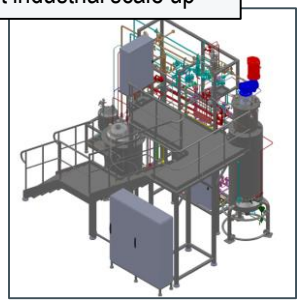
Proof of concept and prototype

Phase I
Pre-industrialization

Laboratory pilot

Phase II
Industrial pilot

First industrial scale up



Samples production

Phase III
Demo plant

Final scale up before commercial operations

Creation of the commercial technology package

Full-scale plants

IBN-One
Joint Venture with CRISTAL UNION

IBN-Two

IBN-Three

IBN-Four

IBN-n

Demonstration plant - Leuna, Germany

- **The demo plant a glance**
  - Capacity: 100 tons/yr
  - CAPEX: €10m
  - €5.7m public financing
  - €4.4m bank loan
  - Operated by Fraunhofer CBP
  - Startup sequence started December 2016
- **Objectives**
  - Demonstrate process on 1st generation industrial sugars
  - Deliver ton scale batches for market development
  - Provide data for engineering of 1st commercial plant
  - Start testing 2nd generation sugars

IBN-One

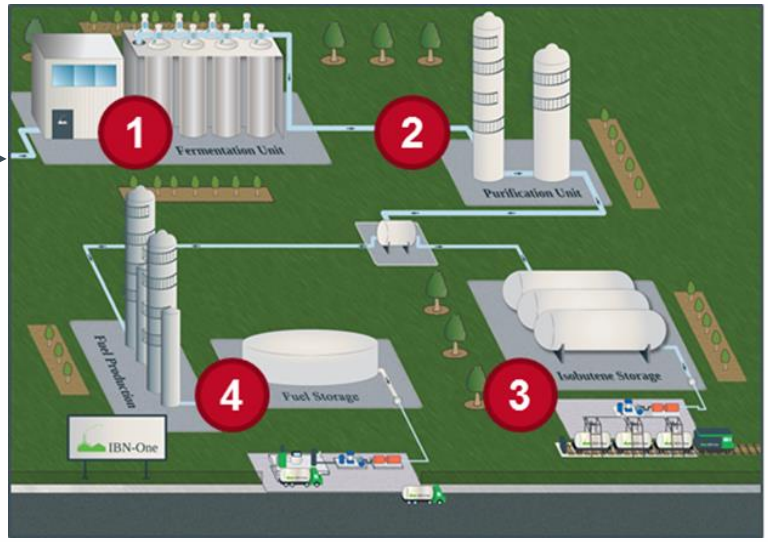
A Joint Venture with CRISTAL UNION

IBN-One: first commercial plant project

- Supported by the ADEME *Investissements d'Avenir* program
- Estimated CAPEX: €115 million to be funded by
  - Cristal Union
  - Public & Private infrastructure funds
  - Banking debt
- Engineering studies: TechnipFMC, IPSB
- Commercial operations to start in 2021
- First agreements signed with L'ORÉAL, ASPEN, Butagaz

1. **Production** – 120-200Kt industrial sucrose are converted into 30-50Kt gaseous, low purity isobutene
2. **Purification** – isobutene is isolated from surrounding fermentation gases
3. **Shipping** – Liquid high purity isobutene (99.7%) is stored and shipped for chemical applications
4. **Conversion** – Part of the production is converted on site into bio-fuels

Sugar mill



Collaborations on isobutene derivatives

Since 2012

Audi

Leading German car manufacturer

Collaboration on '*e-gasoline*' development

Since 2013

ARKEMA INNOVATIVE CHEMISTRY

France's #1 chemicals company

Collaboration on methacrylic acid

Since 2016

L'ORÉAL

World's #1 cosmetics company

Collaboration on cosmetic applications of Isobutene

Since 2017

Butagaz

Leading French gas provider

Commercial agreement on domestic gas applications

Since 2016

ASPEN Fuel for professionals

Leader in specialty fuels

Commercial agreement on isooctane for small engines

Applications tests underway at numerous industrialists including

ARLANXEO Performance Elastomers — World's #1 Butyl rubber manufacturer

CLARIANT — European leader in specialty chemicals

Biobased isobutene into butane : first bottles sold by Butagaz in France

Biobased isobutene into gasoline : first car (Audi A4) driven on renewable gasoline

- A standard Audi A4 car was driven on a blend containing 34% renewable gasoline (from renewable isooctane and ETBE derived from green isobutene)
- Compliant with EN228 European norm for gasoline → **could be sold on the market**
- High performances (high octane number), and possibly reduced particles emission.

Feedstock diversification: sugars from residues

Isobutene from agricultural residues: Optisochem project

Straw

CLARIANT

Hydrolysate

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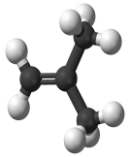
Isobutene



INEOS

Cosmetics, Plastics, Solvents, Lubricants

- European consortium to validate a new value chain (from straw to isobutene-derived products) at Demo scale
- European Union grant: €9.8m (including €4.4m to Global Bioenergies)

Horizon 2020 European Union Funding for Research & Innovation

Bio-based Industries Consortium

BIO-BASED INDUSTRIES Public-Private Partnership

- Partners: Global Bioenergies, Clariant, Ineos, TechnipFMC, IPSB and JKU

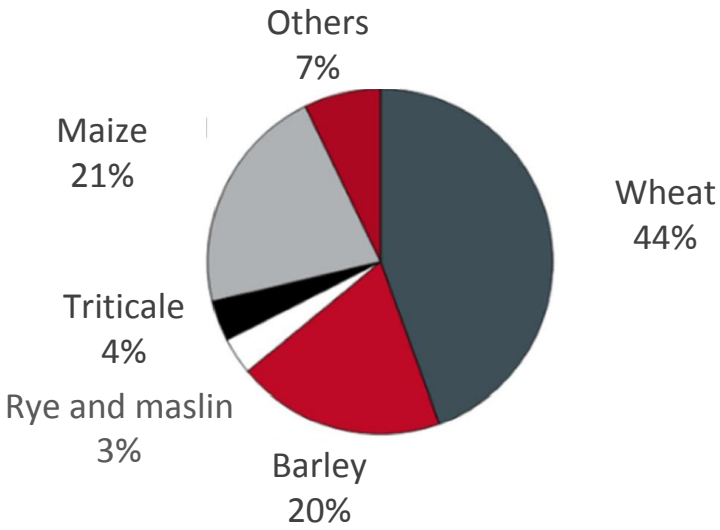
TechnipFMC

IPSB Ingénierie de Procédés Sucres et Biotechnologies

JKU JOHANNES KEPLER UNIVERSITÄT LINZ

Straw availability in Europe

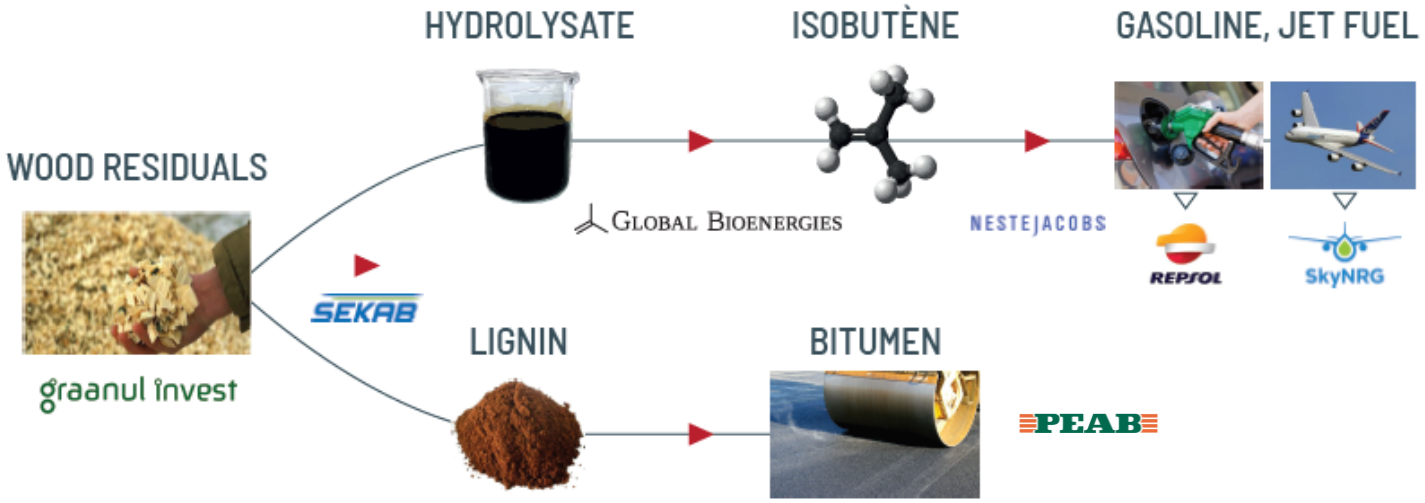
European agricultural residuals origin (2014)



Total production of residuals:
366 million tons

- European cereals production generates 366 million tons per year of residuals (wheat straw, corn stover, …).
- From these 366 million tons, up to 122 million tons of residuals could be sustainably available every year for chemicals and biofuels usage.
- Out of wheat straw, ~45% of the content can be extracted as sugars, ~36% as lignin (available as bioenergy or for materials). ~55 million tons of 2G sugars available from agricultural residuals.

Isobutene from forestry residues: Rewofuel project



- European consortium to validate a new value chain (from wood residuals to drop-in biofuels) at Demo scale
- European Union grant: €13.9m

Horizon 2020
European Union Funding
for Research & Innovation

- Partners: Global Bioenergies, Graanul invest, Sekab, Neste Engineering Solutions, Repsol, SkyNRG, Ajinomoto Eurolysine, Peab, TechnipFMC, IPSB and JKU

Forestry residues available in Europe

Forestry residues European Union; 2015				
Harvest residues (kt/a)	**coniferous**	**non-coniferous**	**Residues from sawnwood production (Kt/a)**	
Branches and various cut-off	36.047	26.587	Saw-dust	10.488
Bark	13.045	5.400	Wood chips	28.602
Foliage	19.905	3.570		
Total	**68.998**	**35.558**		**39.089**

- Availability of wood harvest residues in Europe (2015): 105 Mt per year. Availability of residues from sawn-wood production is estimated to be about 39 Mt per year in Europe → Total feedstock availability of 144 Mt per year in Europe.

- Out of 160 Mt of gasoline + jet fuel consumed every year in Europe, the REWOFUEL project holds the potential to produce millions of tons of drop-in fuels (gasoline and jet fuel),

Contact

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