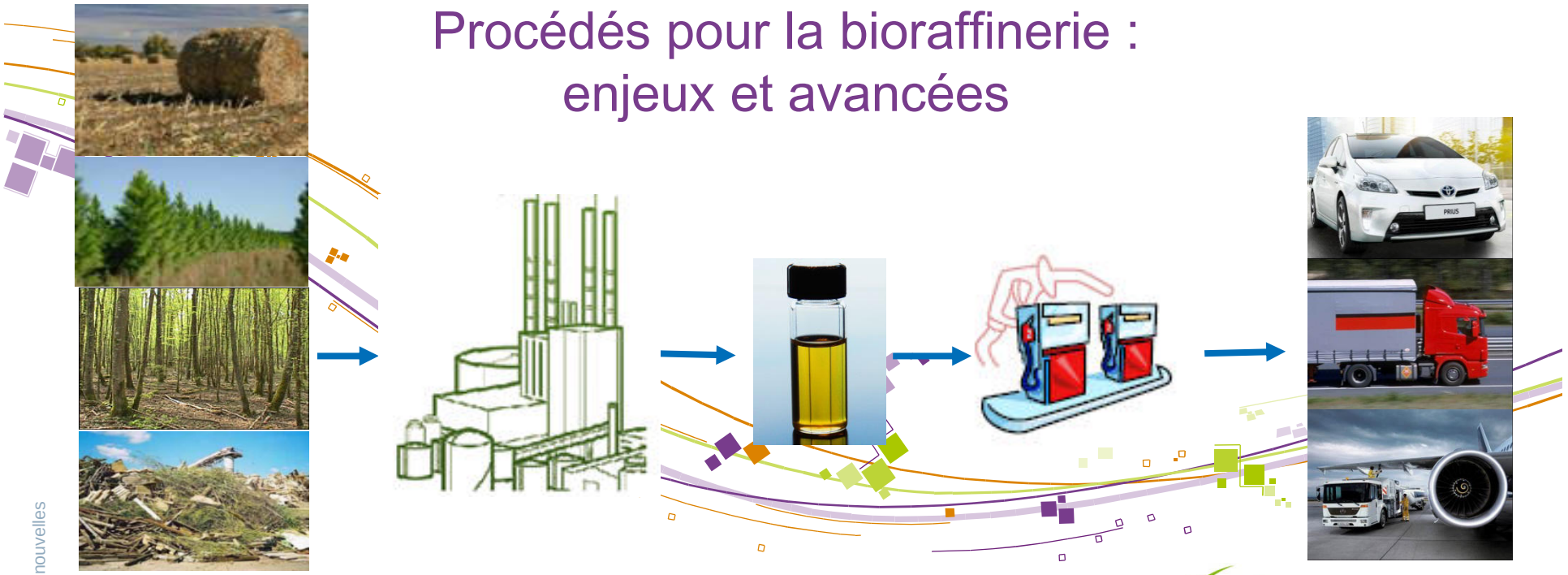
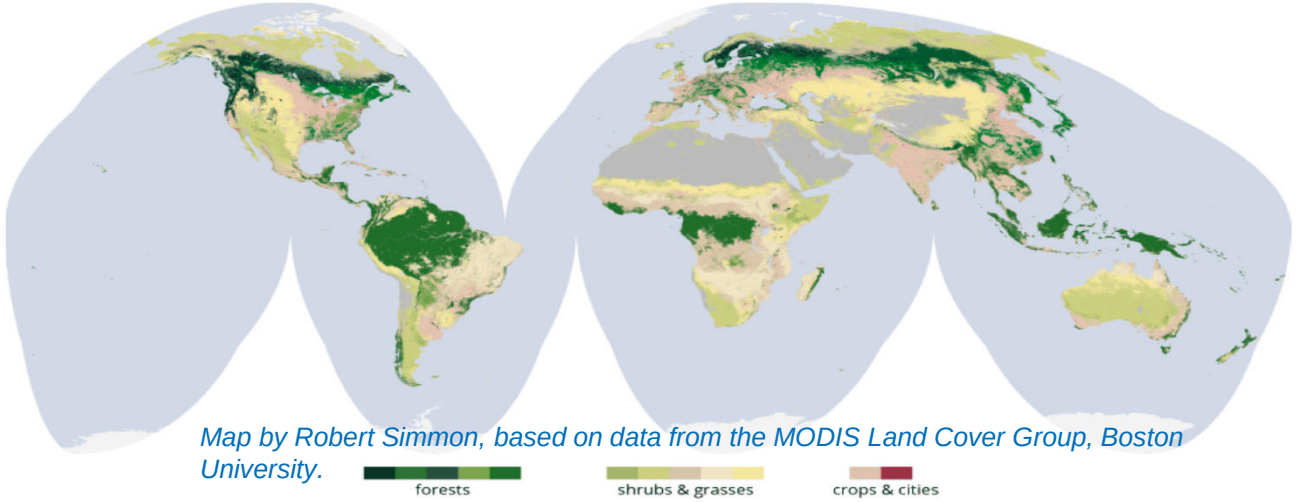
Biomass to 2G Biofuels and Bio-products Processes developed at IFPEN: an overview

Journée J3P
Procédés pour la bioraffinerie : enjeux et avancées



A. Quignard, Nancy, 9 Juin 2015

Ligno-cellulosic Biomass Availability



Map by Robert Simmon, based on data from the MODIS Land Cover Group, Boston University.

- Abundant & Affordable resources all around the World
  - 2G biomass at a lower cost than 1G feed without competition with food
  - Sustainable biomass avialability in 2030: 1,5 to 2 Gtep (IFPEN study)
  - 2G Biofuels:
    - a viable alternative to protect the environment : ~ - 60 to 95% GHG emission v/s fossil
    - a credible alternative for the industrial fuels and chemicals markets
- But
  - 2G Biofuel production remains a scientific, technical & industrial challenge
  - Only at an early stage of industrialization for a few processes

2G Biofuels Development in IFPEN

↳ No with competition with food

↳ Uses the full plant

Temperature (°C)

Agricultural (straw) &agricultural/forest residues

(Oxygen : 40-45 %pds[1])

(HHV : 16-19 MJ / kg[1])

Dedicated crops (Fast Growth Coppices)

1400

700

500

300

< 100

Syngas

(CO, H_2, CO_2, CH_4)

Fischer-Tropsch Synthesis

(HHV_{HC} ≈ 44 MJ / kg[4])

Gasification

Thermo-chemical Liquefaction

Fast Pyrolysis

($HHV_{Bio\text{-}oil}$ ≈ 18-20 MJ / kg[1])

Liquéfaction under P + solvent

(Water[2], alcools, formic acid, salts)

Upgrading

Thermo-Catalytic conversion

Cat. Pyrolysis, Hydropyrolysis, …

Bio-chemical Route with Enzymatic Hydrolysis

Fermentiscible sugar extraction

Alcoholic Fermentation

Bioethanol

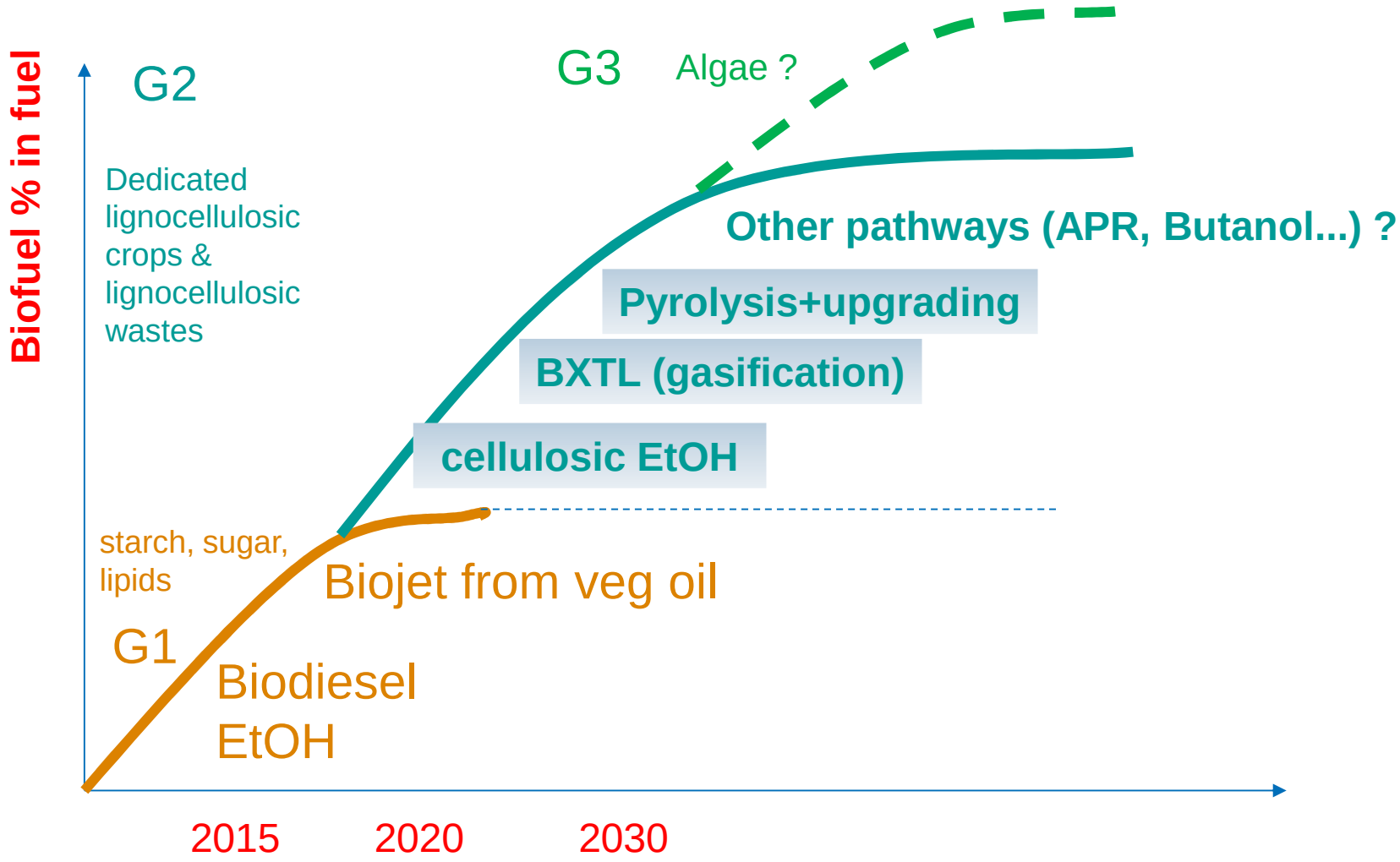
($HHV_{éthanol}$ ≈ 30 MJ / kg[1])

Blend with Jet Fuel / Diesel

Blend with Gasoline

[1][Huber et *al.*, 2006] [2][Goudriaan et *al.*, 2000] [3][Kleinert et *al.*, 2008] [4] [Norton et *al.*, 1998]

Road Map for Biofuels Incorporation



2G Ethanol Futurol Project

R&D ACTORS

ard
INNOVATION IN GREEN

IFP Energies nouvelles

INRA
SCIENCE & IMPACT

LESAFFRE GROUP

INDUSTRIAL ACTORS

VIVESCIA
l'innovation par nature

Office National des Forêts

Tereos

TOTAL

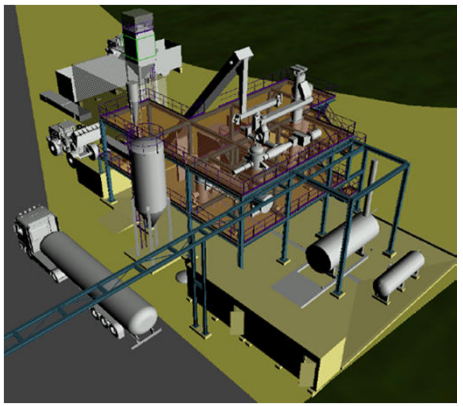
FINANCIAL ACTORS

CA NORD EST

CGB
CONFEDERATION GENERALE DES PLANTEURS DE BETTERAVES

UNIGRAINS

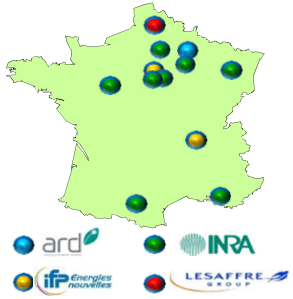
Pilot Plant 1t/j POMACLE
BAZANCOURT Bio-refinery site

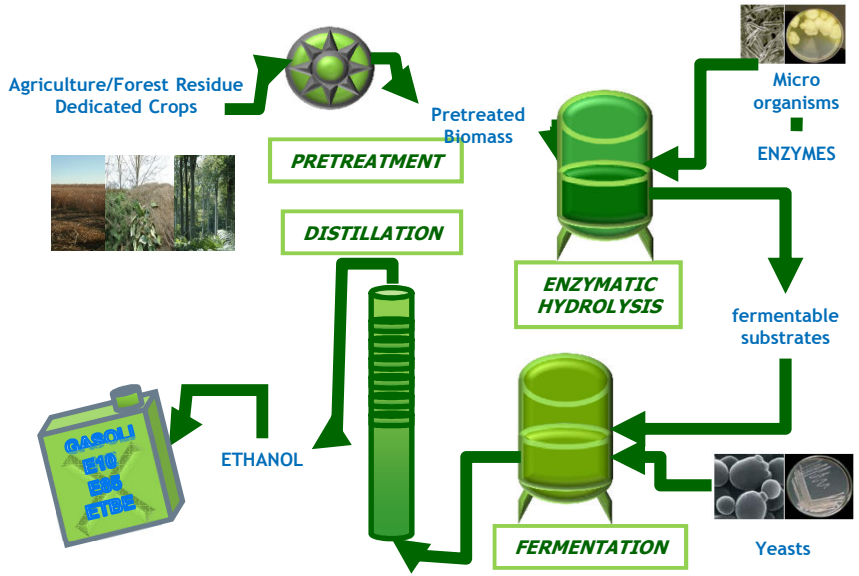


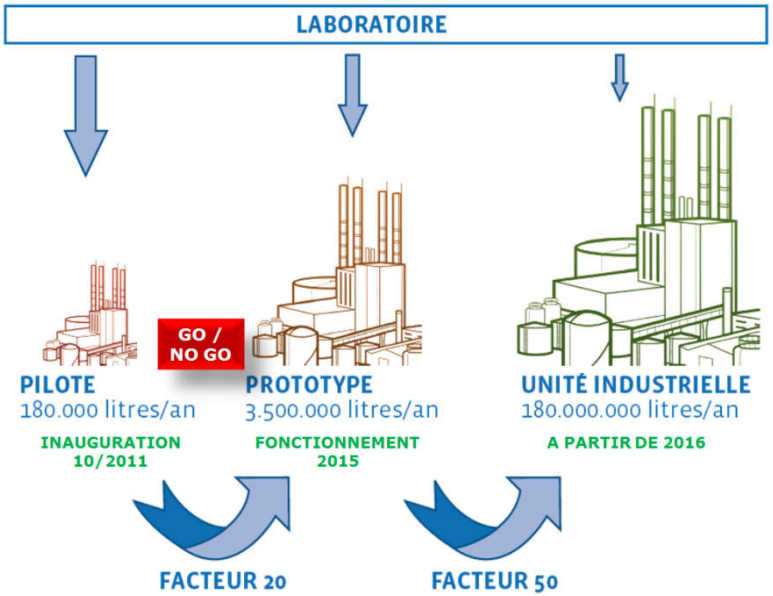
Prototype Futurol100t/j (Bucy le long)
Under construction

2G Ethanol Futurol Project

- **Objective** : to develop a 2G Ethanol process from ligno-cellulose from agricultural & forest co-products or dedicated crops, for biofuels & chemicals
- 11 partners/leaders
  - R&D (4 ~100 researchers & engineers)
  - Industry (4)
  - Finance (3)
- Up-scaling 2015-2016
- Commercialization from 2016 by Axens







2G Ethanol Futurol Project
Process commercialization by Axens

Axens Process Licensing

Futurol™

SIMPLE, INTEGRATED CELLULOSIC ETHANOL PRODUCTION TECHNOLOGY

INTRODUCTION

The chemicals and transportation fuel sectors are facing multiple challenges: reducing their dependence on petroleum resources with cost competitive solutions and addressing today's environmental concerns – sustainability and lower greenhouse gas emissions.
Futurol™ technology addresses these challenges through the production of 2nd generation (2G) bio-ethanol from various biomasses suitable for fuel and chemical applications alike.

THE FUTUROL PROJECT

Futurol technology has been developed since 2008 by a consortium of 4 R&D partners (IFP Energies nouvelles, INRA, Lesaffre and ARD), backed by seven industrial and financial partners. Their expertise covers the whole production chain, from biomass cultivation and transformation - through biocatalyst development and selection - to the development and industrialization of fuels and petrochemical production processes.

Futurol's pilot plant is located at the Bazancourt-Pomacle biorefinery, near Reims (France). In activity since 2011, the 5,000 m² facility benefits from a unique agroindustrial environment.

PROCESS DESCRIPTION

Bio-ethanol production through Futurol Technology is a simple and integrated 4-step process *(Figure 1)*.

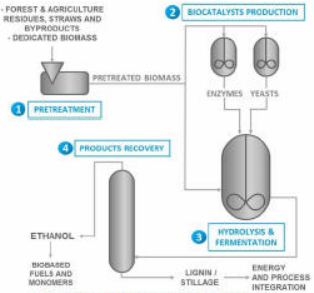


Figure 1: Futurol Simplified Process Flow Diagram

1- Pretreatment
An energy-efficient, single-train, continuous technology was selected and optimized for converting biomass feedstock such as energy crops, agricultural and wood residues to a standardized pretreated substrate, highly digestible and with low moisture. High hemicellulose conversion is attained, while product degradation is minimized.

2- Biocatalysts Production
Inhibitors resistant proprietary tailor-made biocatalysts (enzymes and yeasts) were designed, adapted and improved to optimize process performances. Futurol technology offers on-site enzyme production and yeast propagation using lignocellulosic substrate, which strongly contributes to ethanol production cost reduction.

Axens
IFP Group Technologies

Axens Process Licensing

3- Hydrolysis and Fermentation
Enzymatic hydrolysis of biomass and co-fermentation of C_5 and C_6 sugars take place simultaneously in the same vessel ("one-pot" process). This process configuration capitalizes on a unique synergy between biocatalysts and allows for both CAPEX and OPEX minimization while achieving high ethanol yield through full conversion of C_5 and C_6 sugars.

4- Products Recovery
State of the art distillation and dehydration allow recovery of 2G ethanol suitable for bio-fuel applications or for further processing in chemical production. Lignin and stillage are recovered and routed to energy production while water is recycled.

KEY FEATURES

- **Simplicity and Robustness**
  Futurol technology produces cellulosic ethanol thanks to a compact scheme with few production steps and simplified operations: single-train pretreatment, one-pot hydrolysis and fermentation.
- **Integration and Cost Competitiveness**
  Energy and water management, as well as on-site biocatalysts production and propagation, were designed to make Futurol technology cost competitive, in line with 1G bio-ethanol production costs *(Figure 2)*.
- **Biomass Flexibility**
  Futurol technology has been developed and tested on a wide range of biomasses. This makes the technology suitable for worldwide deployment by processing any locally available resources and taking advantage of any feedstock opportunities.

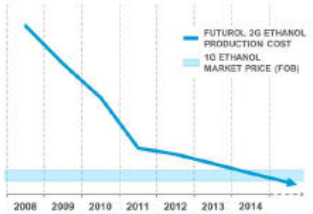


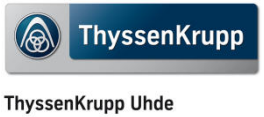
Figure 2: Futurol Bio-Ethanol Production Cost Evolution

COMMERCIALIZATION

Axens has been selected as the single source supplier for Futurol technology commercialization because of its world renowned expertise in process licensing, associated services and ability to provide dedicated customer support throughout the entire plant life.
Futurol technology is part of Axens' portfolio for the production of bio-based chemicals and fuels, a field in which the company has been a pioneer since the early 90's.

information@axens.net
www.axens.net

2G Biojet fuel & biodiesel BTL Project

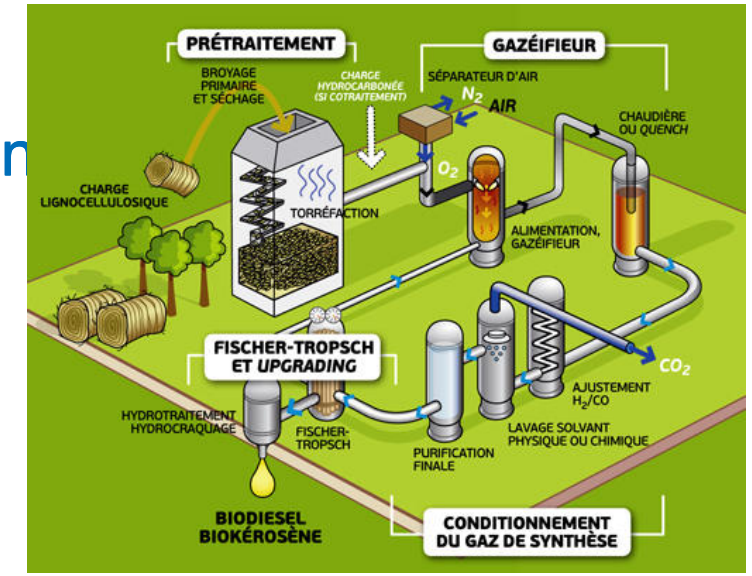


2G Biojet Fuel & Biodiesel BioTfueL project

- Objective
  - to develop a flexible, competitive , environmental friendly and robust full BTL process centered on 2G biojet fuel & biodiesel process
  - from ligno-cellulose from agricultural & forest co-products or dedicated crops



- An outstanding partnership between R&D, licensors & fuel/ biofuel producers
  - Axens, CEA, IFPEN, Avril (ex Sofiprotéol), ThyssenKrupp, Total



- Demo (70 tpd feed)
  - Dunkerque Total site + Avril Venette
  - Under construction 2015 / Starting 2017

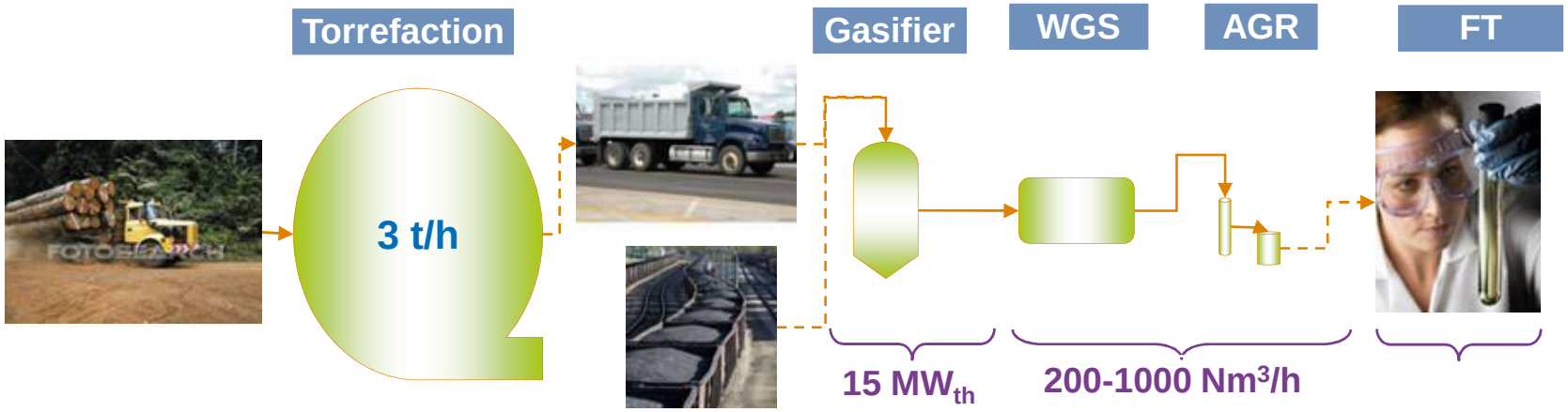
BioTfueL R&D project feature

2 demo on 2 different sites

Multi-scale unit to:

- obtain scale-up rules
- validate several process configurations
- Be applied for industrial cases

Demonstration



Avril Compiègne/Venette

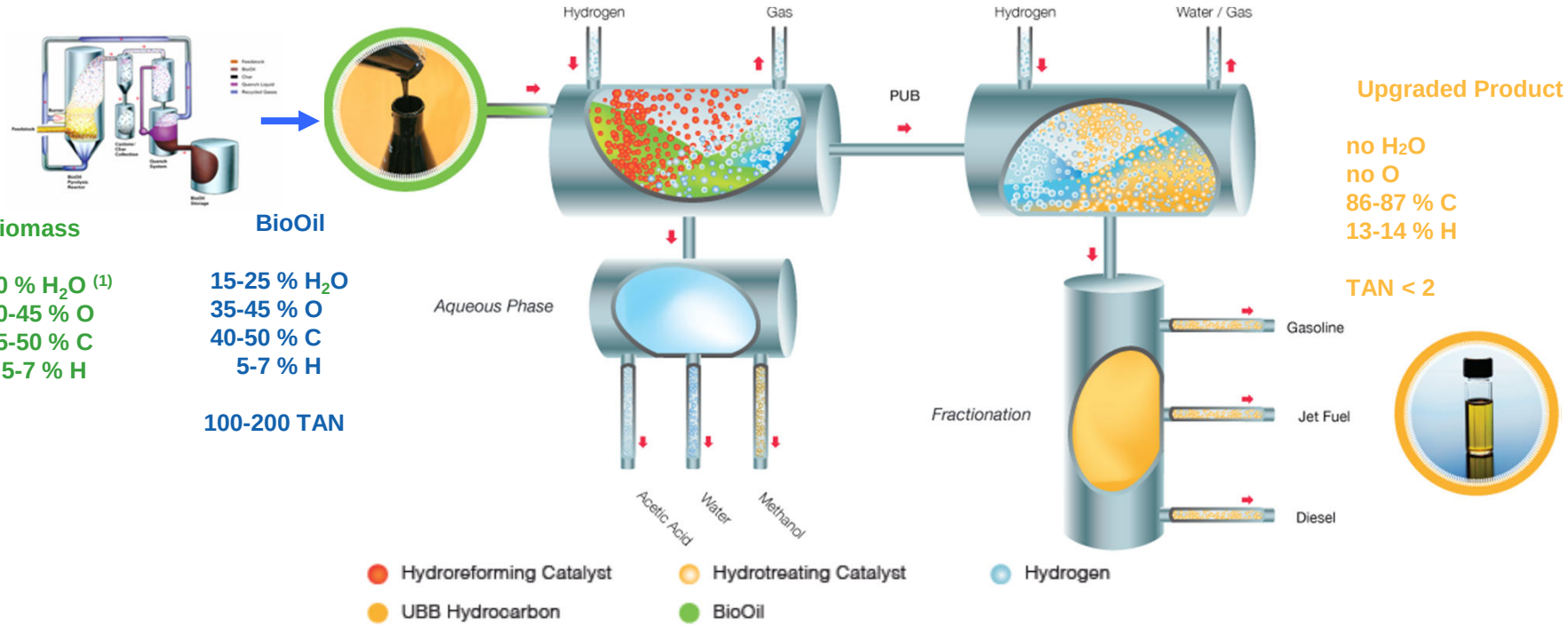
Total RM France (DK site)

Multiple scale Demo plants

2G Biofuels CLHUB project

Catalytic Low Hydrogen Upgrading of BioOils

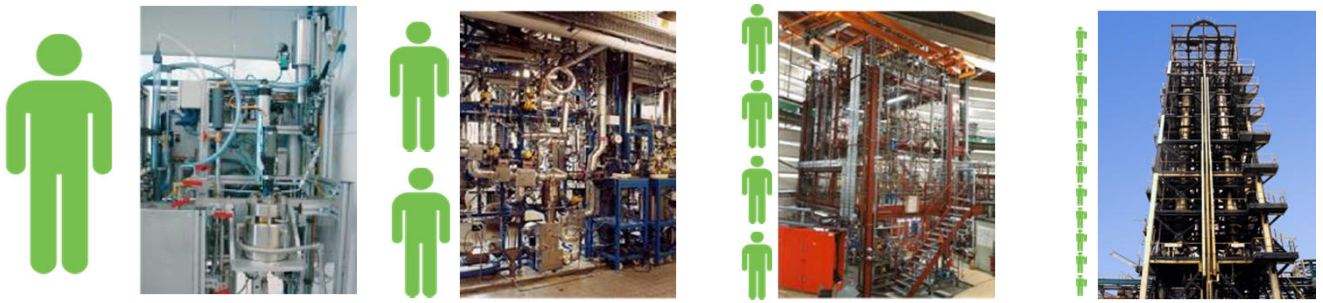
- **Objective**
  - to develop a flexible, competitive , environmental friendly and robust full Bio-oil / Bio-crude upgrading process to produce 2G biofuels (gasoline, jet fuel & diesel) from pyrolysis bio-oils (demonstrated at industrial level), or bio-crudes, issued from ligno-cellulose from agricultural & forest co-products or dedicated crops
- **Development of a new 2 stages upgrading process with a low H_2 consumption**



(1) *Biomass feed for fast pyrolysis typically dried at 10%*

2G Biofuels CLHUB project

- Partnership : Axens, Dynamotive, IFPEN
  - End of R&D: 2020
  - Industrialization: from 2022



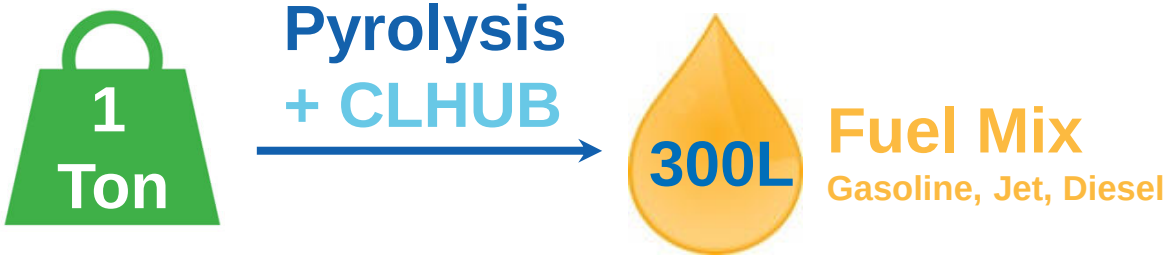
Autoclave
~ 1/10,000,000

Small Pilot Plant
~ 1/100,000

Medium Pilot Plant
~ 1/10,000

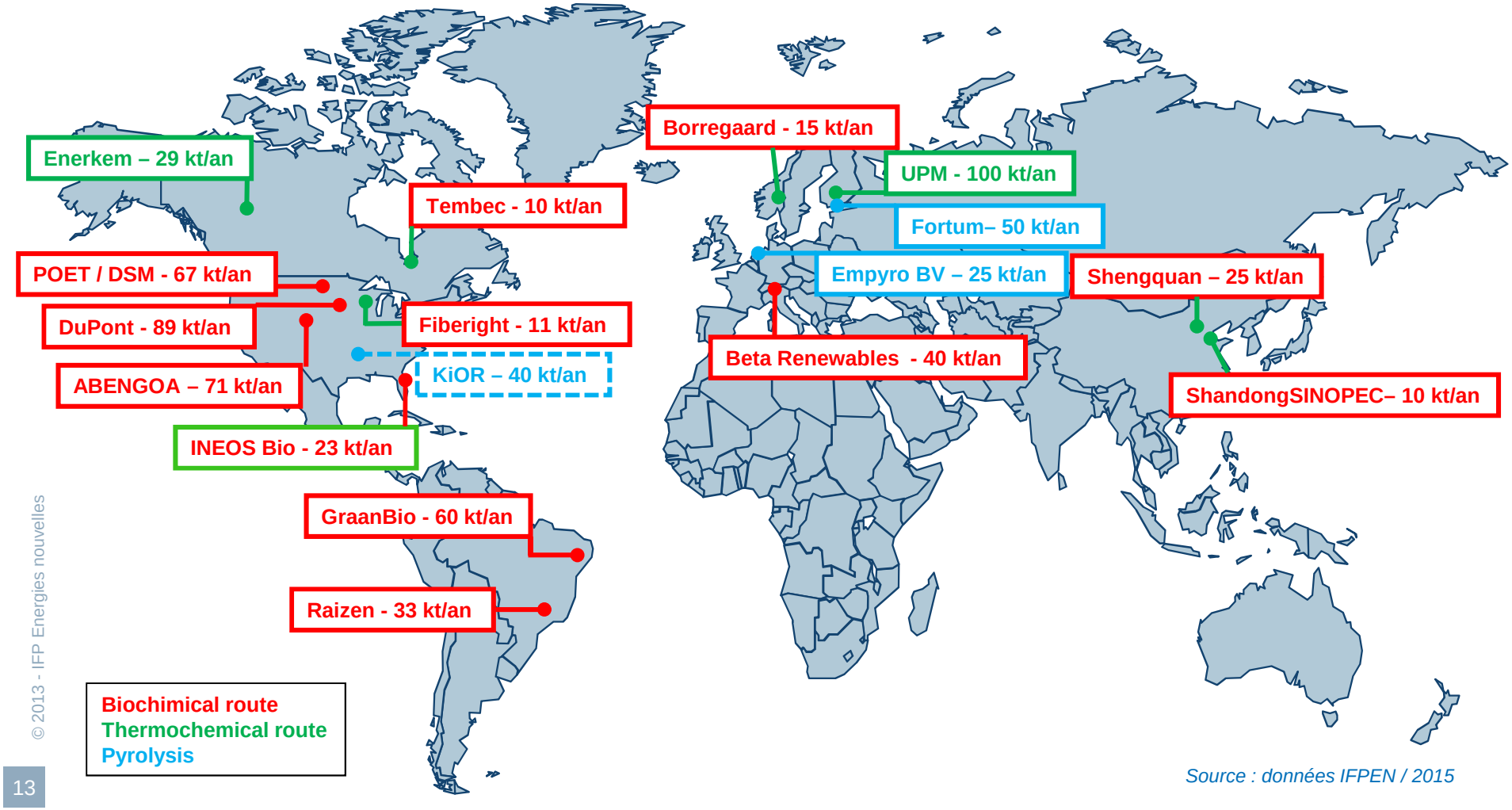
Industrial Plant
1/1
500-2,000 T/D

- CLHUB Process advantages
  - Logistical (transporting liquid products) advantages
  - High 2G-Biofuel yield v/s biomass and v/s existing Biomass to Biofuel processes



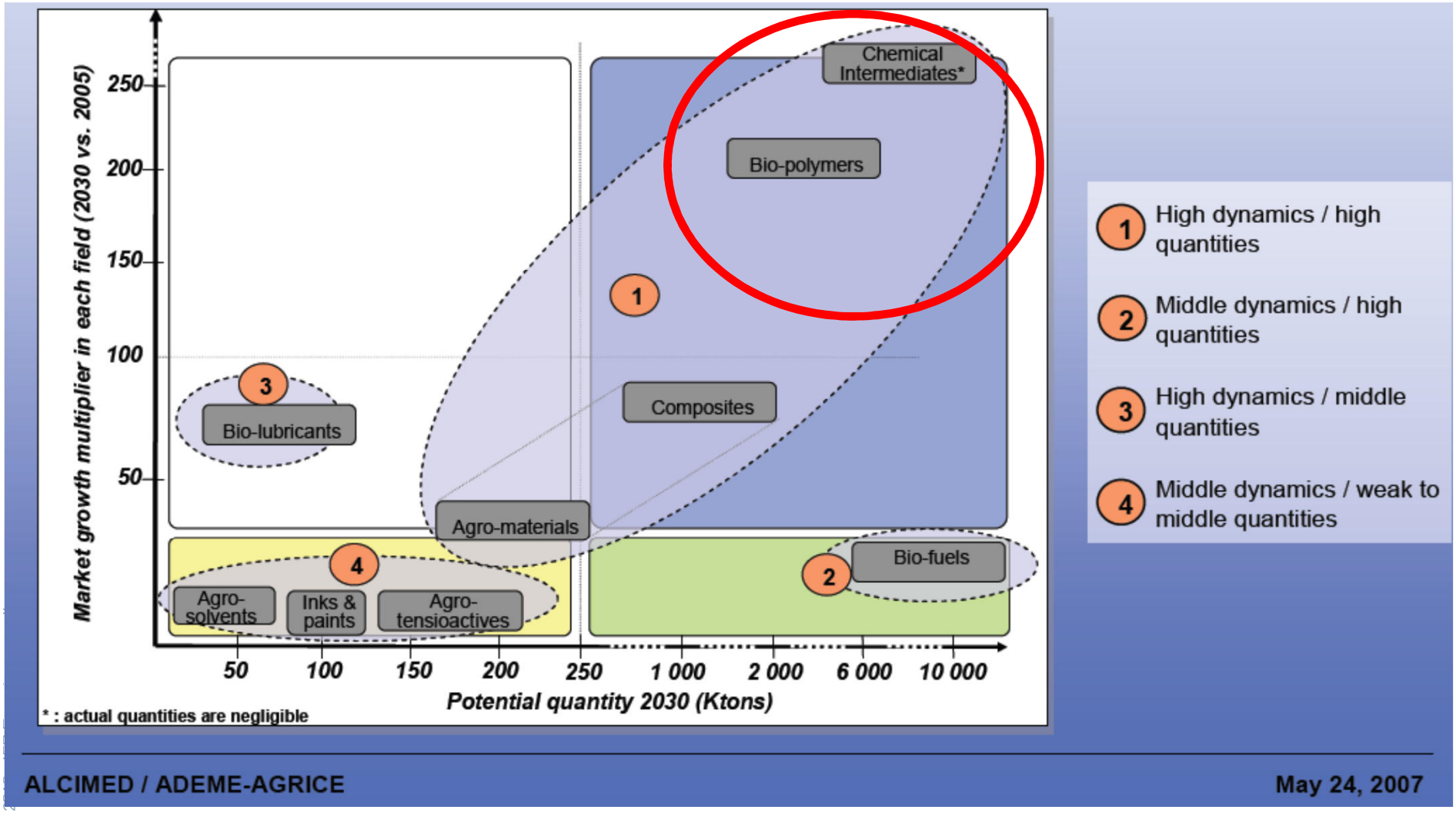
Industrial 2G is taking off !

Built/Under Construction World Capacities > 10 000 t/y

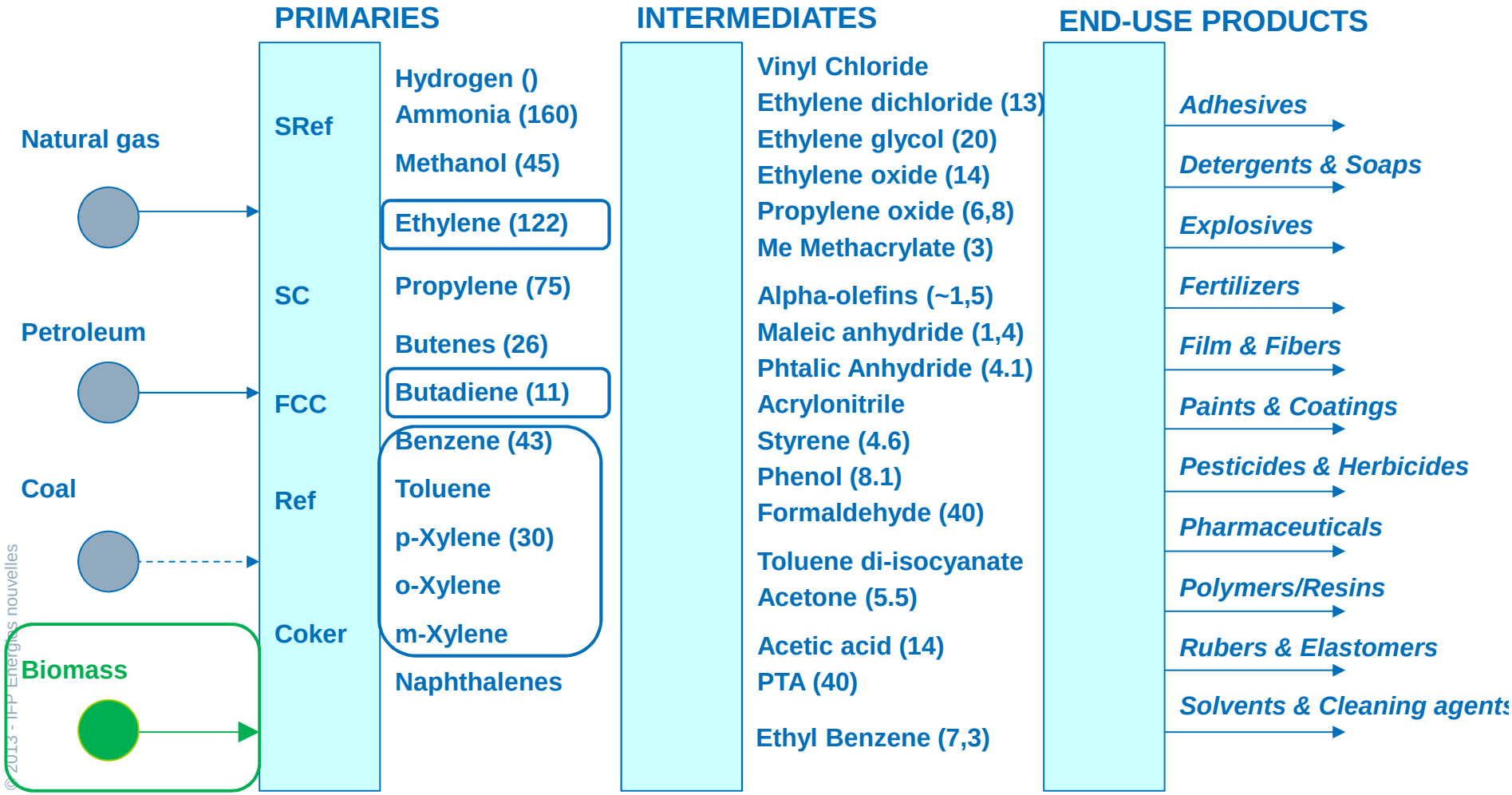


Source : données IFPEN / 2015

Future: a high growing Market for Chemical Intermediates & bio-monomers & polymers



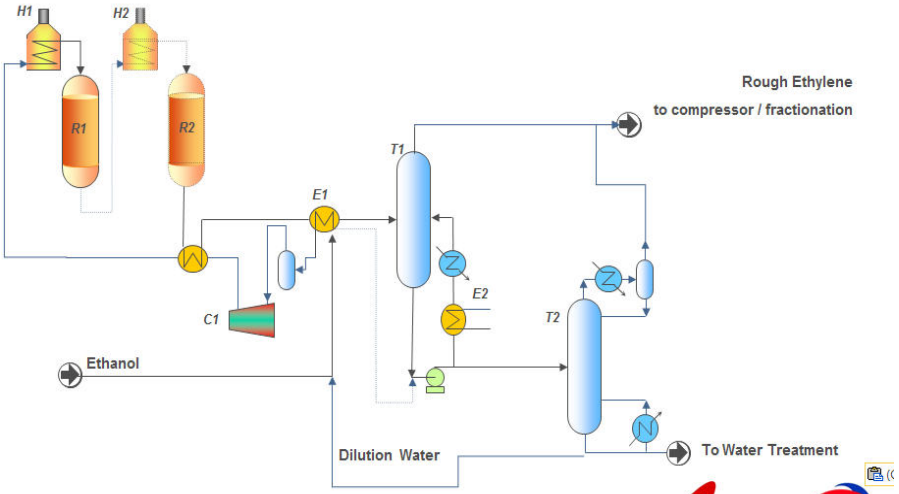
Chemicals/Bio-Chemicals: a lot of products and final markets: ~400 Mt/y in 2010



Source : CMAI2011, IHS2011, IFPEN2011

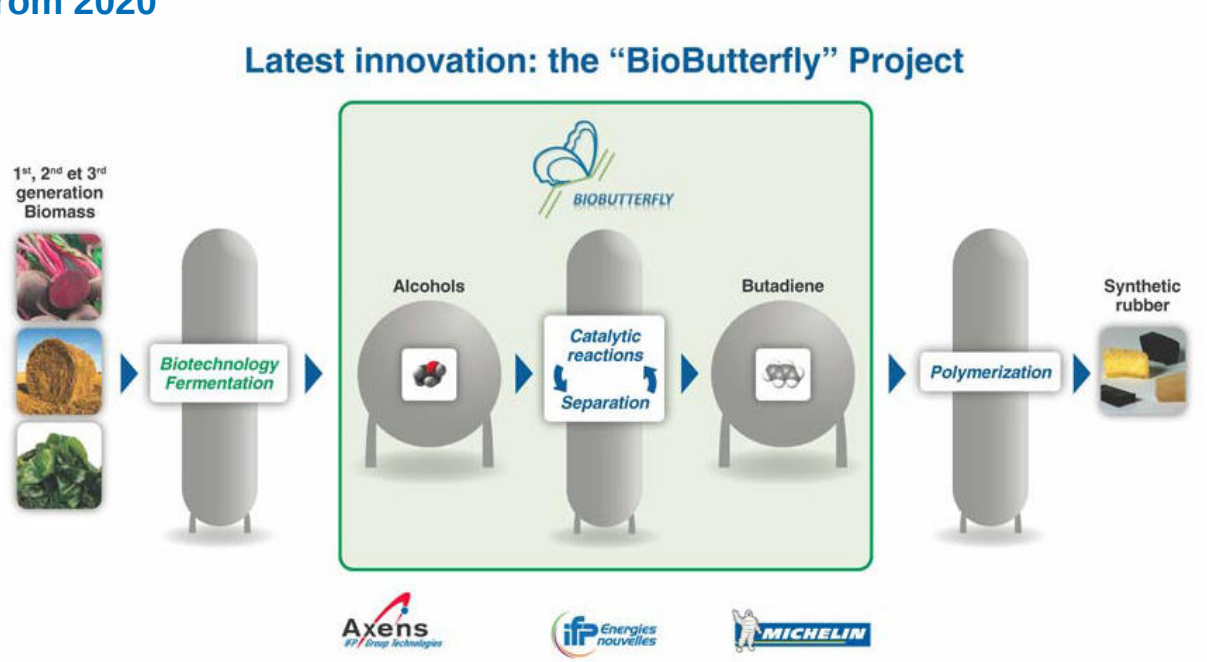
ATOL™ PROCESS (patent WO 2013/011208)

- **Performances**
  - Ethanol from different sources including 1G/2G bio-EtOH with variable purity level (water, impurities)
  - Suitable for PE, PS, PET, PVC & ABS
  - Carbon yield from ethanol to ethylene near to max . thermodynamic yield
  - Lower specific consumption (/t C2=) than competitor dehydratation processesn & about half the fossil fuel (steam cracking) specific consumption
- **Partnership since 2011**
  - Total-Feluy: high performances catalyst formulation
  - IFPEN: catalyst scale-up + heat recovery innovation
  - Axens: catalyst industrialization ATO 201 + process finalization optimizing the energy efficiency
- **Industrialization**
  - Ready, 1st of technologies for the production of other olefinic monomers from bio-derived higher alcohols
- **Proposed for commercialization since 2014**
  - Currently mainly dedicated to MEG (Mono Ethylène glycol) production to be used in PET (1G & 2G mode)
  - -50% energy consumption v/s competitors
  - Linked to C2= and EtOH market price (no subsidies)

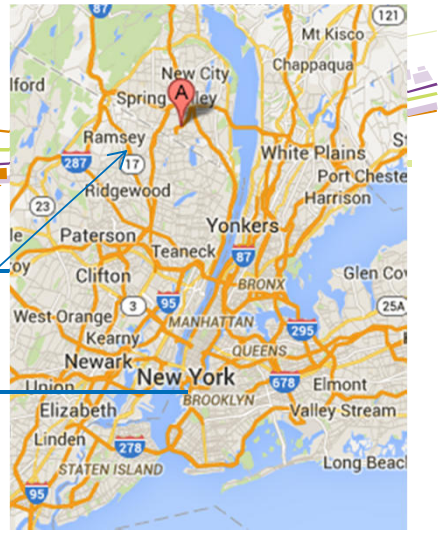


BioButterfly Project: Butadiene production to SBR/PBR market

- **Objective**
  - To develop a sustainable alternative to bio-butadiene for a future bio-sourced synthetic rubber and tire industry (60% of global butadiene output for the tire industry)
  - Producing competitive bio-butadiene with low investment costs
  - Reducing environmental impacts (GHG) across the entire production chain, compared with fossil fuels
  - Manufacturing high-performance synthetic rubber and adapting the process to all uses of bio-butadiene
- **Partnership**
  - Pooling the strengths/skills of the 3 players: R&D, Licenser & Industry, from scientific concept to industrial demonstration
- **Industrialization: from 2020**



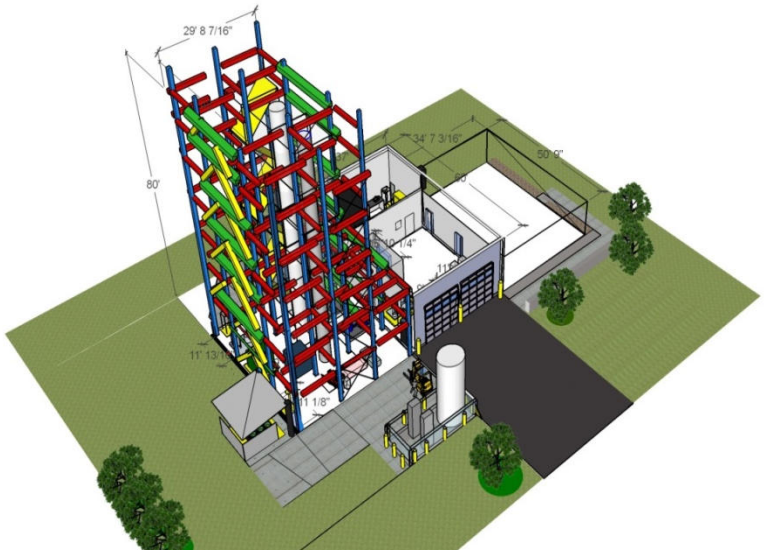
Bio-Aromatics by CFP: Anellotech / Axens / IFPEN Alliance



- Direct BTX production process from ligno-cellulosic biomass through Catalytic Fast Pyrolysis (CFP)

- Anellotech :
  - US Start-up founded in 2008
  - Develops the CFP process based on Prof Huber laboratory work (Univ Mass) at lab & pilot plant level on Pearl River Site
- IFPEN :
  - Main contribution in continuous pilot plant (PS3) design, pilot start-up , hydrodynamic studies, and process scale-up to Demo plant/industrial unit
- Axens :
  - Industrial development, White Process Book , Marketing & licensing, Basic engineering, start-up services

Continuous Pilot Plant (DS3) to be installed on Pear River site in Aug. 2015



Technology expected to be ready for industrial implementation in 2019

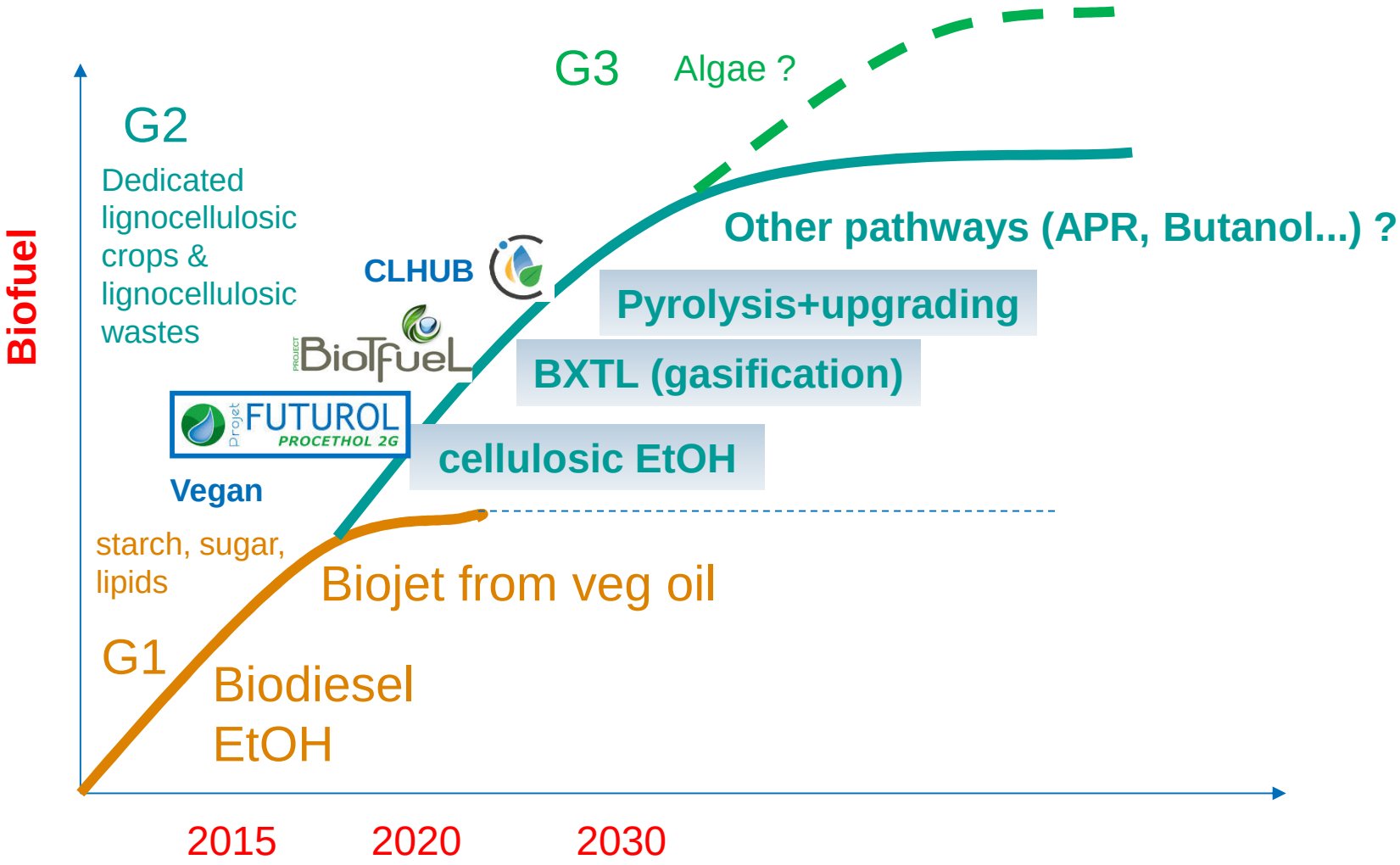
Bio-Aromatics : A low cost process for “drop in” green aromatics

Non-Food Biomass	Base Aromatics	Desired Green Products	Key End Use Markets
Low Cost Feedstocks	***Novel Process***	***Key Chemicals***	***Large consumer markets***
• Wood Chips	• One Reactor	• **PET**	• Packaging
• Corn Stover	• Economical Catalyst	• PS	• Automotive
• Palm residues	• Benzene, Toluene, **Xylenes** (BTX)	• PC	• Apparel
• Bagasse		• PU	
		• Nylon	

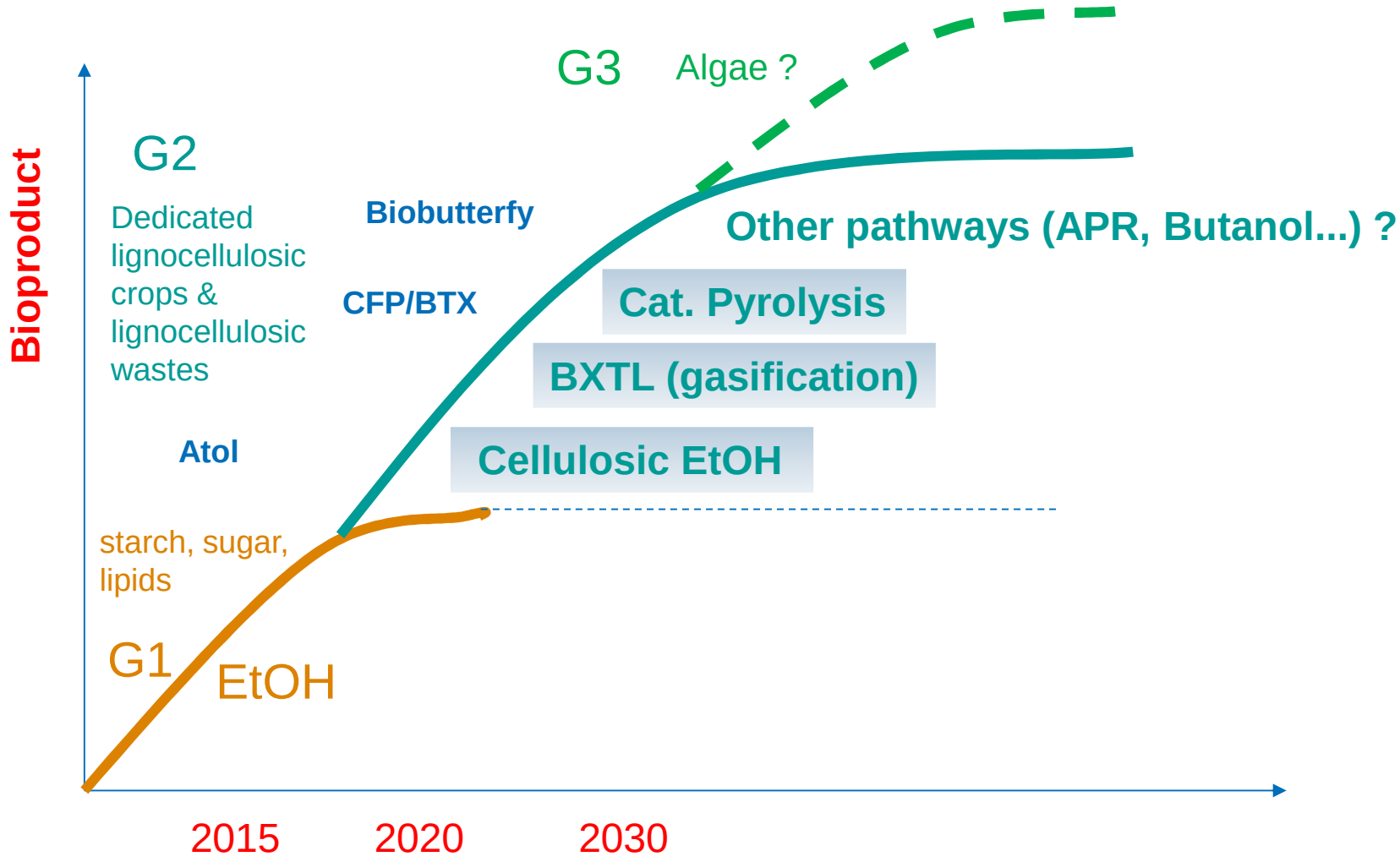
ccc

Anellotech · Johnson Matthey Process Technologies · IFP Energies nouvelles · Axens IFP Group Technologies

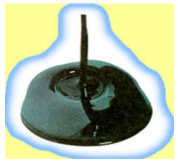
To conclude : Biomass to 2G Biofuels processes developed at IFPEN



To conclude : Biomass to Bio-products processes developed at IFPEN



Order of magnitude to remind !!!



Hydroskimming Oil Refinery

- 1 Mt/y crude oil

- 600 kt/y (+ 350 kt/y heavy fuel oil)

Shenhua Direct Coal Liquefaction unit (China)

- 1 Mt/y low ash Coal (<5%)

- 290 kt/y (no residue) (x 3)

Biofuels conversion & upgrading

- 1 Mt/y Biomass (d.b.)

- 150-200 kt/y

Biochemicals conversion/upgrading

- 1 to 2 Mt/y Biomass (d.b.)

- 100 to 150 kt/y butadiene or BTX

Innover les énergies

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