SUSTAINABLE JET FUEL FROM PROESA™

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FIRST ANNUAL WORKSHOP OF ISAFF
ROME, 4 NOVEMBER 2014

Mossi Ghisolfi background

1953 - 1979	1979 - 2000	2000 - TODAY	
Packaging Manufacturing Phase	Chemical Specialty Manufacturing Phase	PET expansion phase	*Renewables*
HDPE and PVC packaging production	Development and production of PET resins for food packaging	Acquisition of PET Shell activities and Rhodia from Rhone Poulenc Acquisition of Chemtex from Mitsubishi Corporation Construction of the world's largest plants for PET production in Altamira (Mexico) and Suape (Brasil) Plans announced for a new plant in Corpus Christi (Texas, USA)	2006 -2008 - Lab scale technology development for 2nd gen ethanol 2009 - Pilot plant for cellulosic ethanol 2011 - Beta Renewables is founded, dedicated to sustainable chemistry. 2012 - Beta Renewables and Novozymes partnership. 2013 - World's 1st commercial-scale plant that produces biofuels from non-food biomass (60.000 ton/year)

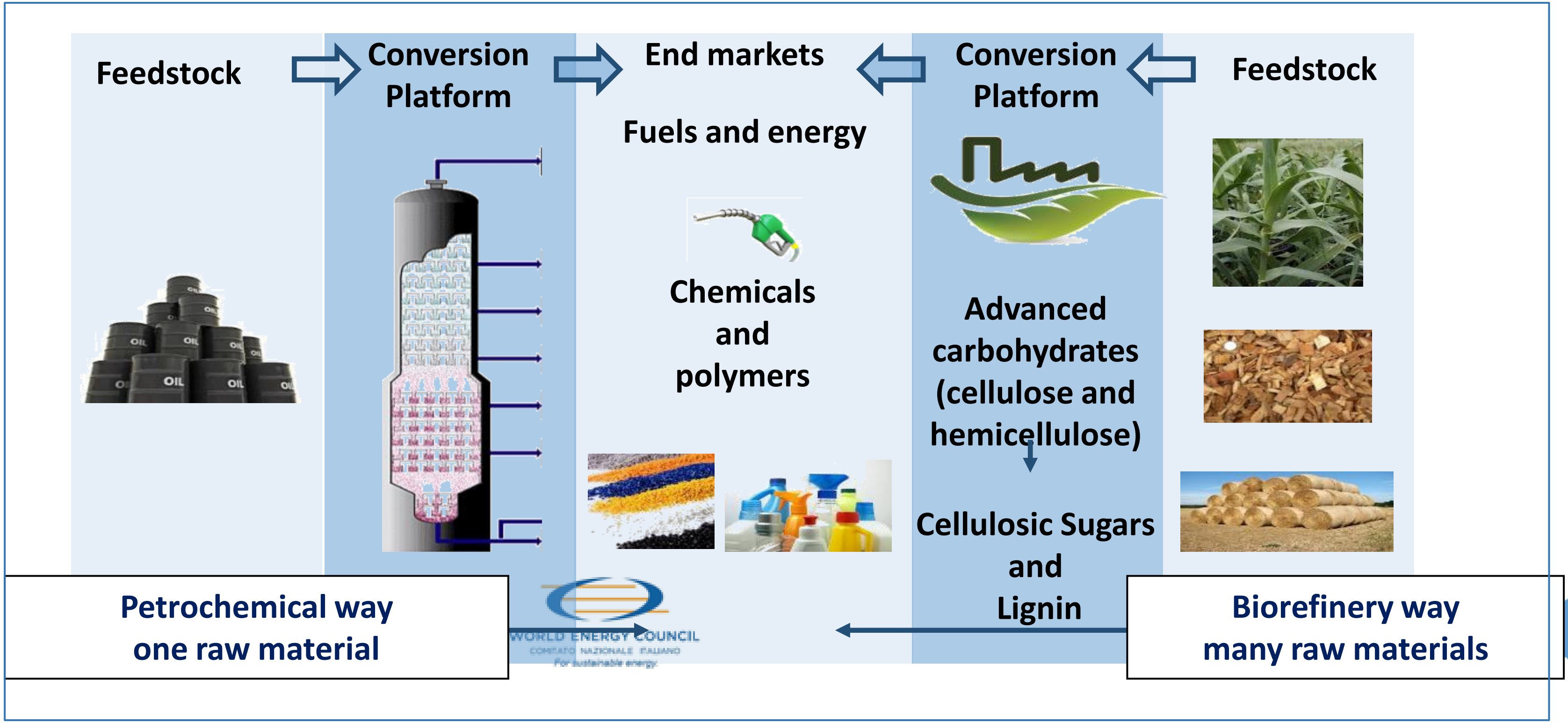
WHERE WE ARE LOCATED

Biochemtex

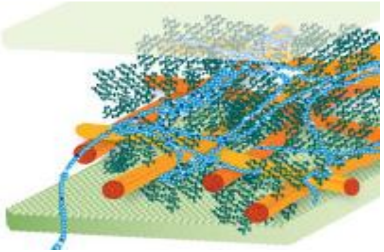
- Biochemtex is a global engineering and technology company wholly-owned by Italy's Gruppo Mossi Ghisolfi.
- Biochemtex is specialized in delivering value-added project solutions for its clients in the bio-fuels, renewable chemicals, energy, environmental.
- Biochemtex is the prime engineering contractor for Beta Renewable's 60,000 ton per year plant in Crescentino.
- Biochemtex works as a subcontractor to Beta Renewables to create the engineering plans that are part of a PROESA™ license.
- Additionally, Biochemtex enables rapid plant deployment, by supplying some equipment needed for a PROESA™ based plant along with implementation services.

The Biorefinery Concept

The biorefinery concept is analogous to today's petroleum refinery, which produces multiple fuels and chemicals from petroleum.



LIGNOCELLULOSIC MATERIALS COMPOSITION



CELLULOSE **HEMICELLULOSE**

BIOFUEL (EtOH)

LIGNIN

CHEMICALS, ECOCOMPOSITES, FUELS

CELLULOSE

Long chains of beta-linked glucose, Crystalline structure, Polymer of 6-carbon sugars (mainly Glucose)

HEMICELLULOSE – XYLANS, ARABINOXYLANS

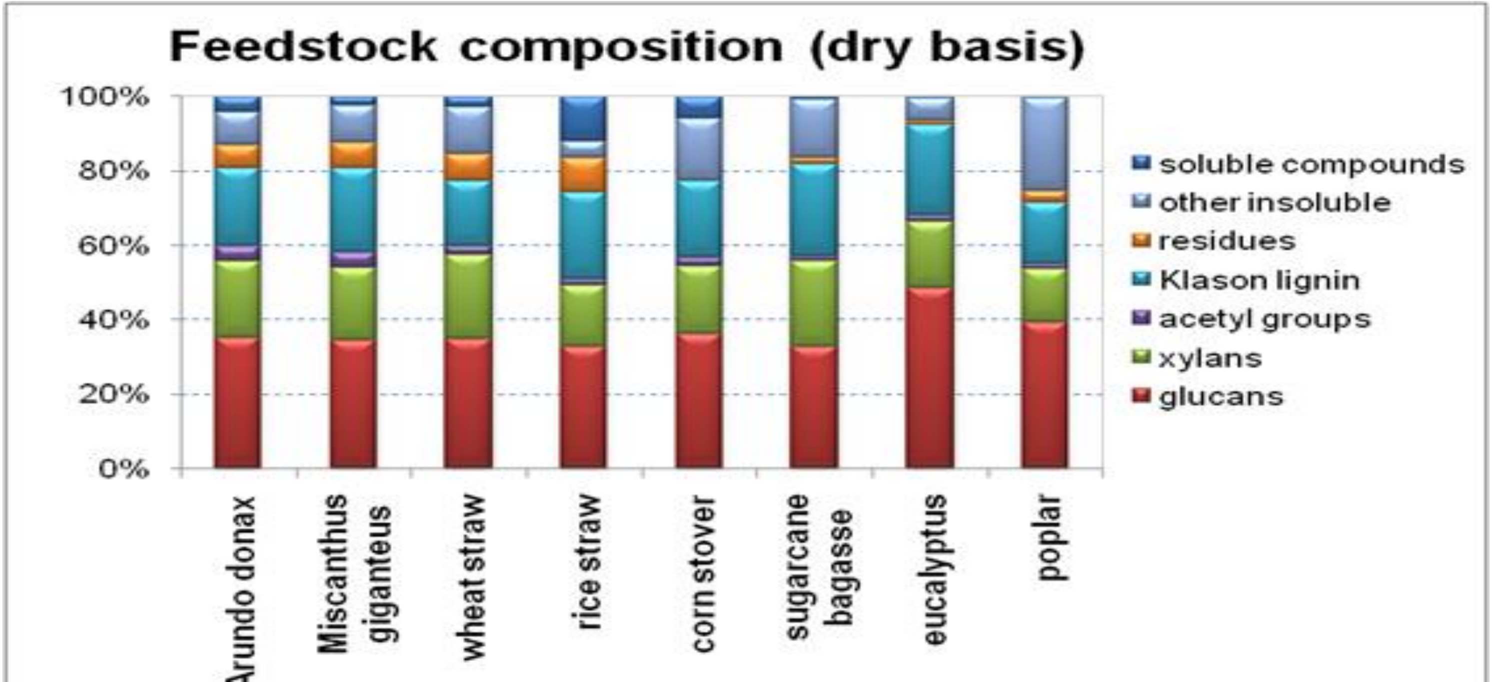
A polymer of 5- and 6-carbon sugars linked together in long, substituted chains branched

LIGNIN

Complex network of aromatic compounds, High energy content

LIGNIN CONTENT IN BIOMASS

Lignin content in biomass varies depending on type of biomass and on harvesting time and zone, as shown in the graph below where several biomasses were evaluated and tested as a feedstock for the PROESA technology in Rivalta labs:



Internal analysis according to Chemtex methods

Possible Lignin Sources

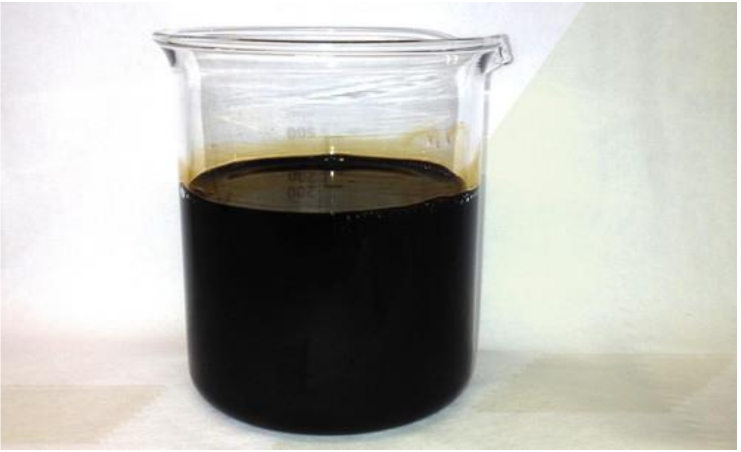
Lignin, as part of the biomass, can be derived from many different sources:

- ✓ Pulp and Paper (Black Liquor)
- ✓ Biorefinery - by product from bioethanol production
- ✓ Industrial Biomass Based Waste (Olive pomace, Sawmill Residues, Wood Industry Residues etc..)
- ✓ Agricultural Waste (Wheat Straw, Rice Straw, Sugar Cane Bagasse, Olive Tree Pruning etc..)
- ✓ Energy Crops (Arundo Donax, Switchgrass, etc..)

Pulp and Paper Lignin

Sulfite Pulping - Lignosulfonates

Lignosulfonates are isolated from spent sulfite pulping liquors and are the most important commercial source of lignin today (global production: 1 MMT/y). They contains sulfonate (-SO3-) groups bonded to the polymer and are therefore soluble in water at a wide range of pH. The common applications of lignosulfonates are as dispersants, binders, complexing agents and emulsifying agents.



Kraft Pulping – Black Liquor

In this case strong alkali with a sodium sulfide catalyst is used to separate lignin from the cellulose fibres. The lignin and hemicellulose that is dissolved in the pulping stage is known as “black liquor” and is sent to a recovery system where it is burned.

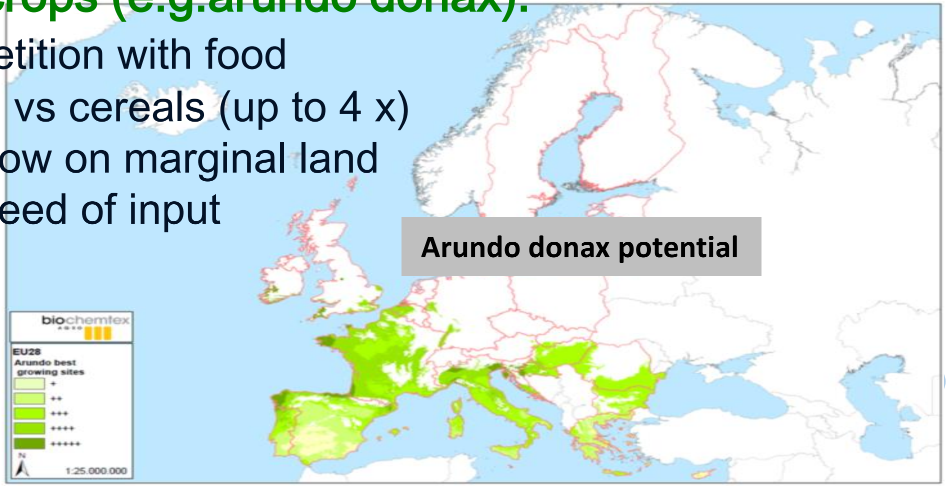
AGRI-RESIDUES (STRAW) AND NON-FOOD ENERGY CROPS

Wheat Straw

- Widely available in Europe (exceeding 200 Mtonn/y) and the whole World (approx 600 Mtonn/y)
- No competition with food
- Other agricultural residues, global availability (4,6 Btonn/y)

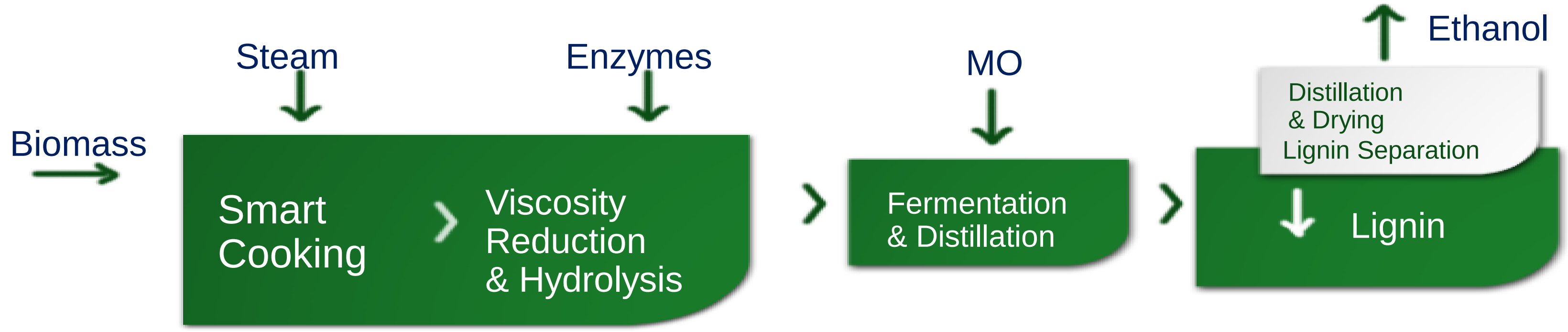
Non-food crops (e.g.arundo donax):

- ✓ No competition with food
- ✓ High yield vs cereals (up to 4 x)
- ✓ Able to grow on marginal land
- ✓ Minimal need of input



Source BNEF @ 2030-Tonn dry biomass

BIOREFINERY LIGNIN – BY-PRODUCT FROM PROESA BIOETOH PRODUCTION



PROESA® Technology benefits:

Feedstock flexibility

Patent Pending "smart cooking" and "viscosity reduction": continuous process, no chemical addition, optimal C5 & C6 sugar extraction and low enzyme dosage

Fully integrated process design using continuous equipment to enable large scale plants

Best in class technology with lowest capex and opex backed with process and performance guarantees

Biorefinery Lignin

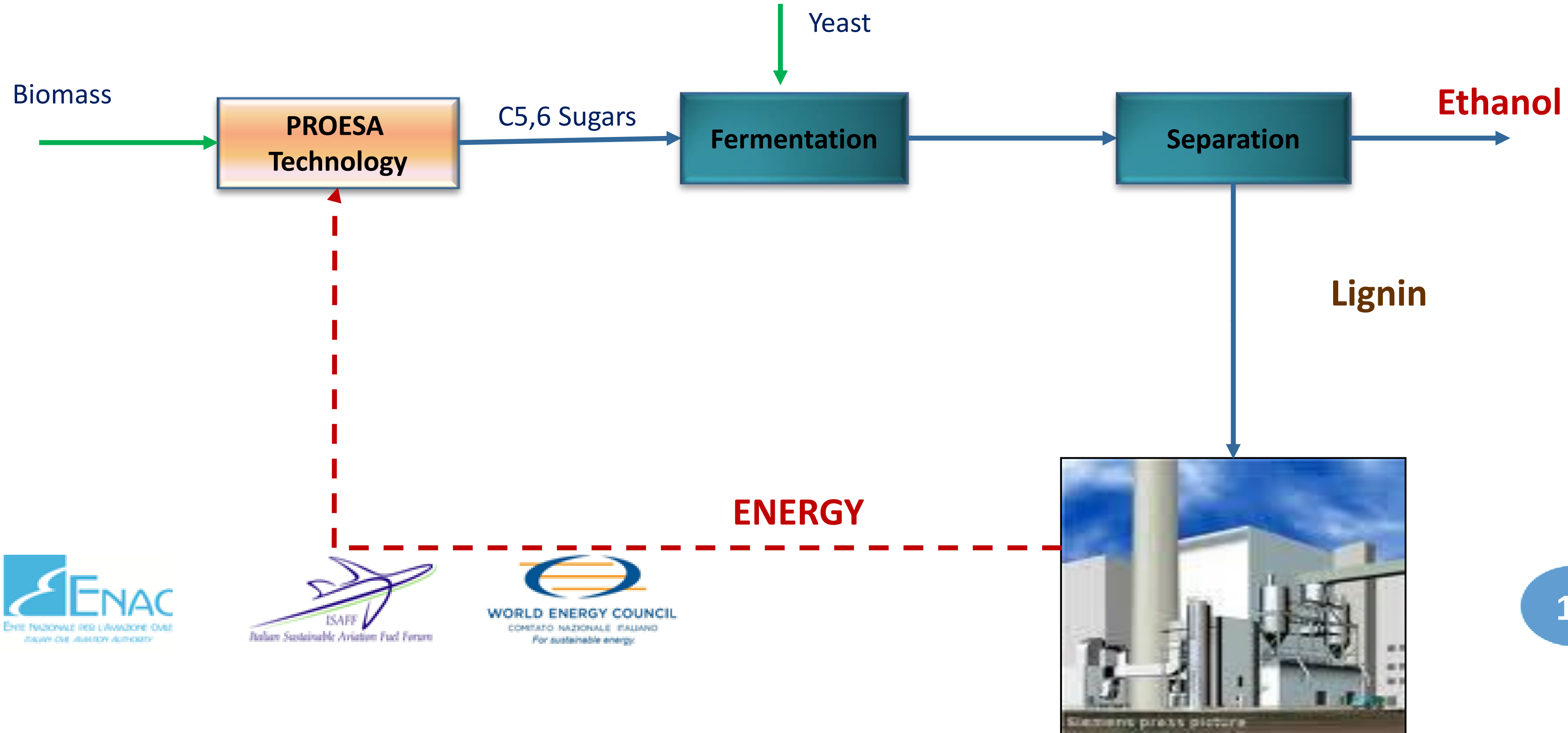
Lignin from PROESA process is recovered after filtration of the bottom product of ethanol distillation (stillage).

Characteristics of this lignin are:

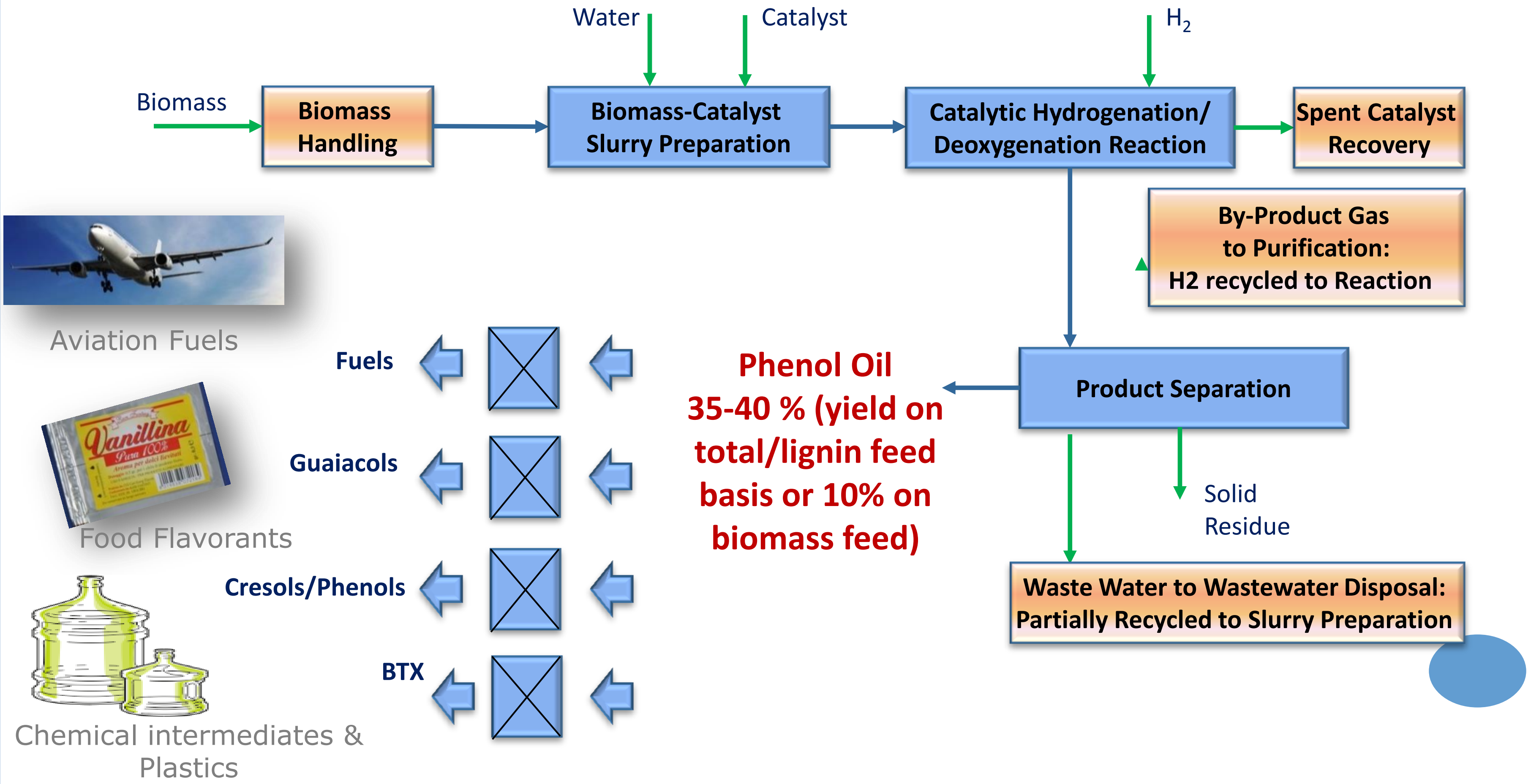
- Particularly pure as the PROESA process doesn't use chemicals during the pretreatment step
- Low content of sulfur and halogens (<1%)
- Micronized, size distribution in the range of 0.53 to 25 µm

Lignin Usage in Crescentino Plant

In Crescentino Proesa Plant lignin is burned to produce energy for the plant itself.



THE MOGHI PROCESS: PLATFORM FOR CHEMICALS



ENOUGH BIOMASS TO MEET EU 2020 TARGET ?

EU TARGET 2020: 2 Million tonns biojet fuel

Residual biomass sustainably available in the EU: exceeding 200 Mtonns/y

Up to 65 Mtonns/y lignin

Up to 20 Mtonns/y phenol oil
10 TIMES THE EU NEED !!!

MOGHI RESEARCH: SHARON CENTER, OHIO

The process was developed on a lab scale (batch and continuous reactors) and then transferred to a continuous pilot plant:

- 2009, Characterization of various lignin products
- 2010, Batch and continuous experiments, process parameters study
- 2011, Designing of continuous process and pilot plant construction at Chemtex Technology Center
- 2012 Pilot Plant start up, June 11th

Bio-Lab

Batch reactors:
50 cc, 8 L, 12 L

Continuous Reactors:
500 cc

Lignin Pilot Plant

Lignin to Jet Fuels Pilot Plant

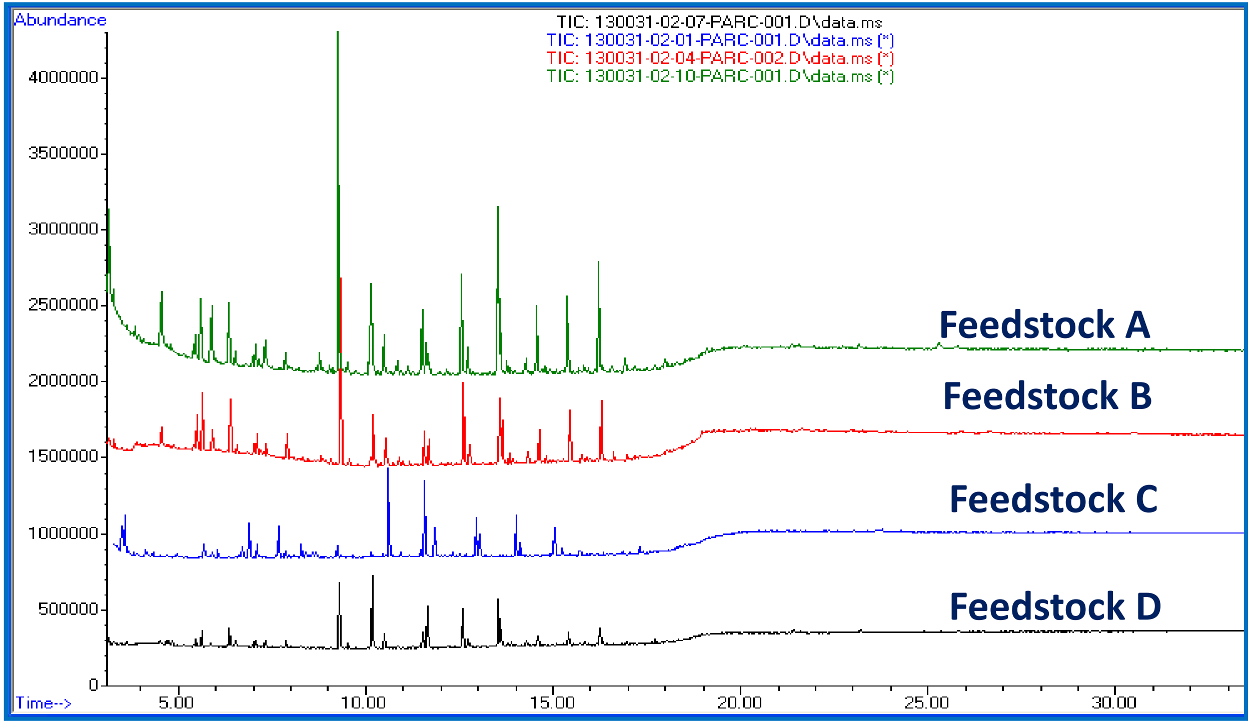
2.5 kg/h Lignin Capacity

Area: 100 m2

ENAC Ente Nazionale per l'Aviazione Civile — ISAFF Italian Sustainable Aviation Fuel Forum — World Energy Council Comitato Nazionale Italiano

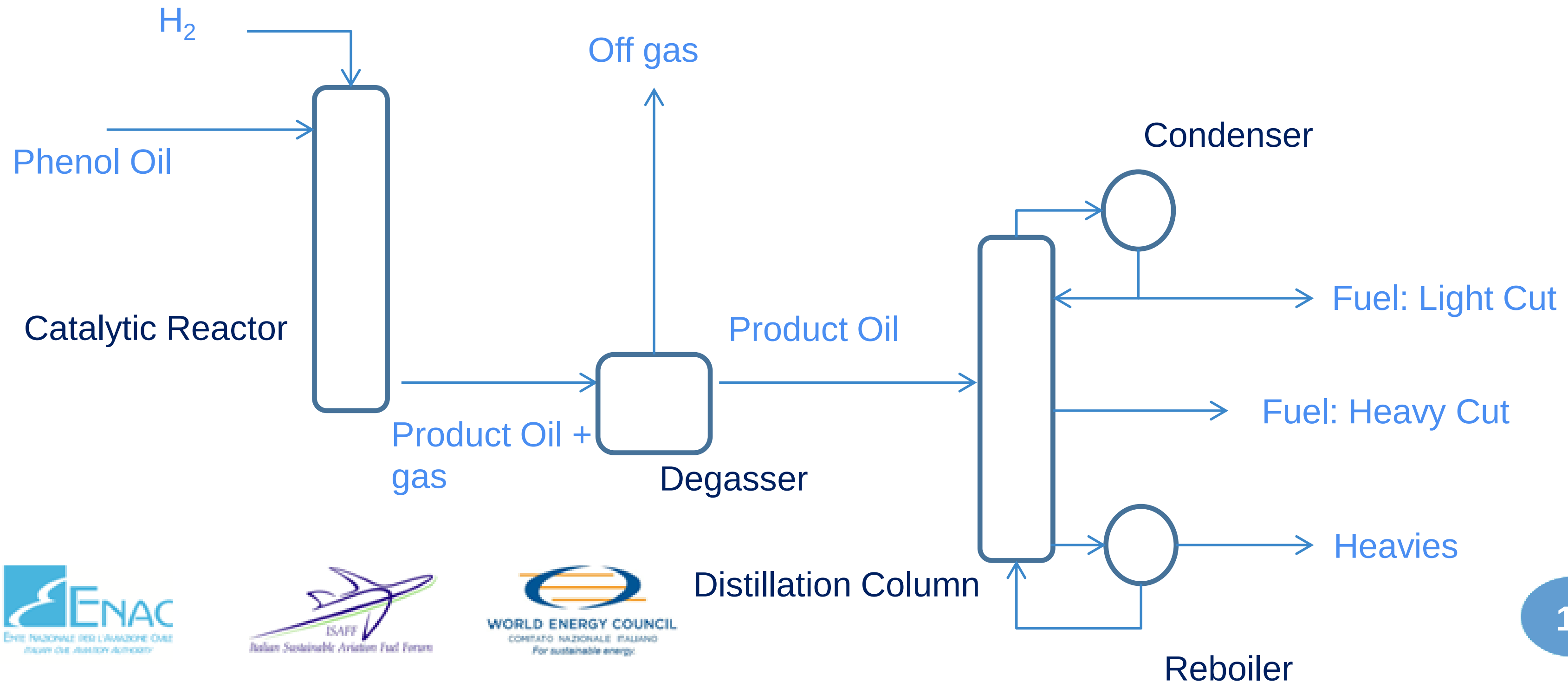
TESTS ON VARIOUS BIOMASSES

MOGHI Process can work starting from different feedstocks. It can use not only different lignins, but also black liquor and residual biomasses. No main changes in Phenol Oil composition are evidenced.



From Phenol Oil to Jet Fuels

Once obtained, phenol oil can be converted to long chain alkanes via catalytic hydrogenation and well-known separation/distillation processes.



Jet Fuel Types

Jet fuel is a mixture of different hydrocarbons:

Kerosene-type jet fuel: C8 - C16
Wide-cut or naphtha-type jet fuel: C5 - C15

<u>Jet fuel types (Kerosene type):</u>

Jet A: used in the United States

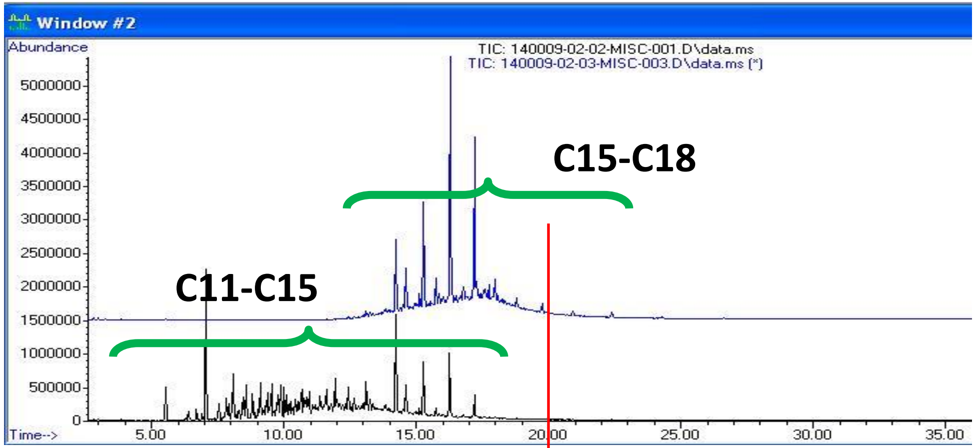
Jet A-1: standard specification fuel used in the rest of the world (Mandatory addition of an anti-static additive).

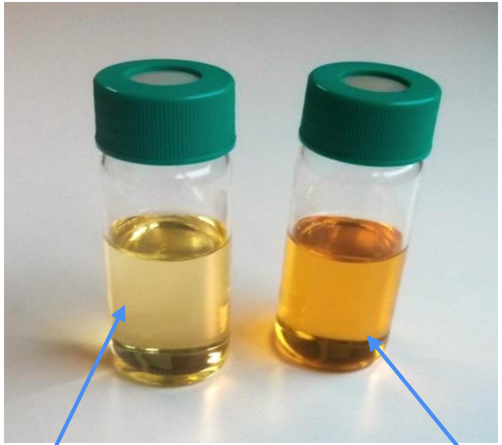
<u>Jet Fuel (Blend type)</u>

Jet B: naphtha-kerosene type, for enhanced cold-weather performance. Dangerous to handle, rarely used.
Wide-cut fuel: blend 30% kerosene - 70% gasoline. Primarily used in the US and some military aircraft.

JET FUEL SAMPLE FROM PILOT PLANT

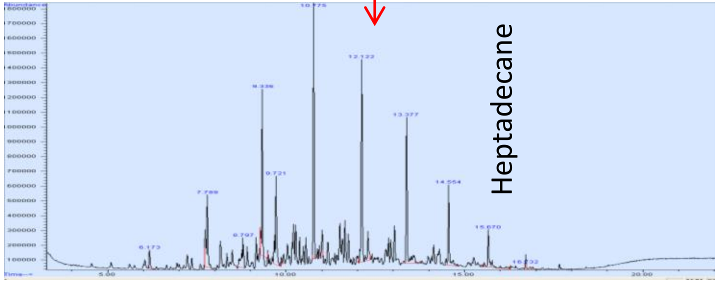
Several lab testing confirm that our jet fuel composition is comparable to a Jet A-1 for aviation. Different cuts of jet fuels were produced.





Light cut (150-260° C)

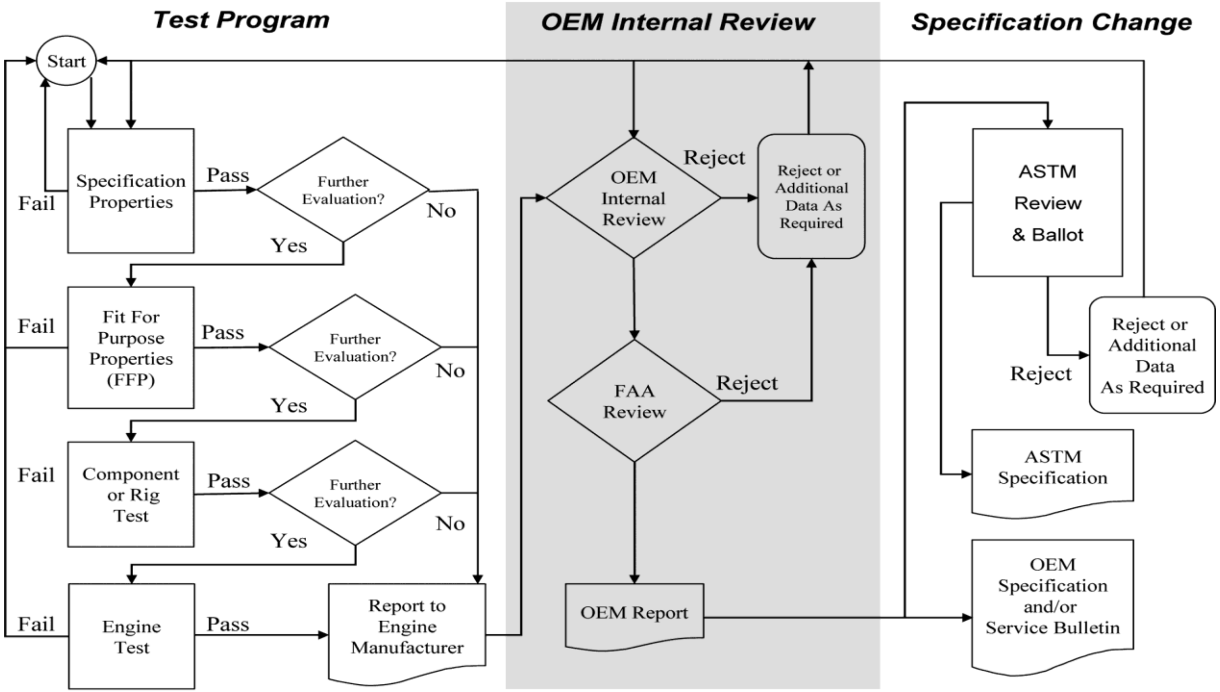
Heavy cut (260-290° C)



Jet A-1 Chromatogram

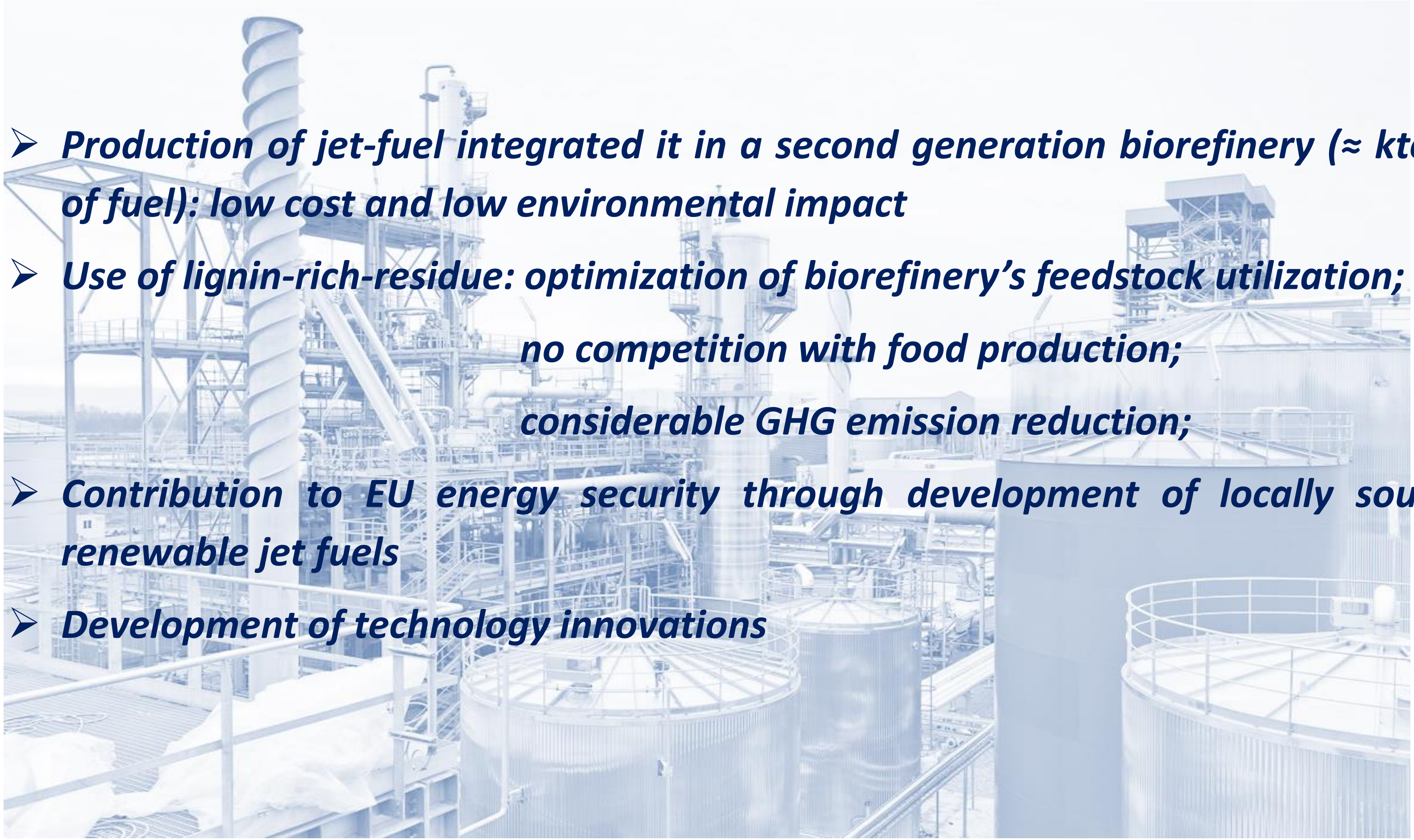
Jet Fuel Samples: Future Developments

The samples will be submitted for the approval procedure following the ASTM D4054 (Qualification and Approval of New Aviation Turbine Fuels and Fuel Additives)



ENAC
Ente Nazionale per l'Aviazione Civile
Italian Civil Aviation Authority

JET FUEL DEMO PLANT: BIOREFLY



- ***Production of jet-fuel integrated it in a second generation biorefinery (≈ kton/y of fuel): low cost and low environmental impact***
- ***Use of lignin-rich-residue: optimization of biorefinery's feedstock utilization;***
  no competition with food production;
  considerable GHG emission reduction;
- ***Contribution to EU energy security through development of locally sourced renewable jet fuels***
- ***Development of technology innovations***

THANKS FOR YOUR ATTENTION!

ENAC
ENTE NAZIONALE PER L'AVIAZIONE CIVILE
ITALIAN CIVIL AVIATION AUTHORITY

ISAFF
Italian Sustainable Aviation Fuel Forum

WORLD ENERGY COUNCIL
COMITATO NAZIONALE ITALIANO
For sustainable energy.