European Biofuels TECHNOLOGY PLATFORM

Status report on Demonstration Plants for advanced Biofuels Production

- Biochemical Pathway

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Disclaimer

The presenter has gathered most of the information from contacts with project owners and technology suppliers and to some extent from Internet.

Some deviations from factual situation may be presented.

The presentation does not claim to completely cover the given topic.

Lignocellulosic feedstocks

Sustainable energy crops

SUGARS

5 Ethanol and higher alcohols from sugar via **FERMENTATION**

Main markets: Renewable transport fuels as gasoline components, E85

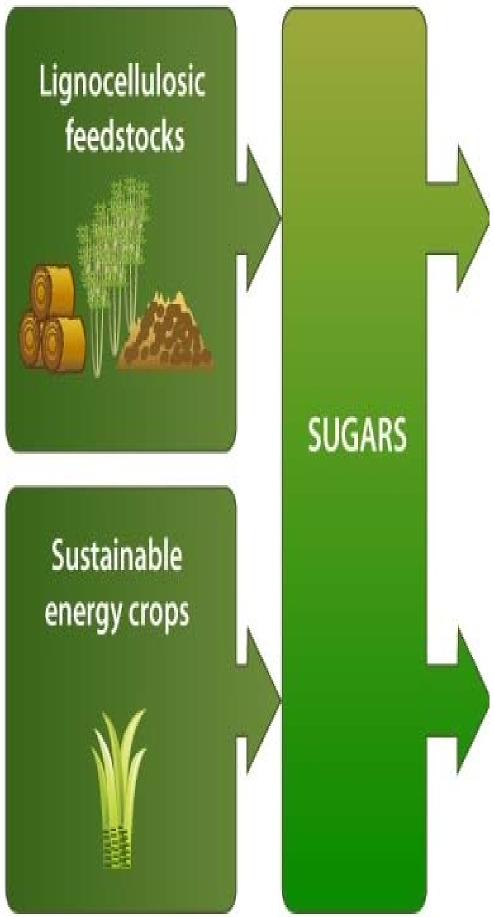
6 Renewable hydrocarbons from sugar-containing biomass via **BIOLOGICAL PROCESSES** and/or **CHEMICAL PROCESSES**

Main markets: renewable transport fuels for jet and diesel engines

Aquatic biomass (e.g. macroalgae, microalgae)

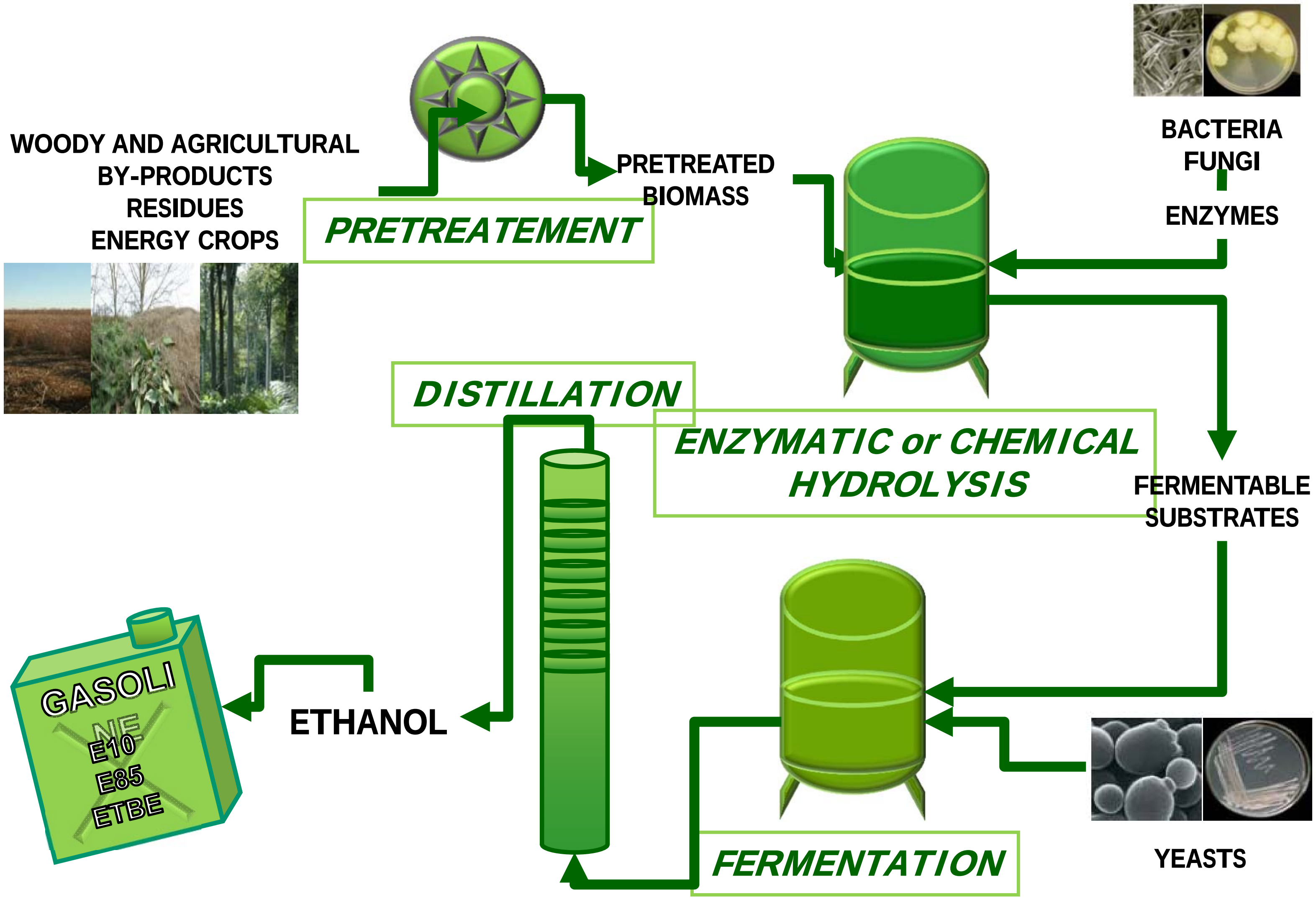
7 Bioenergy carriers from CO_2 and light through **MICROORGANISM -BASED PRODUCTION** and upgrading into transport fuels and valuable bioproducts

Value Chain 5:



- **Main issues**
- **Cellulosic EtOH demo and planned plants => potential**
- **Biobutanol plants**

Cellulosic ethanol: generic process scheme



Value chain 5: main issues

- EtOH cost
  - Pretreatment
  - Enzymes
  - C5 conversion
  - By-products use
  - ...
- Feedstock availability
- Biorefinery integration
- Biobutanol ?

Main cellulosic EtOH running demos (>1000 t/y) in EU

Plant Owner	Location	Input capacity (t/year)	Output capacity (t/year)
Clariant (ex Sud Chemie)	Straubing, Germany	Agriculture residues, wheat straw	1 000
Abengoa Bioenergy, Biocarburantes Castilla y Leon, Ebro Puleva	Babilafuente, Salamanca, Spain	25 000 t/year (barley/wheat straw, corn stover)	4 000
Inbicon (Dong Energy)	Kalundborg, Denmark	30 000 t/year (wheat straw, other lignocellulosics)	4 300
Chempolis	Oulu (Chempolis R&D Center), Finland	25 000 t/year (non-wood, non-food raw material) formicobio ™ process	running ?
Beta Renewables (JV Chemtex (M&G), TPG, Novozymes)	Crescentino, Italy	Non-food biomass (giant cane and wheat straw)	40 000

Clariant facility

- **Start up in July 2012**
- **Feedstocks**
  - agricultural residues as feedstock (Phase 1)
  - dedicated energy crops (Phase 2)
- **The Sunliquid® process** involves: a hydrothermal pretreatment at mild process conditions, a process-integrated production of enzymes, enzymatic hydrolysis, a specialized fermentation organism that simultaneously converts C5 and C6 sugars into ethanol in a « one-pot reaction », adsorption-based separation of ethanol

Courtesy Clariant

Abengoa facility

- **Start up in September 2009**
- **Feedstocks:**
  - Wheat straw, barley straw
- **The production process** involves: preparation of biomass, thermochemical pretreatment, enzymatic hydrolysis and fermentation with enzymes and yeast, distillation to produce ethanol and a solid co-product

Courtesy Abengoa

Inbicon facility

- **Start up in Dec 2009**
- **Feedstocks**
    - process developed on wheat straw
- **Process:** hydrothermal pretreatment (30-40% Dry Matter), continuous enzymatic liquefaction and hydrolysis, use of externally-produced enzymes, production of C5 molasses, Energy co-production

Inbicon Biomass Refinery at Kalundborg

Courtesy Inbicon

Beta Renewables facility (M&G Chemtex)

- **Start up in December 2012**
- **Feedstocks: non-food biomass**
  - developed on Arundo donax (Giant cane) and wheat straw
- **Initial capacity** 40,000 tons/y then 60,000 tons/y
- **Production** process : PROESA®

Courtesy Beta Renewables

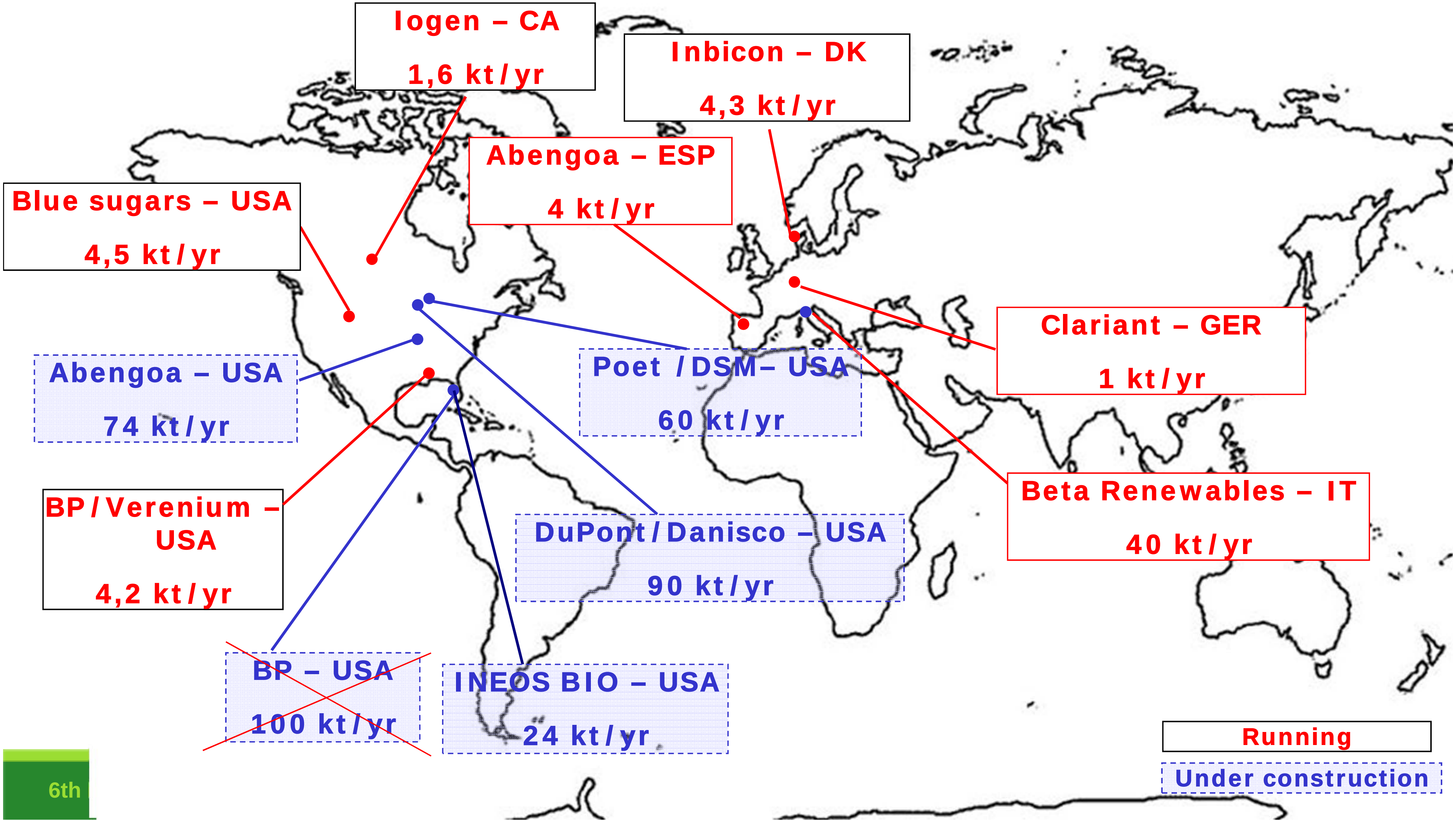
Main announced EtOH G2 demos (>1000t/y) in the EU

Plant	Location	Input raw material	Output capacity (t/year)	Planned Start-up date
Biogasol (BornBio-Fuel 2)	Aakirkeby, Bornholm, Denmark	Various lignocellulosics incl. grasses, green waste, straw	4 000	2013
INEOS Bio	Seal Sands, Tees Valley, UK	Biodegradable household and commercial waste	24 000	2015
Procethol 2G (Futurol)	Lillebonne, France	Various lignocellulosics	1 500	2015
NER300 project CEG (Sekab)	Goswinowice, Poland	Agricultural residues: wheat straw, corn stover	48 000	
NER300 project BEST	Crescentino, Italy	Giant cane, wheat straw	40 000	

Main running EtOH G2 demos (>1000t/y) in North America

Plant Owner	Location	Input capacity (t/year)	Output capacity (t/year)
IOGEN Corporation	Ottawa, Ontario, Canada	30 t/d (wheat, barley and oat straws)	1 600
BP (Jennings Demo Facility)	Jennings, LA,US	Sugarcane bagasse, switchgrass, wood products	4 180
Blue Sugars Corporation (KL Energy Corporation)	Upton, Wyoming, US	33 500 t/y (bagasse, wood, pulp) (integr. enz. prod.)	4 500
BlueFire Renewables	California, US	acid hydrolysis, various wood and paper wastes, bagasses	11 100 ?

2G Ethanol projets running or in construction 2012 - UE/USA (> 1000 t/y)

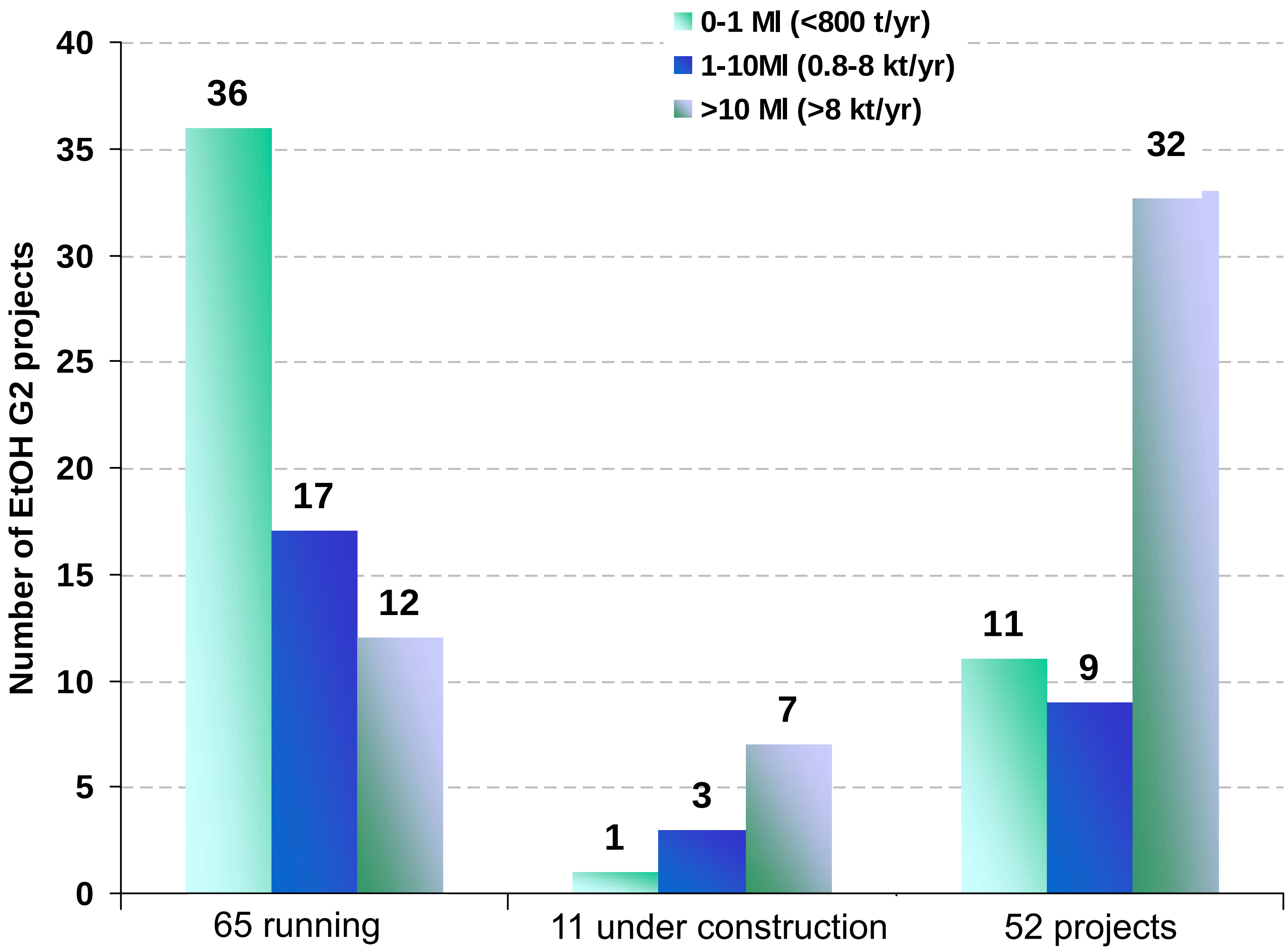


Main EtOH G2 demo units outside EU

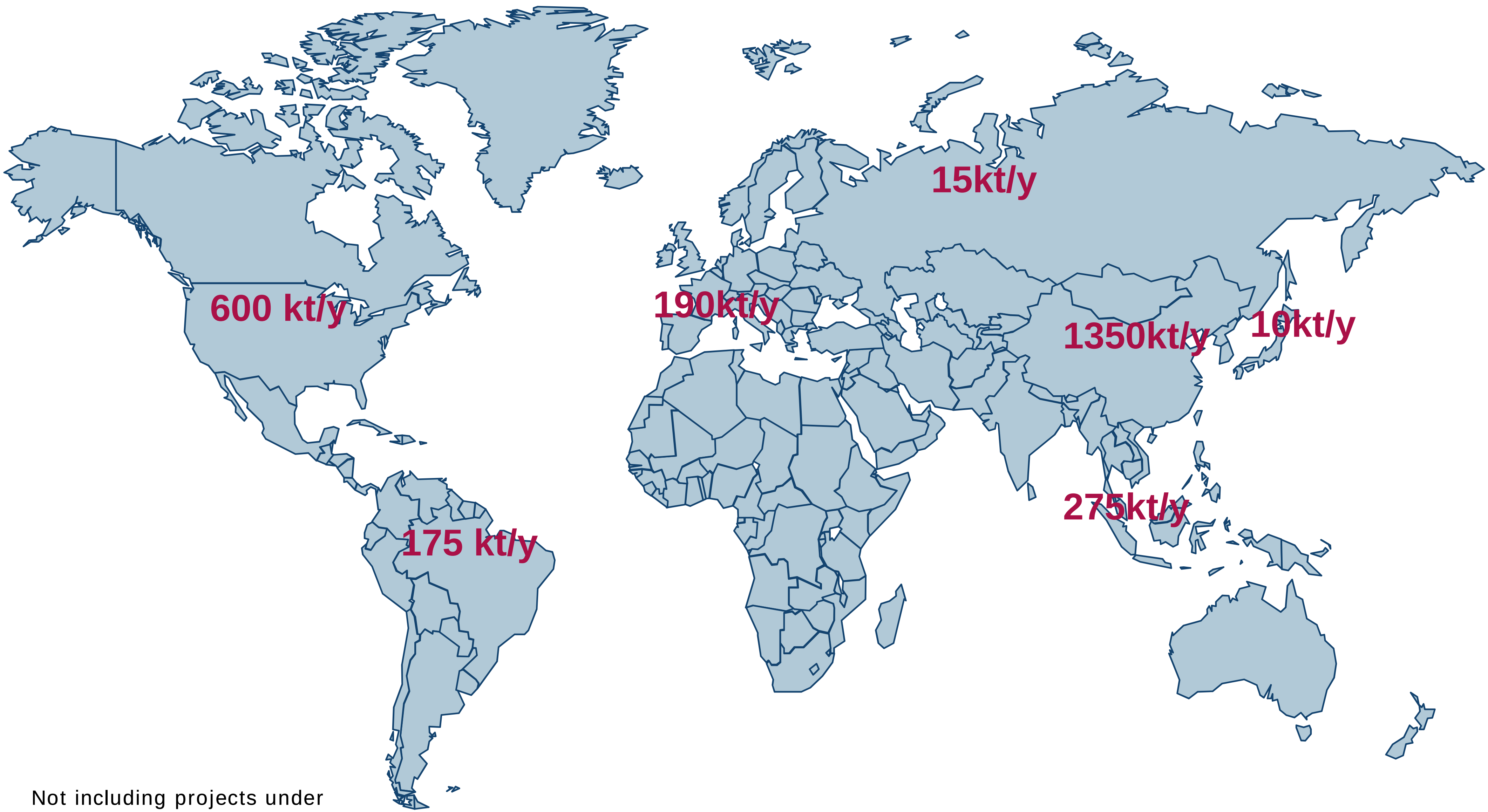
- Running
  - BP/Verenium j-v – USA – 4180 t/y
  - DuPont Danisco/UT-Genera Energy – USA – 750 t/y
  - Blue Sugars – USA – 4500 t/y
  - Mascoma – USA – 600 t/y
  - Iogen – Canada – 1600 t/y
  - Jilin Jiuxin Industry group – China – 30000 t/y
  - Beijing Tiandi Riyue Biomass technology – China – 8000 t/y
  - Chinese Academy of Agricultural Engineering – China – 4000 t/y
  - Henan fuel ethanol – China – 8000 t/y (2 units)
  - CNPC – China – 3000 t/y (2 units)
  - Shandong Longlive Bioenergy – China – 40000 t/y
  - Shandong Wande – China – 8000 t/y
  - Shandong Xueling Starch – China – 3000 t/y
  - ZTE Energy – China – 30000 t/y
  - Bioethanol – Japan – 1000 t/y
  - Kirin Brewery –Japan – 8000 t/y
  - Kirov Biochemical – Russia – 15000 t/y
  - Thai Roong Ruang Energy – Thailand – 25000 t/y
  - BlueFire Renewables- USA – 11 100 t/y ?

- Announced
  - **Abengoa Bioenergy Biomass of Kansas – USA – 74000 t/y**
  - ADM - USA - 3000 t/y
  - BlueFire Ethanol - USA – 55000 t/y
  - BP – USA – 100000 t/y (canceled)
  - Colusa Biomass Energy – USA – 30000 t/y (canceled?)
  - **Fiberight – USA – 11000 t/y**
  - ICM – USA – 150000 t/y
  - **INEOS Bio - USA – 24000 t/y**
  - Mascoma – USA – 60000 t/y
  - Poet / DSM – USA – 60000 t/y
  - IOGEN – Canada – 68000 t/y (canceled)
  - Blue Sugars/Petrobras – Brazil – 7900 t/y
  - Dupont Danisco - 90000 t/y
  - GraalBio – Brazil – 65000 t/y
  - TMO/Usina Santa Maria - Brazil- 7880 t/y
  - Beta Renewables – USA – 60000 t/y
  - Zeachem – USA – 750 t/y

Projects statistics



Potential EtOH G2 announced capacities



Not including projects under construction

Source : CEDIGAZ

Biobutanol

- **Butamax** (JV Dupont/BP): Demo 30t/y Hull , UK (Startup 2010)
- **Gevo:**
  - 55,000t/y Luverne, USA (Operating 17 weeks since May 2012 then switch to EtOH production for flexibility demonstration)
- **Cobalt Technologies**: 1440t/y Thomaston , USA (Startup 2013)
- **Green Biologics**

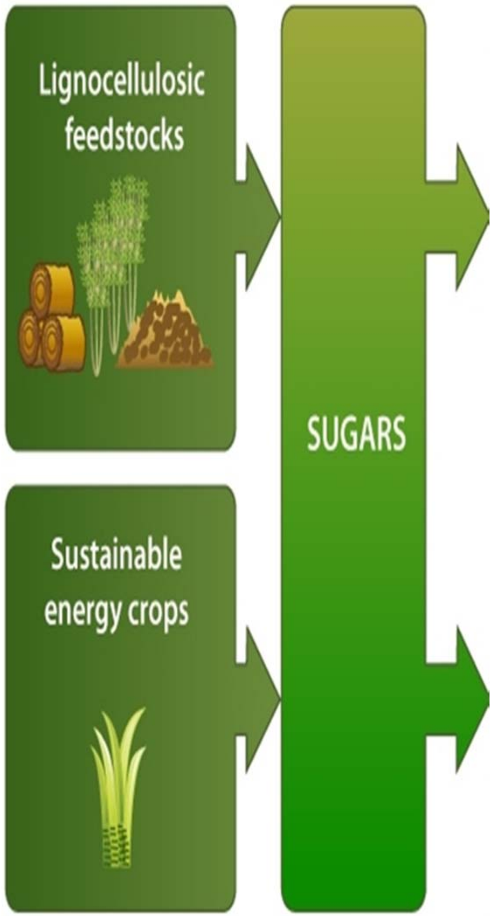
Ethanol hybrid processes

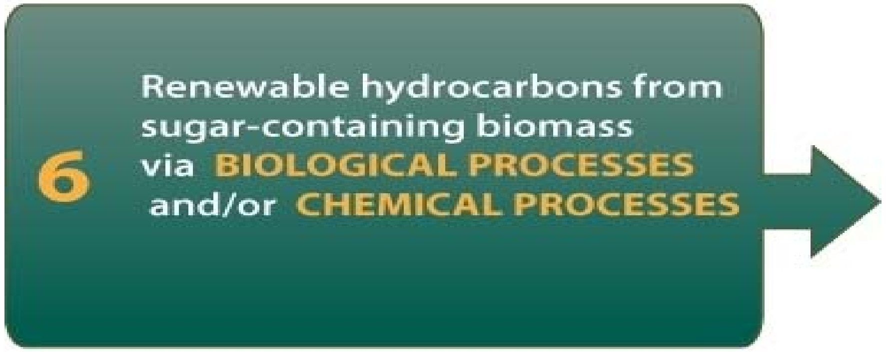
- **Zeachem** : fermentation of C5-C6 sugars to acetic acid, esterification and hydrogenation to EtOH with hydrogen from gasification of lignin :
  - 750t/y : Boardman, USA (Construction completed in October 2012; EtOH production should have started since end 2012; conversion of sugar to ester operational)
  - 75000t/y : co-located with pilot plant

- **Coskata** : Gasification then fermentation of syngas to EtOH (Syngas now produced from gas and not biomass)

- **INEOS Bio** : Indian River, USA : 24000t/y + 6 MW (Construction completed in June 2012; power production in October; EtOH production should have started since end 2012)

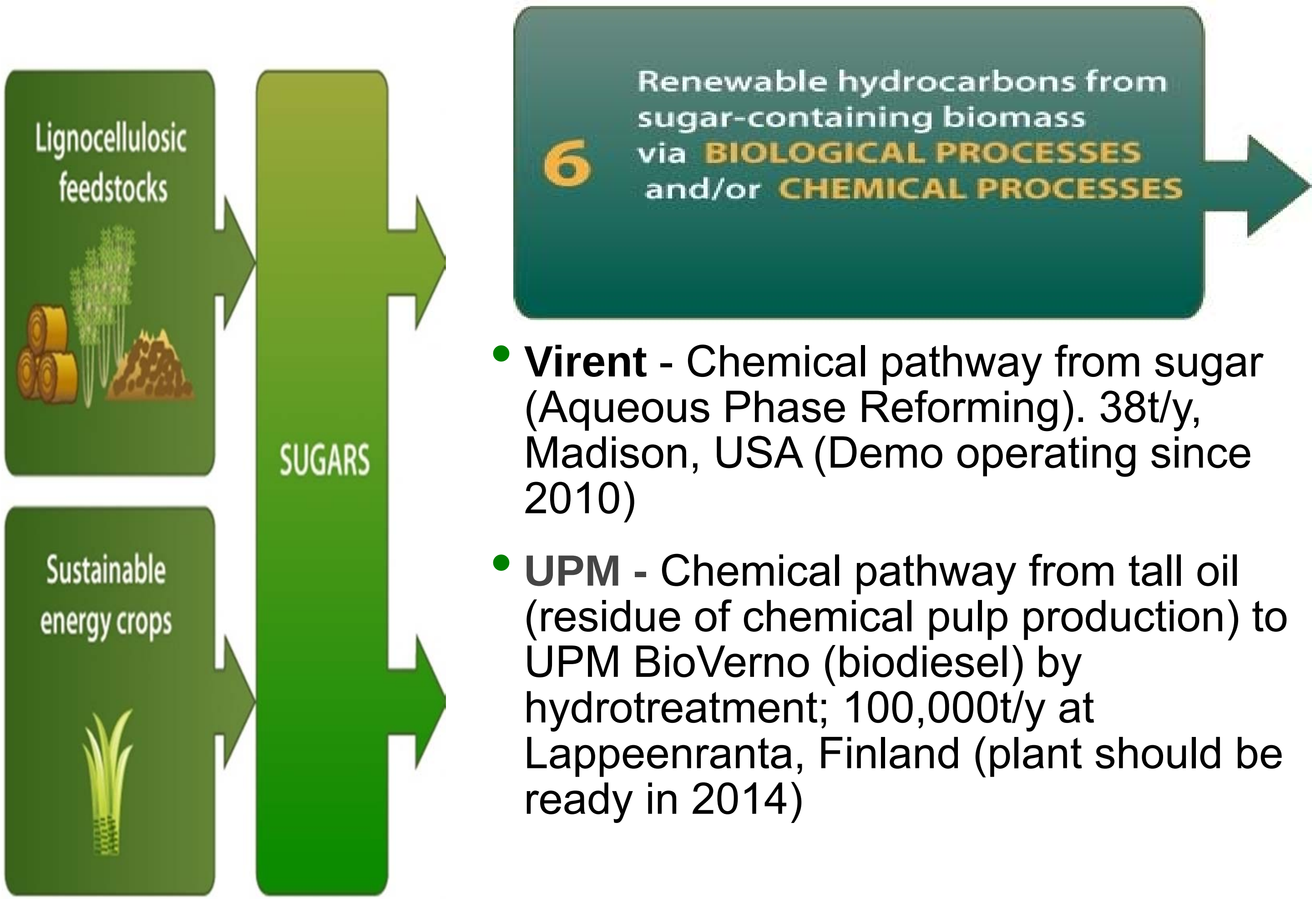
Value Chain 6: Biological processes





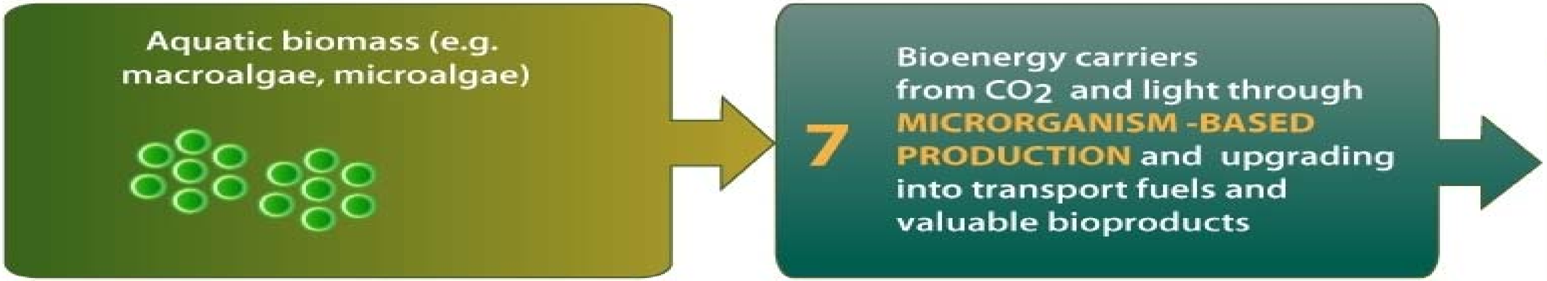
- **LS9** – fermentation pathway from sugar to fatty acid /alcohol; 270t/y, Okeechobee, USA (operating since Sept 2012)
- **Amyris -** fermentation pathway from sugar to «Biofene»; 40,000t/y at Paraiso, Brazil (production since 27/12/2012; full capacity for 2015)

Value Chain 6: Chemical processes



- **Virent** - Chemical pathway from sugar (Aqueous Phase Reforming). 38t/y, Madison, USA (Demo operating since 2010)
- **UPM** - Chemical pathway from tall oil (residue of chemical pulp production) to UPM BioVerno (biodiesel) by hydrotreatment; 100,000t/y at Lappeenranta, Finland (plant should be ready in 2014)

Value Chain 7:



- Heterotrophic and autotrophic organisms
- Difficult to obtain reliable data on demo plants (capacity and production)
- **Refer to the Algae Task Force of the EBTP**

Conclusions

- **Cellulosic EtOH development still faces technical and economic issues but many large projects announced all over the world**

- **RFS2 maintains 2022 targets on advanced biofuels**
    - **In 2013, 14 Mgal (52 000 t) cellulosic EtOH should be produced in USA (Abengoa Bioenergy, Fiberight, INEOS Bio and KiOR Inc)**
    - **« 2013 will be a "pivotal" year for the cellulosic and advanced biofuels industries to demonstrate commercial and economic viability** in order to contribute toward the proposed 2013 volumes » (Bio Association)

- **Slower development of the other pathways (value chains 6 & 7)**

- **Europe:**
    - **The first commercial plant (Beta Renewables)**
    - **+ 2 new large demo plants (NER300) (and may be more)**

Converting straw to biofuel still needs to be demonstrated !

Thank you