Overview of EU Aviation Biofuels research and demonstration projects

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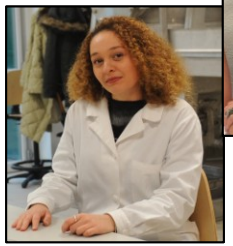
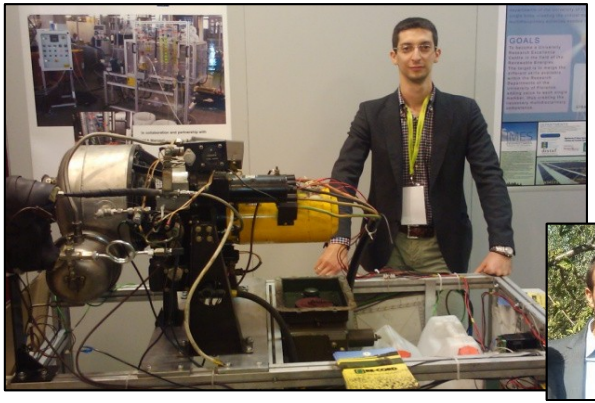
RE-CORD / CREAR, University of Florence

First Annual Workshop of ISAFF
Rome, 4 November 2014

..our group…

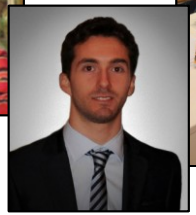













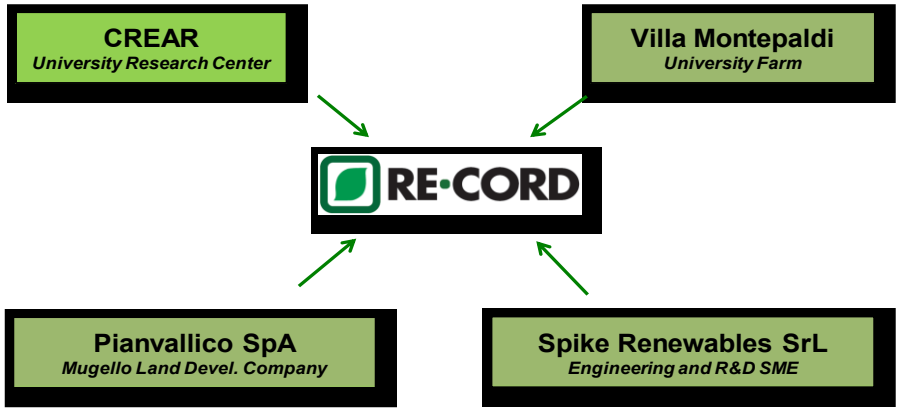


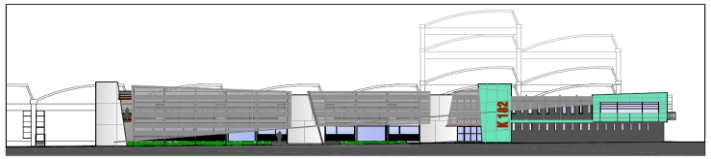
RE-CORD

Renewable Energy Consortium for R&D

- ✓ **No-Profit Research Institution**
- ✓ **R&D&D on Bioenergy/Biofuels and other RES**

MEMBERS





FACILITIES

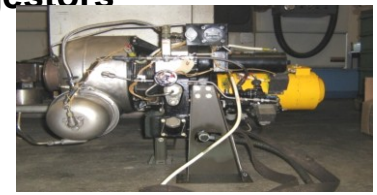
- ✧ **Chemical lab** (**Pianvallico** area)
- ✧ **Biomass energy conversion pilot/demo unit**
- ✧ (Gasification, Pyrolysis, Torrefaction, HTL, Methanation..)

Some National & International Networks

- **Internat. Energy Agency – Bioenergy: Country representant T39**
  - T39, Liquid Biofuels, jointly with M&G Group (formerly: T34-Biomass Pyrolysis)
- **UN-ICAO CAEP AFTF**
  - Committee for Aviation Environmental Protection - Alternative Fuel Task Force
- **EU Biofuel Technology Platform**
  - WG4-Sustainability
- **Italian Biofuel Technology Platform**
  - WG2 – Conversion
- **FREE** - Italian RES Association
- **DBFZ -** German Biomass Res.Center-RAC (Research Advisory Council)
- **THERMALNET** (Intelligent Energy for Europe)
- **International Master Course IMES on Bioenergy and Environment**
  - **The 1st Italian Master on Bioenergy (established in 2002)**
  - Jointly with Univ.Nova de Lisboa, Aston Univ. and three US Universities
    EU DG Edu

Short list of pilot plants at RE-CORD/CREAR

- Intermediate and catalytic **Biomass Pyrolysis** pilot unit (1.5 kg/h)
- **Briquetting** equipment (100 kg/h)
- **Torrefaction/Carbonisation** plant (*under design/construction*)
- **Methanation & HTL** reactors (*under design/construction, with Spike*)
- **Open-top twin-fire gasification** unit (up to 100 kg/h, 100 kW_e)
- **Downdraft Imbert-type gasification** system (10 kWe)
- Capstone **microgasturbine** converted to biofuels (30 kW_e)
- Garret **microgasturbine** converted to raw biofuels (20 kW_e)
- **Externally fired biomass/NG** Turbec **gas turbine** system (50-100 kW_e)
- **Straight vegetable oil engine-based microCHP** (5 kWe/10 kWth)
- Pilot **ponds for algae** (with DIBA/F&M)
- **Straight vegetable oil engine** (7 kW_e)
- Lab scale **anaerobic digestors**



Laboratory fully dedicated to Biomass/Renewable Energy

(feedstock + solid, liquid, gaseous biofuels)

INSTRUMENTS AND ANALYTICAL LABORATORY RE·CORD

RE-CORD system provides the skills and resources (laboratories and equipments) of its members, creating a critical mass capable to develop research and activities of primary-level science and technology.

Main analytical chemistry laboratory equipment

Strumentazione

- Atomic Absorption
- HPLC and GC-MS
- Ion chromatography
- Portable Micro GC
- CHNS
- TGA
- Viscometer
- Hydrometer
- Karl Fischer and Electrochemical analysis Instrumentation
- Chemical fume hood
- Biohazard Hood
- Calorimeter
- Ash melting furnace
- Ultrapure Water System
- Vacuum Filtration System
- Hydrogen Generator
- Centrifuge
- Muffle furnace
- Moisture Analyzer

Possible applications

- Determination of metals contamination on food, beverages, land. Quality control of industrial products, paints, ceramics, glass. Environmental Analysis (Particulate matter, sewage sludge), clinic analysis...
- Analysis of liquid fuels, biological molecules, quality control on chemical products and pharmaceutical organic pollution analysis
- Analysis of water, separation of amino acid mixtures
- Analysis of soils, solid chemical or biological materials
- Recognition of substances, thermal decomposition of organic molecules, polymers and inorganic species study

Main instruments solar and wind laboratory

- Pyrheliometer for direct solar radiation
- Verification and testing photovoltaic systems and three-phase multipurpose tool
- Anemometry tower (30 m)

Other instruments

- Gaseous emissions analysis tool
- Analysis of flows in pipes
- Doppler effect 2D-3D speed measuring tool

Pilot and demo plants

- Several bio-fueled microturbines
- Cogeneration / liquid fuel engines
- Gasifier
- Pyrolyzer / torrefaction roaster

In addition: NDIR/Electrochem.Producer Gas Analyzer, Portable MicroGC Gas Analyzer, Portable Tar sampling collection system

Biofuels…a complex issue, today..

…and.. that's just ethanol for cars!…

AVIATION FUEL: looking back..

AVGAS

Embraer EMB-202A

- 10 years of certification
- 25% less fuel
- 7% power increase
- By 2014, Embraer [illegible]

- AvGas is the fuel used by General Aviation (GA) small aircrafts, single and twin propeller/piston powered aircraft carrying 2-10 passengers and small cargo
- Avgas first developed in the 1940’s. Mixtures used today are the same as 1940s.

SourceBiofuels International, 2014

SIZE OF AVGAS MARKET (2011)

- AVGAS includes all flights other than military and scheduled airline and regular cargo flights.
- The largest market for Avgas is the US which currently uses 186 million gallons per year.
- The main consumers of avgas at present are North America, Australia, Brazil, and Africa (mainly South Africa). Not all airports carry Avgas
- Cost of Avgas in US in 2011 was $ 5.50 average while in remote rural areas it was up to $50/gallon

Source: G.Zanin, ISAF-Verona, 2011

OVER 6000 HOURS OF FLYING ON ETHANOL, METHANOL AND ETBE ACCUMULATED IN SINGLE ENGINE TRAINERS, HIGH PERFORMANCE SINGLE ENGINE AIRCRAFT, AEROBATIC AIRCRAFT, AGRICULTURAL AIRCRAFT AND MULTI-ENGINE AIRCRAFT

1980 - Bellanca Decathlon
(Lycoming IO-320, 7.0:1, E 95)

1982 - Pitts Special S1C
Lycoming IO-360,Experimental 10.5:1, E 95 and 50%Ethanol / 50% Methanol

1987 – SIAE Marchetti SF260
Lycoming IO-540, 8.5:1, E 95 and 50%Ethanol / 50% Methanol

1987 –Storck / Wallaby
Rotax 512, 8.5:1, E 95 and 50% Ethanol / 50% Methanol

1988 – Velocity
Lycoming IO-360 Experimental, 10.0:1, E 95

1992 – Piper Pawnee
Lycoming IO-540, 8.5:1, E 95

1991 – Pitts Special S2B
Lycoming IO-540 Experimental, 8.5:1, E95

1992& 2006 – Cessna 152
Lycoming O-235, 9.75:1, E95

1995 – Pitts Special S2B
Lyc. IO-540 Exper., 10.5:1, E 95 & ETBE

1992-2005 – Piper Pawnee
Lycoming IO-540, 8.5:1, E 95

2004 – Cessna 172
Lycoming IO-320, 9.75:1, E95/100LL blends

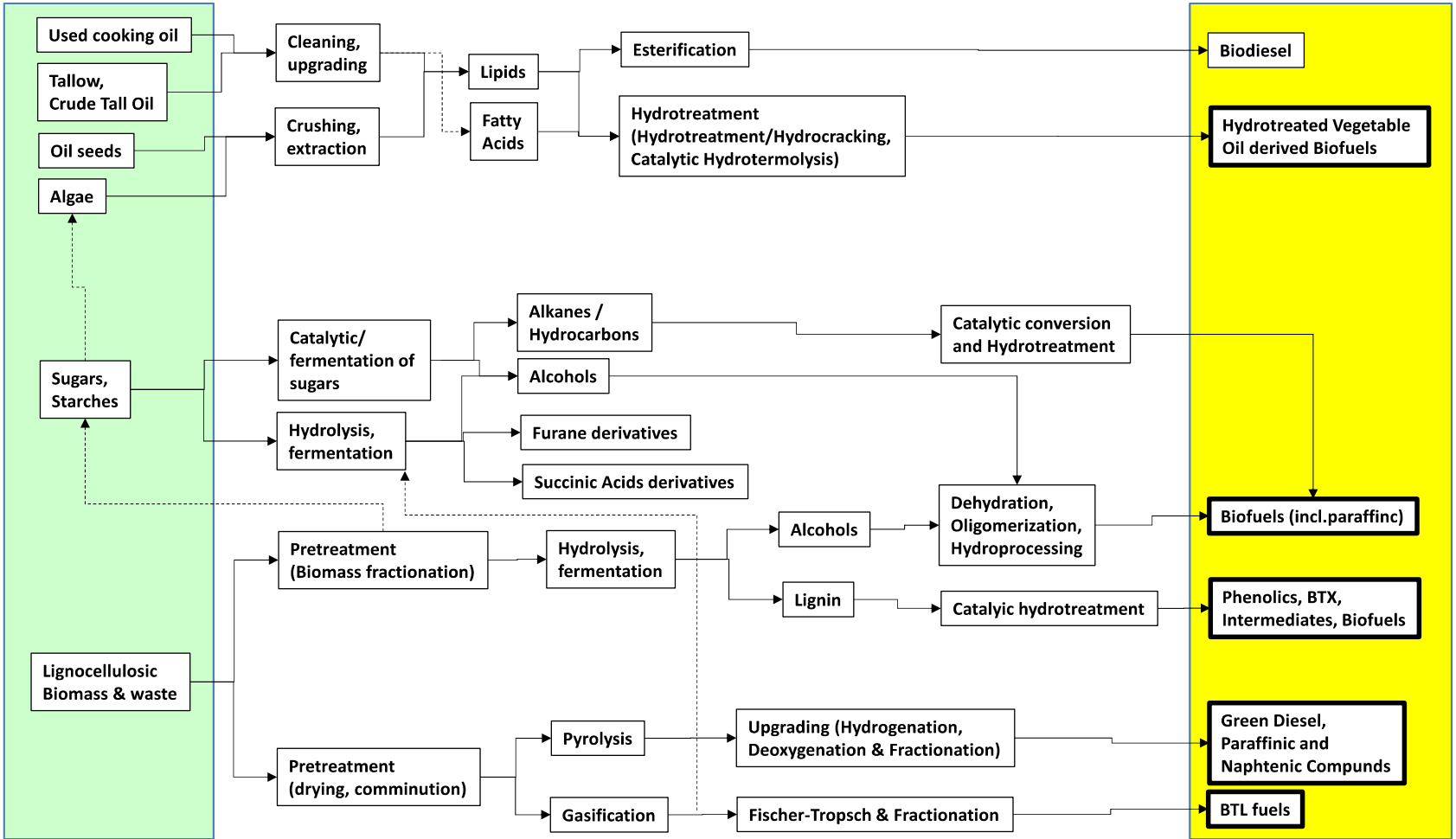
present – Sniffer
Rotax 912 UL, E95

THE FIRST TRANSATLANTIC FLIGHT ON ETHANOL FUEL WAS AWARDED THE HARMON TROPHY IN A CEREMONY AT THE WHITE HOUSE.

THE HARMON TROPHY IS THE HIGHEST AWARD IN AVIATION. PREVIOUS RECIPIENTS INCLUDE CHARLES LINDBERGH, AMELIA ERHART AND CHUCK YEAGER

Source: G.Zanin, ISAF-Verona, 2011

Possible routes to Aviation Biofuels (in bold)



Status of advanced biofuel technologies

	Basic and applied R&D	Demonstration	Early Commercial	Commercial
Bioethanol (gasoline-type biofuel)			Lignocellulosic Ethanol	Ethanol from sugar and starch crops
Diesel-type biofuel	Sugar-based hydrocarbons	BTL[1]-diesel (from gasification+FT[2]) renewable diesel from sewage oil	CTO[3]-Diesel and HVO	Biodiesel from oilseed crops and waste
Algae-derived biofuels	Algae to Hydrocarbons Algae oil to Biodiesel and HVO[4]			
Other fuels and additives	HTL[5]-fuels Pyrolysis based and lignin-based fuel	Biobutanol; DME[6]	Methanol	
Biomethane		Anaerobic Digestion (Upgraded Biogas by separation)		
		Gasification (by Thermochemical Methanation)		
		CO2 methanation (thermochemical or biological)		
Biomethane-rich gas	HydroThermal Gasification of Algae			

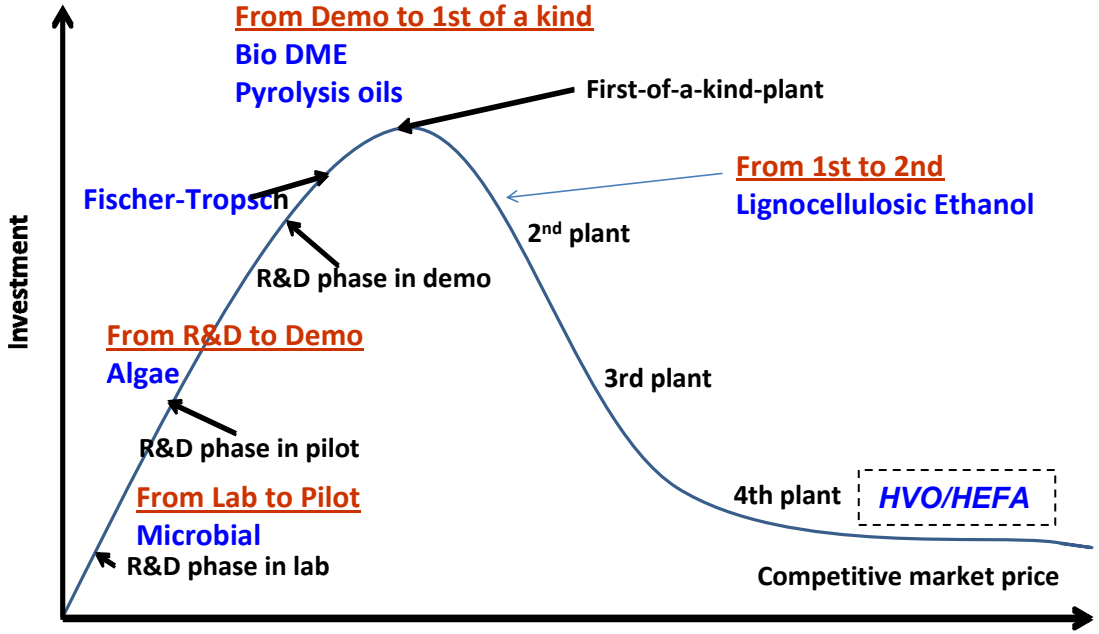
Liquid biofuel Gaseous biofuel

1. Biomass-To-Liquid 2. Fischer-Tropsch 3. Crude Tall Oil 4. Hydrotreated Vegetable Oil 5. HydroThermal Liquefaction 6. Dimethylether

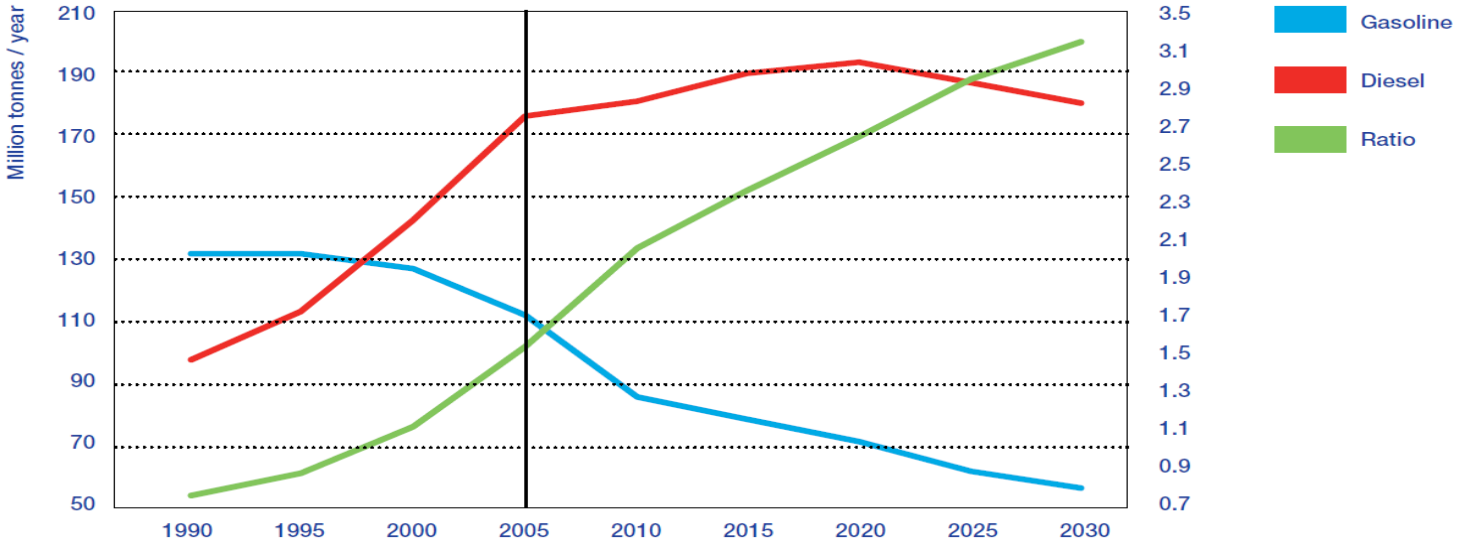
Source: modified from Bauen et al, 2009; IEA Technology Roadmap Biofuels for Transports 2011

RE·CORD

Technology Valley of death : Positioning of FP7 supported technologie



Source: European Commission, DG Energy, K.Maniatis



Source: European Commission, DG Energy, K.Maniatis

- **Structural imbalance between gasoline and diesel market**
- **16 EU refineries shut down since 2008**
  - ✓ ***France lost 25%, Germany 11%, UK 11% and Italy 8% between 2008 and 2012***
- **Gasoline market declined by 3%/y, Diesel import increased from 49 Mt/y (2008) to 53 MT/y (2012)**

Source: www.energyglobal.com/news/processing/articles/Facing_headwinds37.aspx

Jet fuel and transport fossil fuels

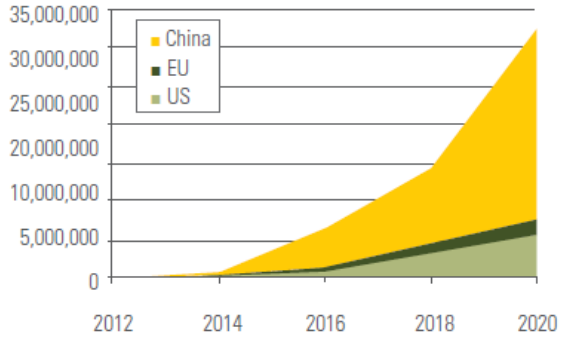
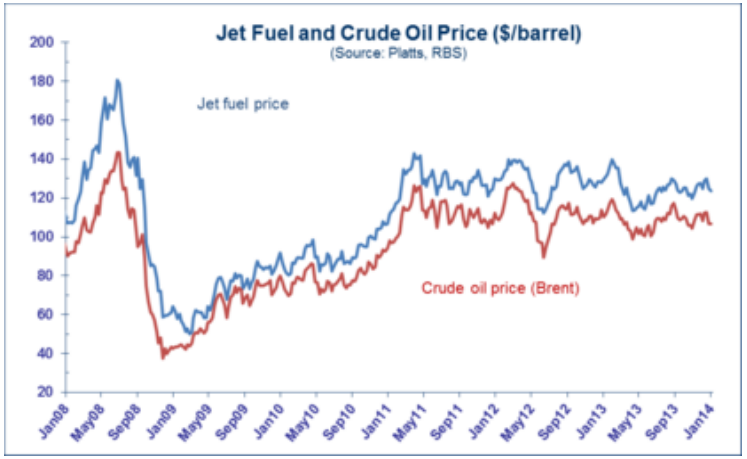
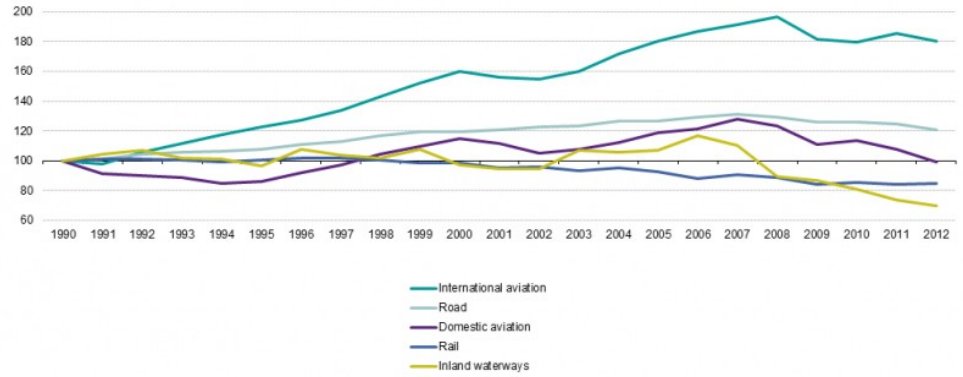


Figure 1 - A global framework of aviation biofuel targets





Source: Eurostat (online data code: nrg_100a)

Only aviation fuel considerably grew between 1990 and 2008 (EUROSTAT, 2013)

Advanced Biofuels are needed for Aviation

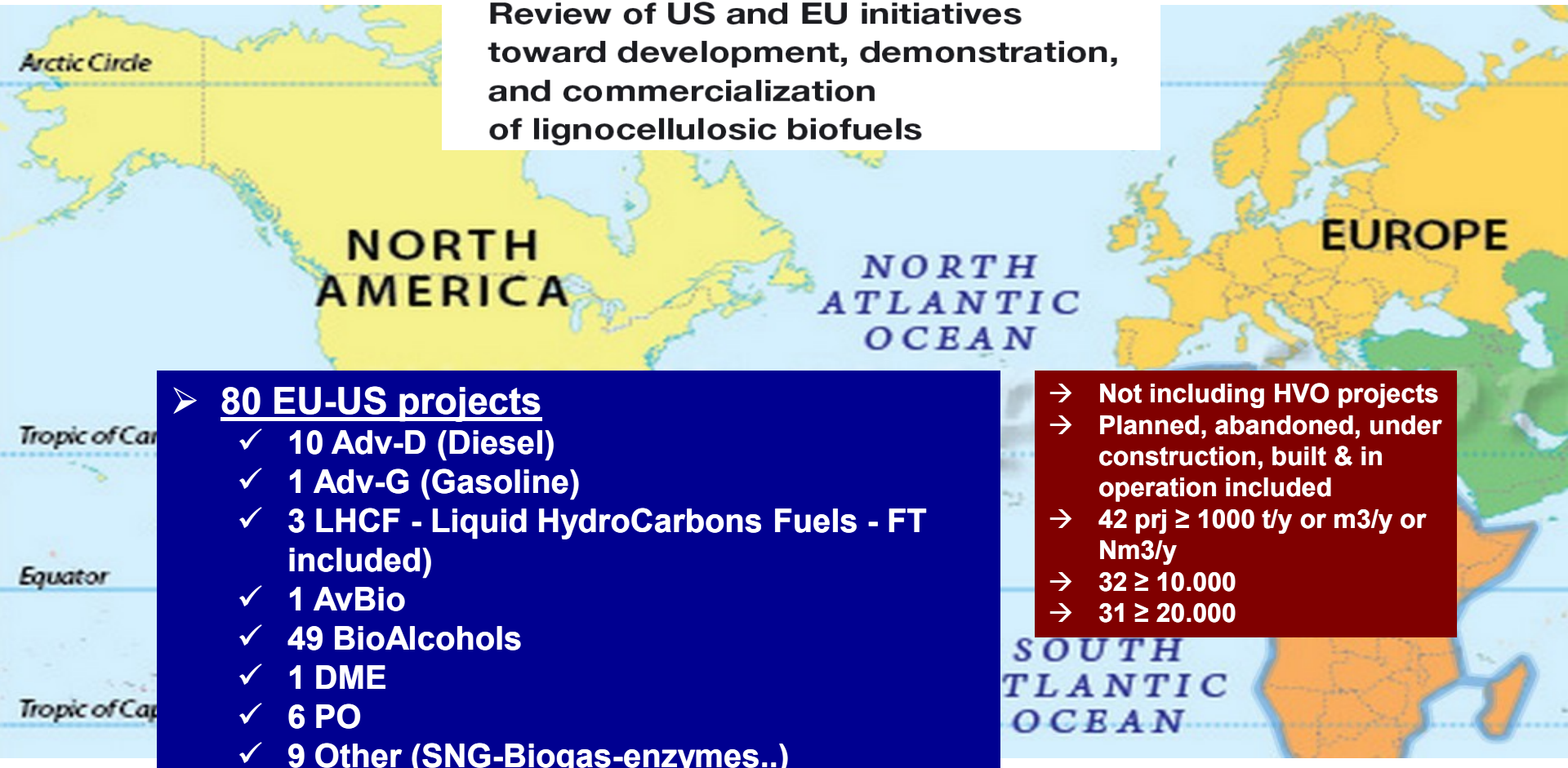
…but…

- Problem #1: definition of Adv. Biofuel !
- Problem #2: who defines Adv Biofuel ?
- Problem #3: How these investments (CAPEX) and Operation (O&M) differs from 1G Biofuels ? How to address financing these large investments?
- Problem #4: who's competing with Aviation Biofuels on the market ?

Industrial Initiatives on Advanced Biofuels (road transport mainly)

Some sources for information

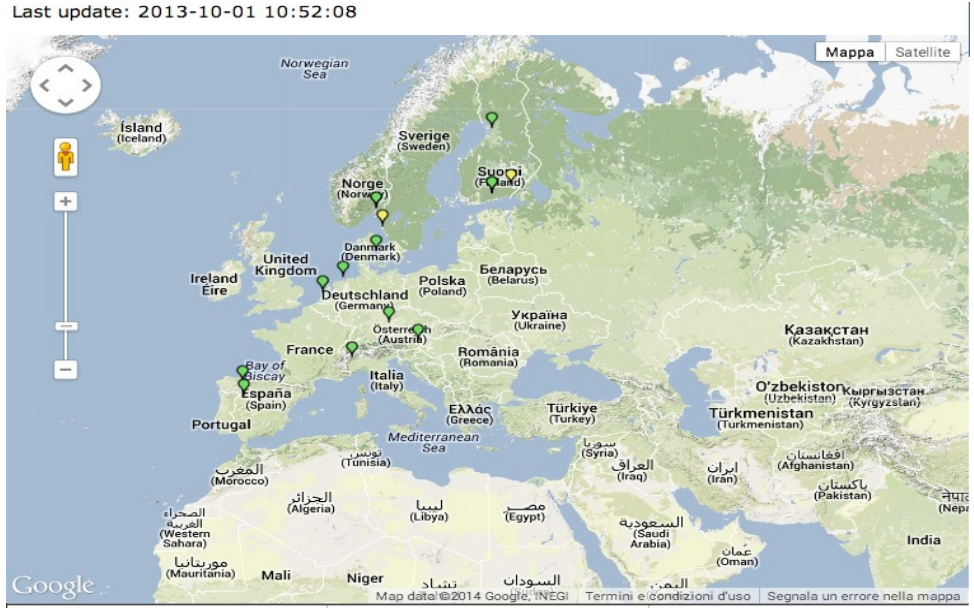
Review of US and EU initiatives toward development, demonstration, and commercialization of lignocellulosic biofuels



- **80 EU-US projects**
  - ✓ 10 Adv-D (Diesel)
  - ✓ 1 Adv-G (Gasoline)
  - ✓ 3 LHCF - Liquid HydroCarbons Fuels - FT included)
  - ✓ 1 AvBio
  - ✓ 49 BioAlcohols
  - ✓ 1 DME
  - ✓ 6 PO
  - ✓ 9 Other (SNG-Biogas-enzymes..)

- → Not including HVO projects
- → Planned, abandoned, under construction, built & in operation included
- → 42 prj ≥ 1000 t/y or m3/y or Nm3/y
- → 32 ≥ 10.000
- → 31 ≥ 20.000

Lignocellulosic Advanced Biofuels
Demo projects in EU & US



Technology	Type	Status
☐ biochemical	☑ commercial	☐ planned
☐ thermochemical	☑ demo	☑ under construction
☐ chemical	☐ pilot	☑ operational
		☐ stopped

Source:
http://demoplants.bioenergy2020.eu/projects/mapindex - IEA Task 39

Source: DOE -
http://www1.eere.energy.gov/biomass/integrated_biorefineries.html

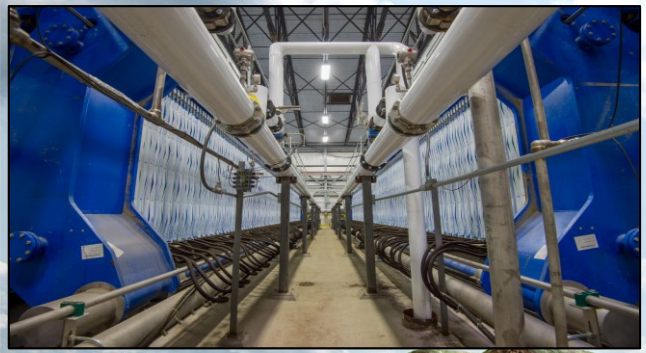
M&G: lignocellulosic EtOH (PROESA™Lignocell EtOH - Biochemtex)

- ✓ Grand Opening: 9/10/2013
- ✓ 20 Million Gallon EtOH/y

(75000 m3 – 40000 t/y)

- ✓ 150 M€ investment

US POET-DSM: Project Liberty



- Grand Opening: 3/9/2014
- 20→25 Million Gallon EtOH/y

  (94600 m3 – 74600 t/y)
- 285000 t/y biomass,770 t/d
- 275 MUS$ investment

US Abengoa Hugoton

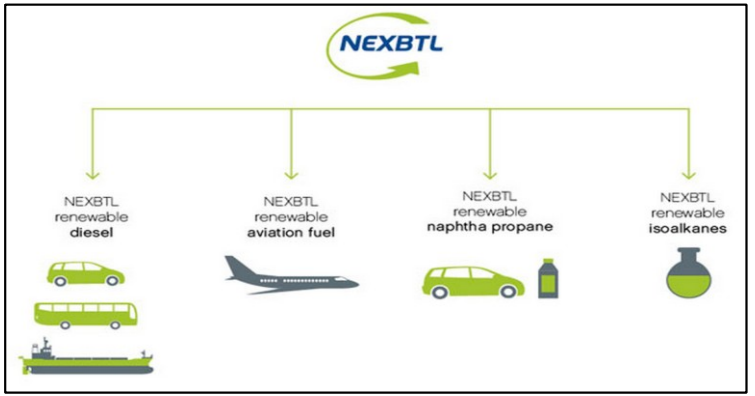
- Grand Opening: 17/10/2014
- 25 Million Gallon EtOH/y

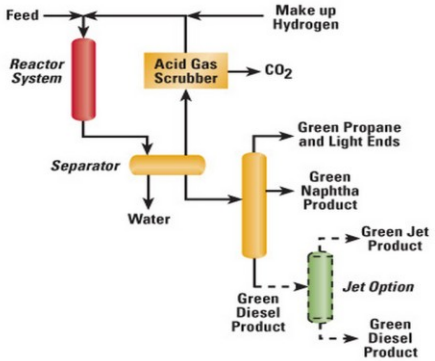
  (94600 m3 – 74600 t/y)
- 21 MW electricity
- 1000 t/d of biomass
- 132.4 M$ US Loan Guarantee +

  97 MUS$ Grant
- 17 MUS$/y to local economy

HVO: the most abundant, suitable for aviation, technologically ready, not lignocellulosic

- **NESTE: NEXBTL Renewable Diesel**
  - Porvoo (2 unit, 190+190): 380.000 t/y
  - Singapore: 800.000 t/y (installed capacity)
  - Rotterdam: 800.000 t/y
  - ✓ *Total investment 1.5 Bill.€*
  - ✓ *Total prod cap ≈2 Mill.t/y, to be increased up to approx. 2.3 Mill.t/y (+15%)*
- **ENI (ENI-UOP Ecofining): Green diesel**
  - 600.000 t/y (Porto Marghera) design capacity
  - Possible new projects





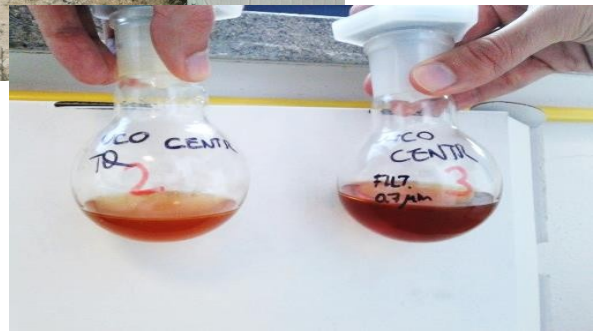
Main issues: sustainability of VO, food vs fuels.

Initiative Towards sustAinable Kerosene for Aviation

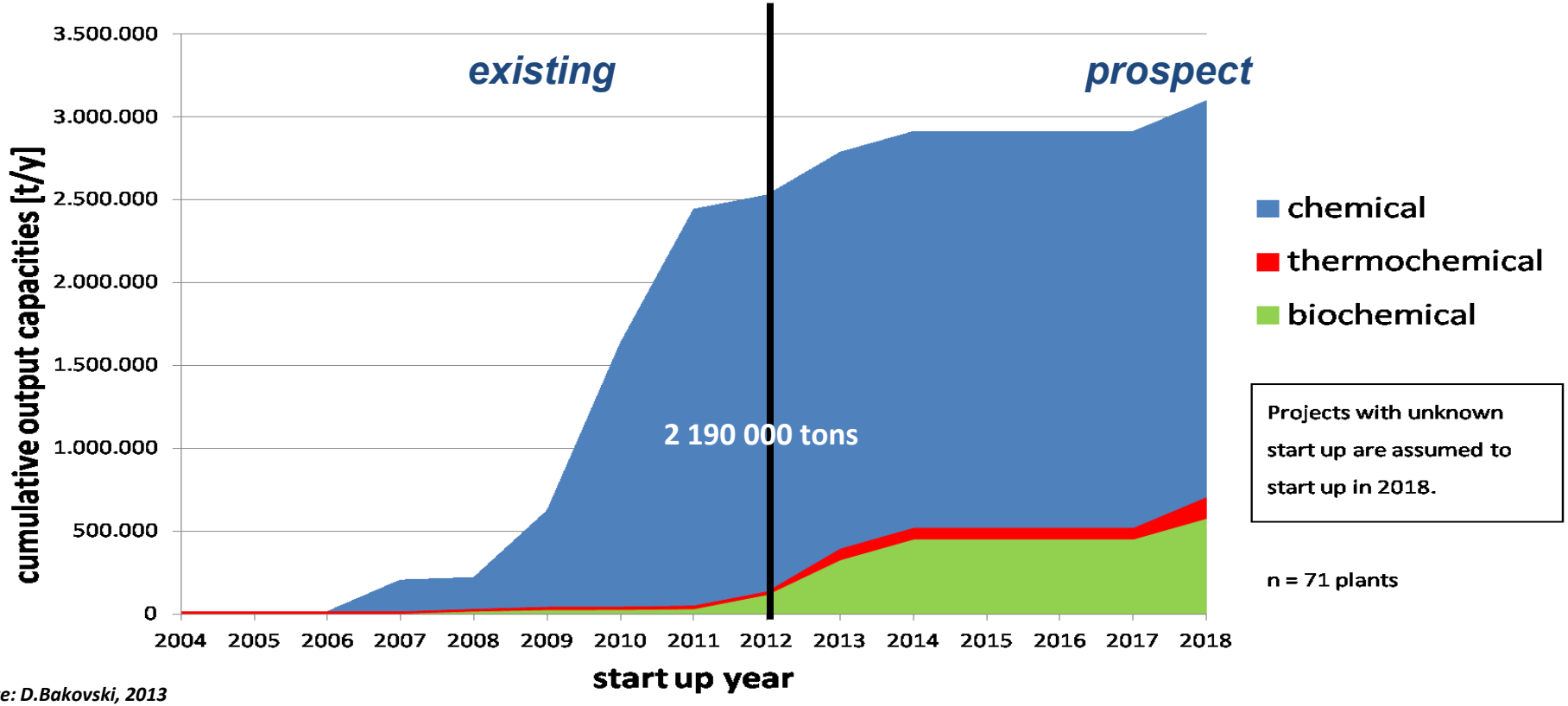
ITAKA will link supply and demand by establishing a relationship under guaranteed conditions between feedstock grower, biofuel producer, distributor and airlines.

- SENASA
- Asociatia Centrul de Biotehnologii Microbiene BIOTEHGEN
- EADS
- EMBRAER
- Neste Oil
- Camelina Company España (CCE)
- Airbus
- Compañía Logística de Hidrocarburos S.A. (CLH)
- École Polytechnique Fédérale de Lausanne (EPFL)
- Manchester Metropolitan University (MMU)
- SkyEnergy
- Consorzio per la Ricerca e la Dimostrazione Sulle Energie Rinnovabili (RE-CORD)

Use of VO-UCO for Biokerosene

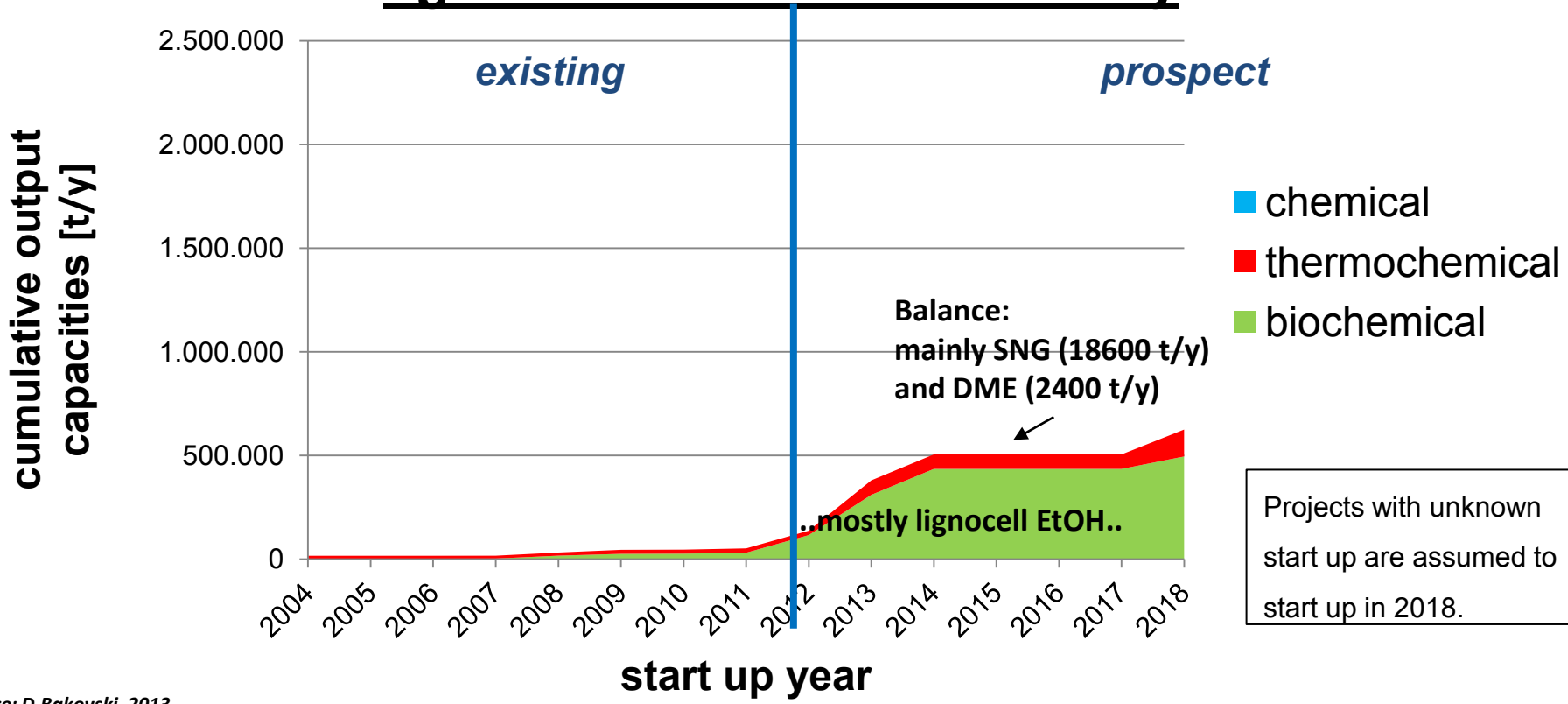


Cumulative production capacities of advanced biofuels



Source: D.Bakovski, 2013

Cumulative production capacities of advanced biofuels - lignocellulosic feedstock only



Projects with unknown start up are assumed to start up in 2018.

Source: D.Bakovski, 2013

Advanced Biofuel/Biorefinery Projects support by EC

- **EC (DG ENER) support** for large scale Demo on 2nd generation/**advanced biofuels** amount to about **154 M€**.
- **EC (DG RES)** support to **advanced biofuels** and **bioenergy** projects amount to about **196 M€, 125 M€ of** which to **biofuels/biorefining**
- **EC DG CLIMA (NER300-1) : ~ 629 M€ to Bioenergy**
  - ⇨**~ 82 M€** (13%) to Biochemical Processes
  - ⇨**~ 547 M€** (87%) to Thermochemical Processes
- Out of **8** projects, **5 to Advanced Biofuels (516 M€)**
  - ⇨**3** Thermochemical, **~457 M€** (88, 170, 199 M€)
  - ⇨**2** Biochemical, **~59 M€** (28, 31 M€)

EC DG CLIMA (NER300-2)
~ 308 M€ to Bioenergy

Category	Project Name	Country	Fund. €m
Bioenergy (MSW-to-ethanol)	W2B	Spain	29.2
Bioenergy (cellulosic ethanol)	MET	Denmark	39.3
Bioenergy (fast pyrolysis)	Fast Pyrolysis	Estonia	6.9
Bioenergy (gasification/torrefaction)	TORR	Estonia	25
Bioenergy (pyrolysis/CHP)	CHP Biomass Pyrolysis	Latvia	3.9
Bioenergy (Bio-SNG)	Bio2G	Sweden	203.7

USA

- Energy Independence and Security Act (2007) → **US target of 36 billion gallon per year** (BGPY) by 2022
  - 15 BGY Cap on Conventional Corn Starch-based Biofuels
- As of Feb. 2012: US-DOE invested more than **1 billion US dollars in 29 integrated biorefinery projects** to advanced biofuels.
- Out of the **29** projects
  - ***16 cellulosic ethanol*** *projects with* ***766 M USD*** *support,*
  - ***11 hydrocarbon fuel*** *projects with* ***326 M USD*** *support,*
  - ***1 butanol*** *project with* ***30 M USD*** *support*
  - ***1 succinic acid*** *production facility with* ***50 M USD*** *support.*
  - **2 R&D bench scale demonstration facility**, **12 pilot** scale demonstration facilities, **9 full scale demo** plants and **6 commercial** scale plants.
  - Main bio-products: **ethanol, butanol, gasoline and diesel (FT liquid and FT waxes), Jet fuels, chemicals**, and **power**.

Source: J.McMillan, NREL, 2012

..shifting to lignocellulosic…

..not an easy taks, but

R&D projects ongoing…

Considerations about industrial status (lignocellulosic feedstocks)

- **Thermochemical route**
  - This pathway for transports did not yet developed as initially expected (..or hoped!)
  - PO for heat and power demo scale (Fortum/Valmet/UPM/VTT, BTG, UOP-Envergent)
  - PO for transport not yet demonstrated at industrial scale (KIOR)
  - Gasification+FT as well (e.g. Choren)
  - Qualified for Aviation fuel from fossil – Not ready today for Biomass-to-AvBio
- **Biochemical route**
  - Today almost ready, for road - commercial maturity.
  - Various demo plants built/under construction in EU&USA (and elsewhere)
  - Ethanol the main product – Not yet ready for AvBio
  - However, co-products (lignin) suitable for being processed into Aviation Biofuels
- **Hybrid route**
  - INEOS Bio, Lanzatech: Demo stage
- **Chemical route**
  - UMP technology from CTO (pulp and paper). Not applied to AvBio.

Jet fuels from Lignin

The advanced Biorefinery with PROESA™

MO's

Fermentation /Separation

Isobutanol
N-butanol
Fatty Alcohols
1,4 BDO
…

YEAST

C5,6 Sugars

BIOMASS

PROESA Technology

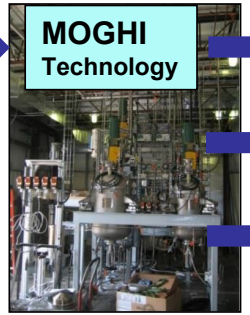
Fermentation

Separation

Ethanol

Lignin

MOGHI Technology



BTX

JET FUEL

PHENOLS

Hydrogen

C5 Sugars

GREG Technology

Polyols

BIOREFLY

2,000 TON/Y INDUSTRIAL SCALE DEMONSTRATION BIOREFINERY ON LIGNIN-BASED AVIATION FUEL

Co-funded by the European Commission in the 7th Framework Programme
Duration: 4 years (2014-2018)
Project Budget: 25.4 m€ – EC Contribution 54%

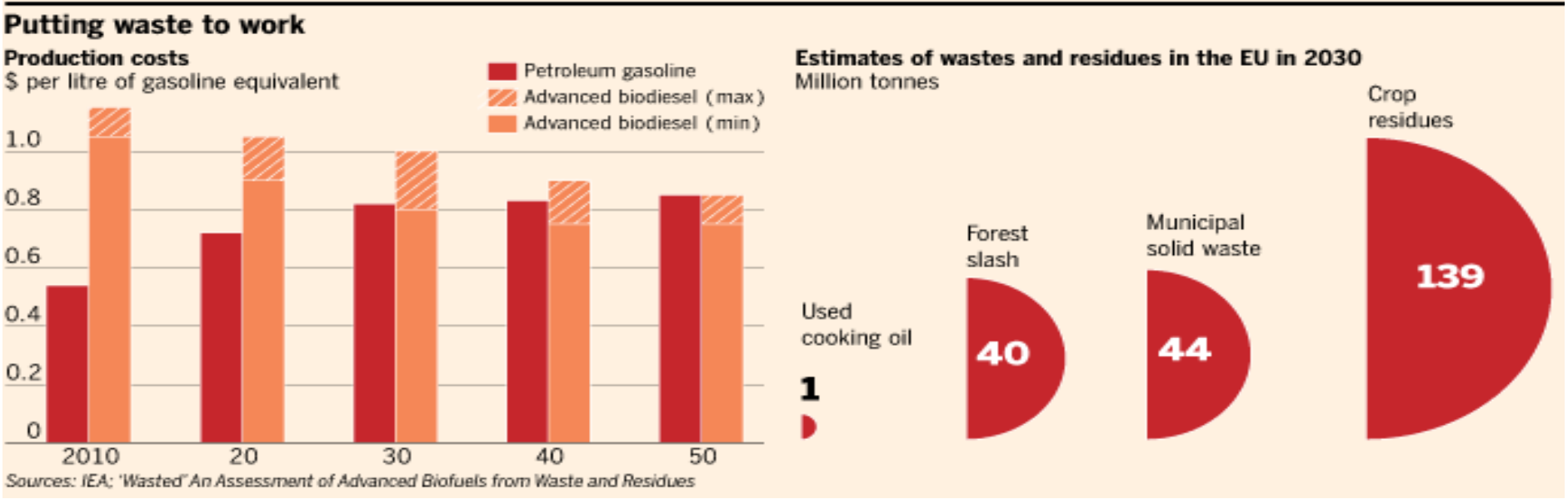
- Validation at pre-commercial scale on novel competitive technologies for lignocellulosic-based aviation fuel production
- Design, construction and operation of a first in its kind paraffinic fuel industrial based on innovative second generation technologies
- Address the complete value chain, thus including the conversion of lignocellulosic energy crops and agro residues into biofuel
- Test of jet fuel use in turbines and engines including demonstration flights

Pilot projects in the EU

- **EU FP7 BFSJ (Swedish Biofuels)**
  - Production of fully synthetic paraffinic jet fuel from wood and other biomass. bio-kerosene via the ethanol route.
  - Key partners Abengoa Bioenergy, Lufthansa, SkyEnergy and LanzaTech
- **British Airways & Lanzatech**
  - Gasification + fermentation process
- **EU PF7 Solarjet**
  - Lab scale investigation. Concentrated sunlight with CO2 captured from air and H2O to produce kerosene by coupling a two-step solar thermochemical cycle based on non-stoichiometric ceria redox reactions with the Fischer-Tropsch process.

Lignocellulosic Biomass

Wastes to Advanced Biofuels: feedstock is available!



- Wastes are available in significant amount in the EU. 900 Mt/y: a quarter of it could be available for energy, i.e. 220 Mt/y.
- Technical potential if converted to transp.biofuels: 16% of road fuels in 2030

Take home message:

Policies are key for advanced biofuel

…technology is almost there..

- Uncertainties in EU on biofuels premium over fossils → **difficult to develop bankable projects**
  - **ILUC** and **post 2020 – STILL UNDER DEBATE**
  - **Specific targets for Advanced Biofuels – MISSING in the EU**
  - **Financing** (guarantees) – **DIFFERENT FROM US AND BRASIL**
  - **Applicable Sustainability Schemes** – **EU syst. extremely complex for lignocellulosic**
- **A large number of approved projects withdrawn** (e.g. **UPM**,170 M€ EU approved grant for a lignocellulosic biorefinery in Strasbourg; **Vapo/Forest-BTL**)
- In total, **300 M€ NER300-1 not used** by 4 approved projects at first round NER300 (Stracel, Westwave, Pyrogrot, AjosBTL)! Other 250-450 M€ at risk.

→ The case of **ITALY**: recent **Decree (Oct 2014) on Advanced Biofuels Mandates (road)** → This is the best approach to motivate both industry and investors to develop advanced biofuel chain, **including those addressing Aviation Fuel!**.

Thanks for your attention

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