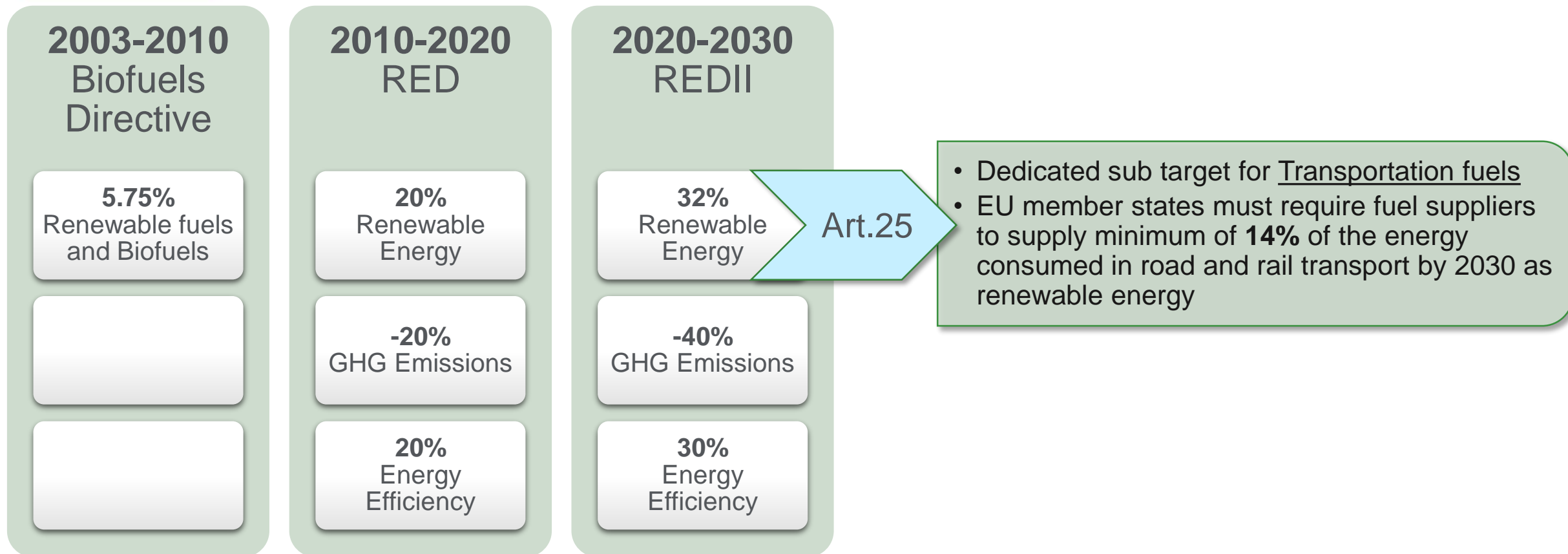


Advanced Biofuels from Fast Pyrolysis Bio Oil


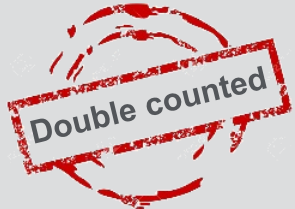


Jacco Kroeze, PRC Europe 2019, May 20-21, 2019

TechnipFMC Process Technology and BTG BioLiquids B.V.

EU POLICY FRAMEWORK ON CLIMATE AND ENERGY



HOW TO REACH 14%: FEEDSTOCK CLASSIFICATIONS

Classification in REDII	Alternative Classification	Feedstocks
First Generation 	Conventional biofuels	Sugar Crops
		Starch Crops
		Vegetable Oils
		Pa X Oil
Second Generation 	Ambiguous (Annex IX Part B) 	Used Cooking Oil
		Animal Fats
		Energy Crops
	Advanced Biofuels (Annex IX Part A) 	Agricultural Residues
		Municipal Solid Waste

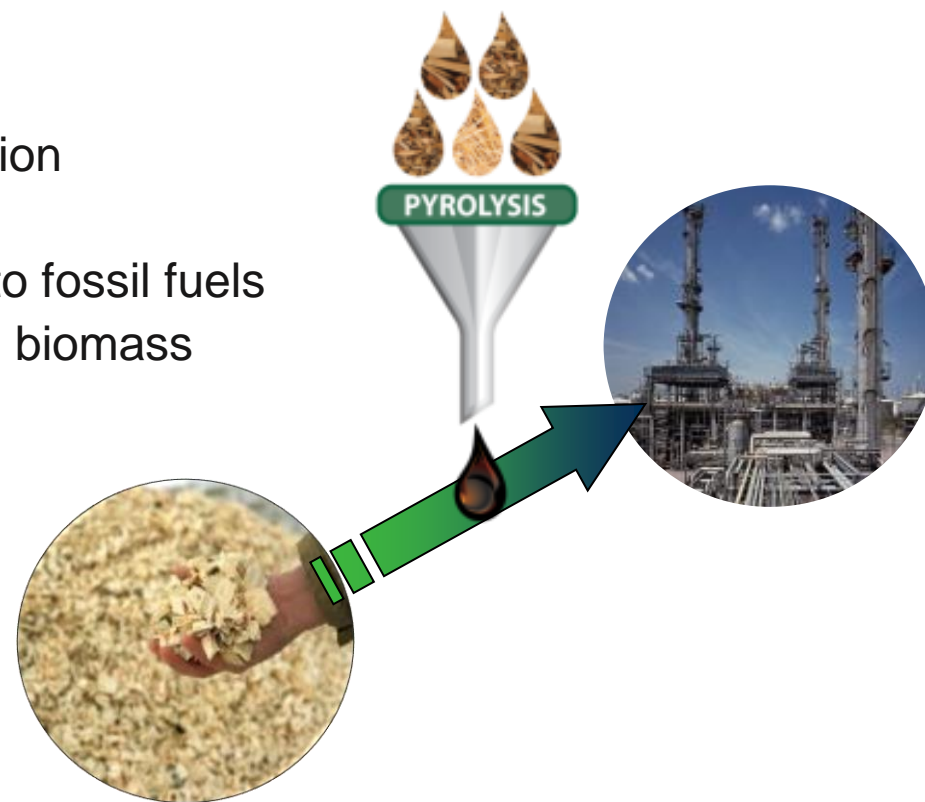
Advanced Biofuels must be supplied at a minimum of:

- > **0.2%** in 2022
- > **1.0%** in 2025
- > **3.5%** in 2030

WHY FAST PYROLYSIS?

- Decouple biomass resource from location and scale of application
- Works with a variety of lignocellulosic biomass feedstocks
- Produces a homogeneous bio-liquid; a sustainable alternative to fossil fuels
- Fast Pyrolysis Bio-Oil is easier to store and transport than solid biomass due to significant volume reduction (on average factor 12)
- High overall efficiency of > 85%
- Versatile application: Heat, power and transportation fuels
- Utilize existing fossil fuel infrastructure:

- Pyrolysis oil provides a viable link between the agriculture and (petro-) chemical industry.
- Can be used as a renewable feedstock for petrochemical industry for the production of **Advanced Biofuels**.



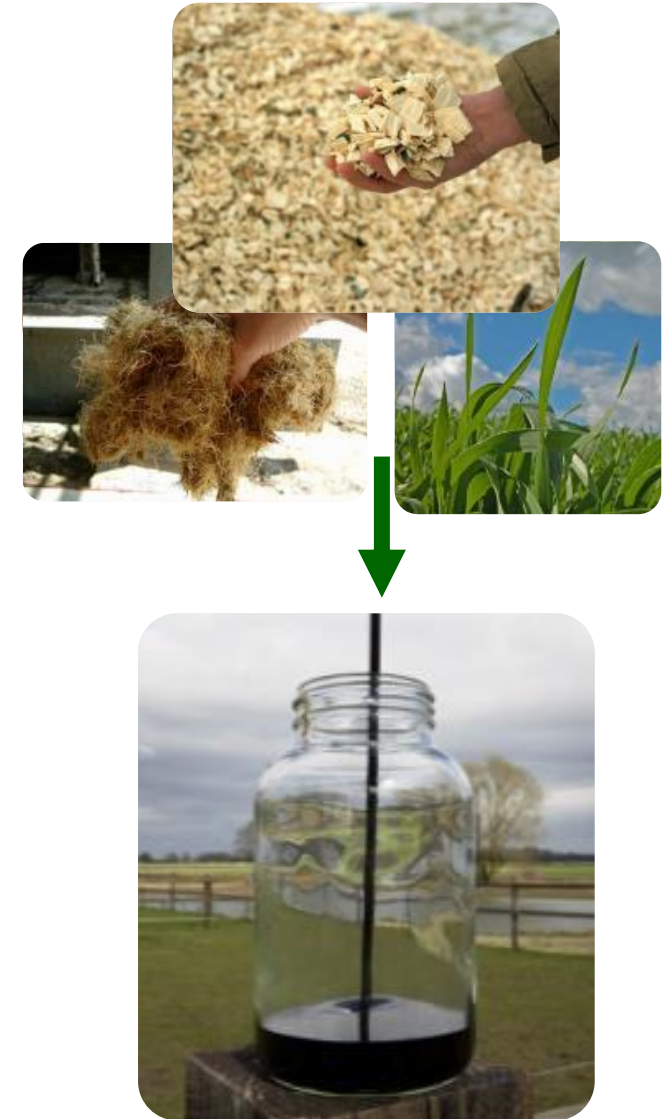
WHAT IS FAST PYROLYSIS?

Thermal cracking of organic material in the absence of oxygen

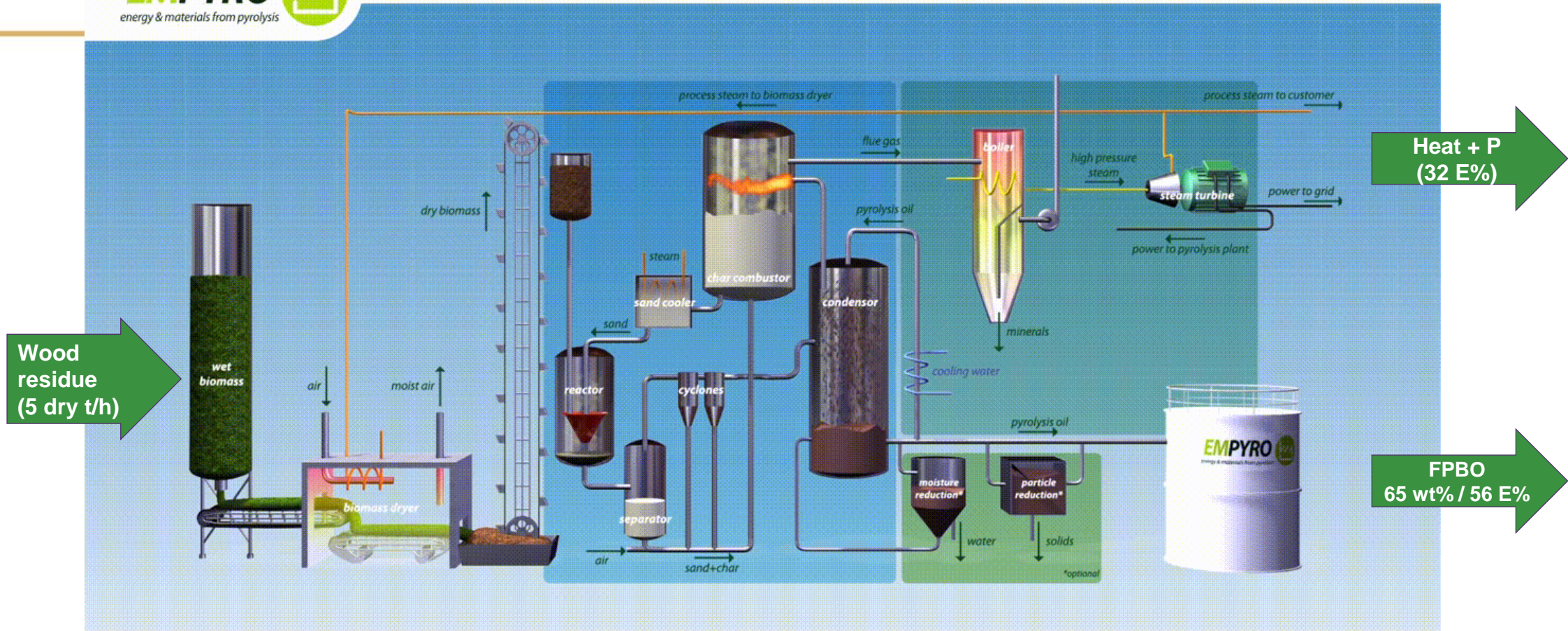
- Main Product = bio-liquid
- Process conditions:
 - > T = 400 - 600 °C
 - > P = atmospheric
- By-products:
 - > Heat (Steam)
 - > Power (Electricity)

Works with most lignocellulosic (waste) feedstocks

- Wood chips, sugar cane bagasse, straw, sunflower husk, etc.



COMMERCIAL FAST PYROLYSIS BIO-OIL PRODUCTION



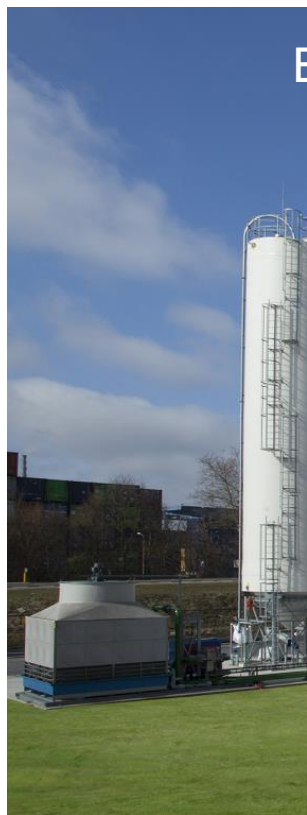
Wood residue
(5 dry t/h)

Heat + P
(32 E%)

FPBO
65 wt% / 56 E%

COMMERCIAL FAST PYROLYSIS BIO-OIL PRODUCTION

BTG-BTL hands over Empyro pyrolysis plant to Twence



 Bioenergy International  Biofuels & Oils  December 12, 2018

In the Netherlands, biomass technology developers BTG-BTL has announced that effective January 1, 2019, the Empyro pyrolysis plant in Hengelo will be taken over by municipal energy utility Twence Holding B.V. The parties will continue working closely together to further develop the plant and explore new sustainable initiatives.



Finland first for Dutch pyrolysis technology developers

 Bioenergy International  Biofuels & Oils  April 2, 2019

Finland is set to invest up to EUR 100 million in bio-oil production facilities using pyrolysis technology developed in the Netherlands and sawmill residues. An initial investment of EUR 25 million will be used for the purchase of a single production facility, but the client intends to purchase three more such facilities, bringing the total order to EUR 100 million.



TECHNIPFMC-BTG-BTL COLLABORATION

Rolling out Fast Pyrolysis Bio-Oil technology & commercial production:

- Complete turnkey (EPC) delivery of Fast Pyrolysis Bio-Oil (FPBO) units
- Operational support for commercial production of pyrolysis oil



About TechnipFMC:

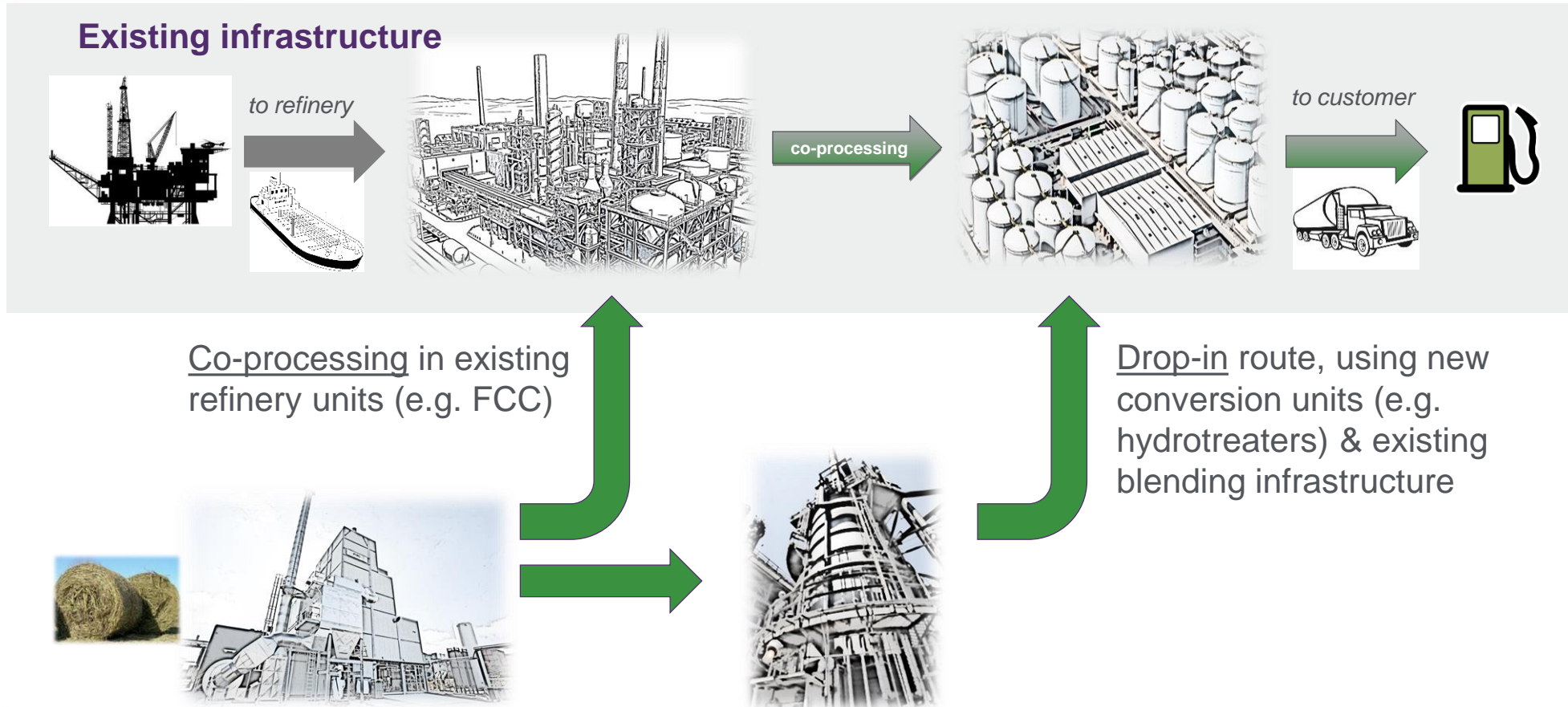
- Global footprint with ~37,000 people in 48 countries.
- Technology leader in hydrogen, ethylene, refining & petrochemical projects.
- >35 years experience in development, design and construction of proprietary FCC technology.



About BTG-BTL:

- Founded in 2007, BTL (BTG BioLiquids B.V.) is a biomass technology provider based in The Netherlands.
- Owns the first commercial scale plant in The Netherlands.
- Owns proprietary technology, originally developed at the University of Twente.
- BTL owns international patents regarding biomass pyrolysis.

ADVANCED BIOFUELS: DROP IN & CO-PROCESSING



FAST PYROLYSIS IN THE BIO-BASED ECONOMY

1. Biomass conversion

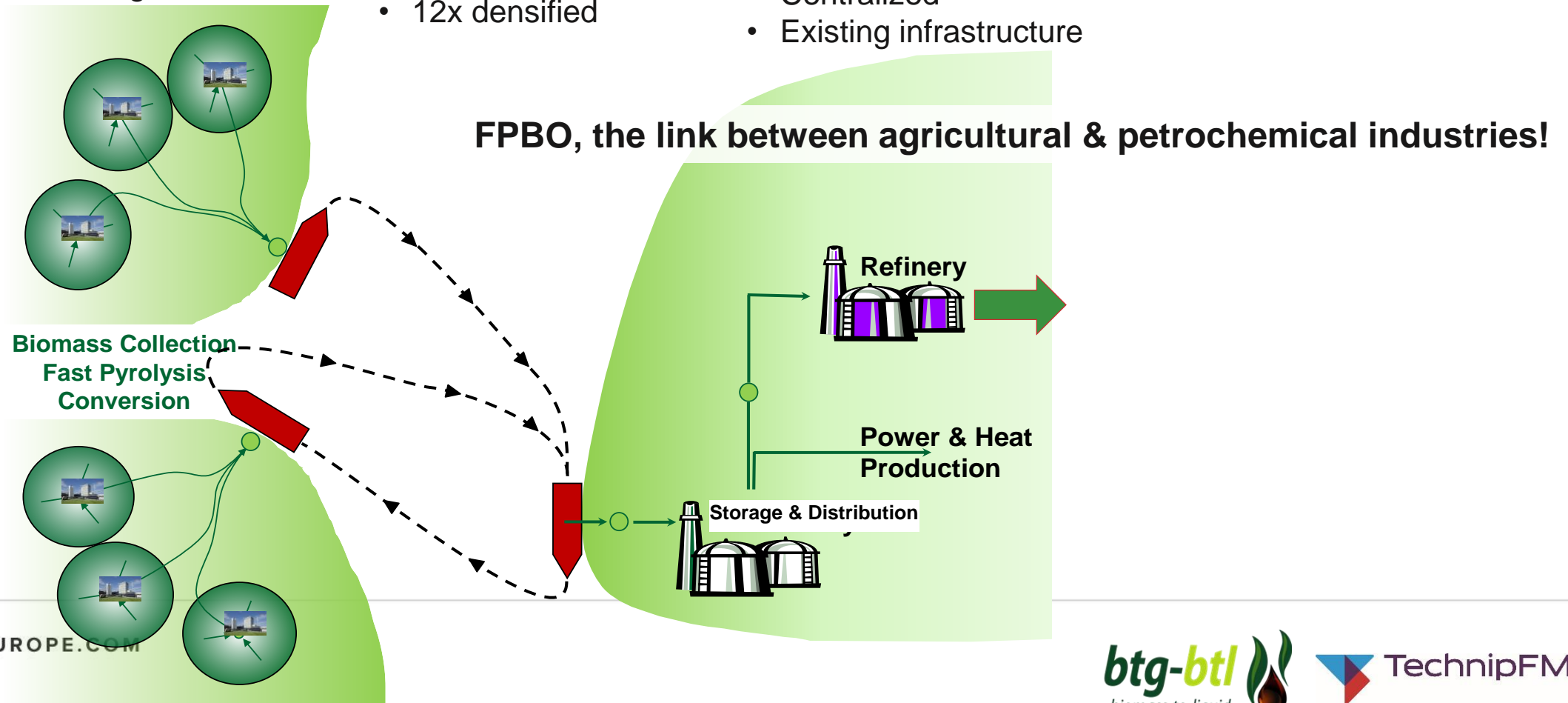
- Local processing
- Returning minerals

2. FPBO transport

- Biomass liquified
- 12x densified

3. Processing & distribution

- Centralized
- Existing infrastructure



CO-REFINING OF FPBO, HOW DOES IT WORK?

Typical Fluidized Cat Cracker scheme:

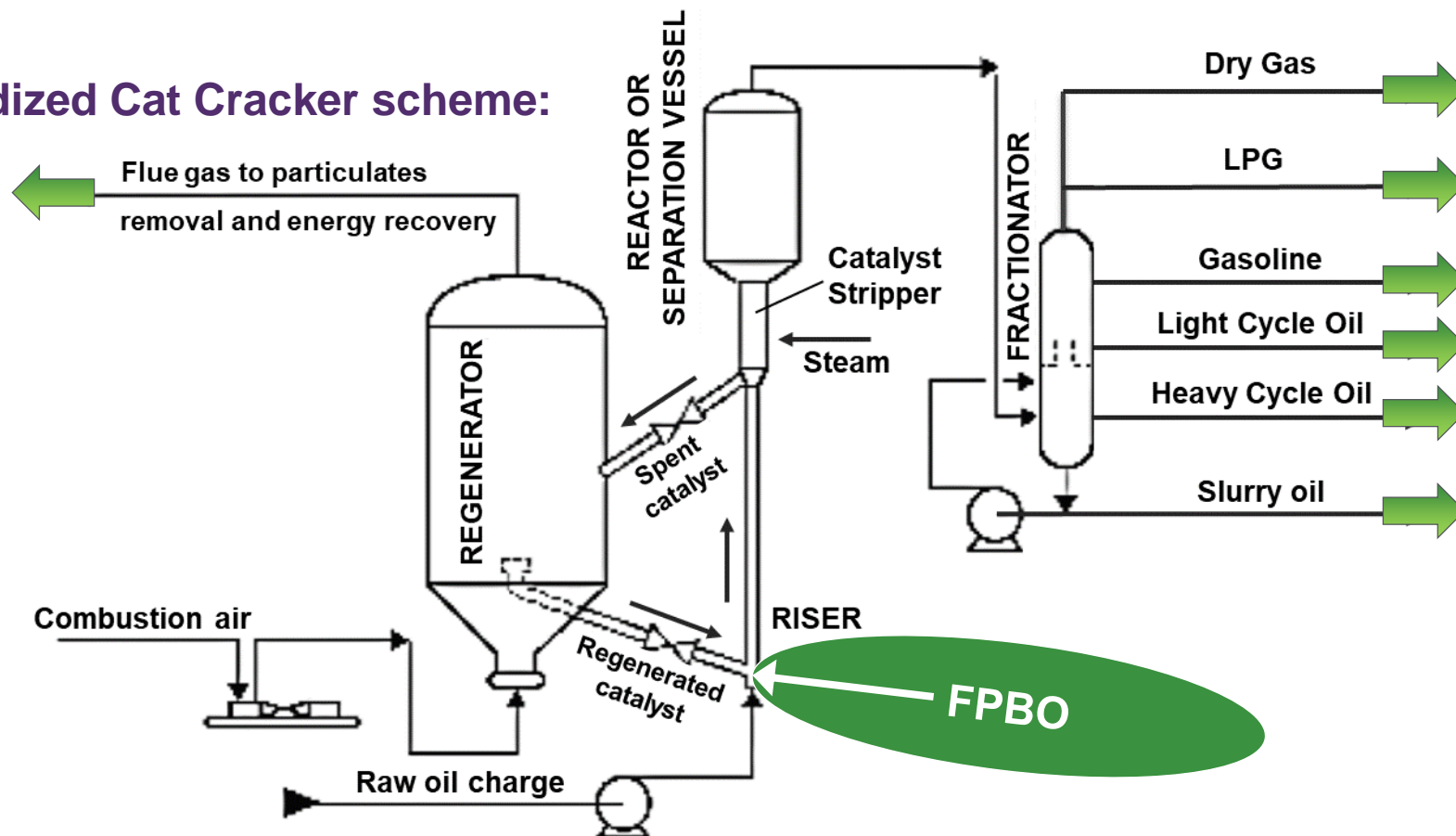
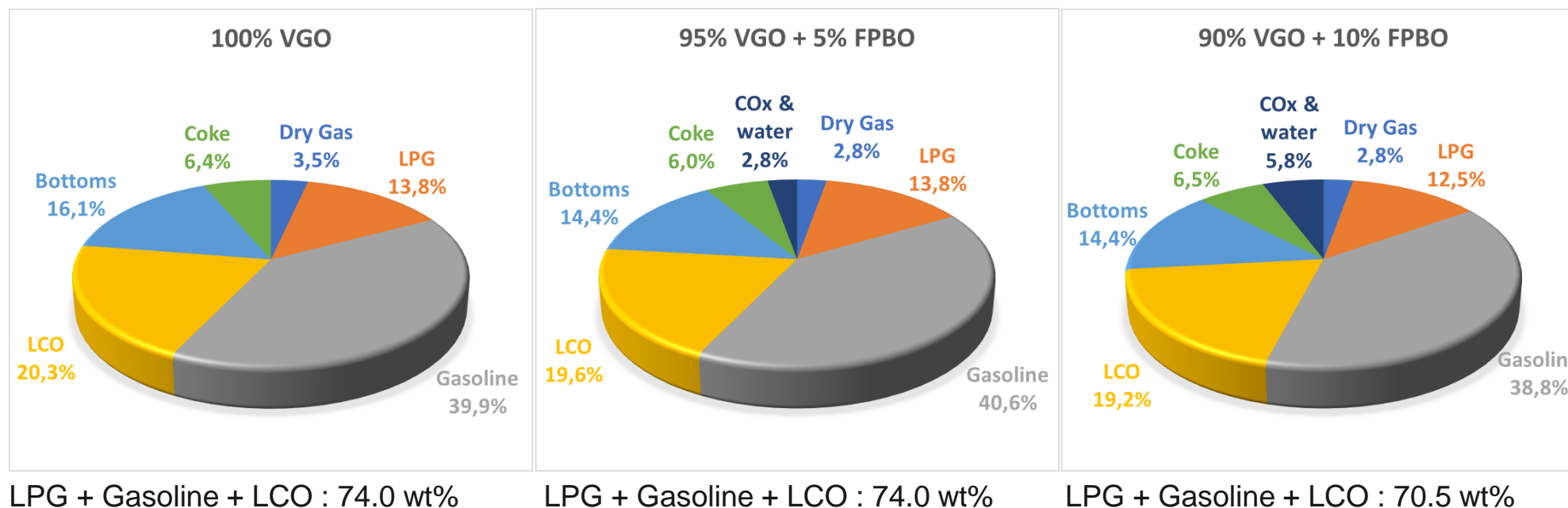


Figure adapted from U.S. Energy Information Administration

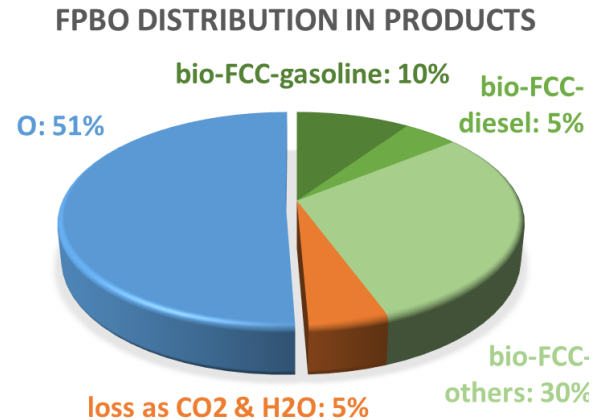
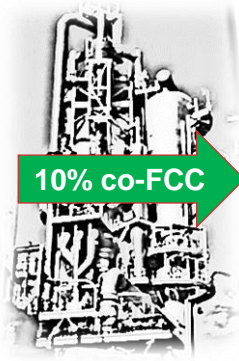
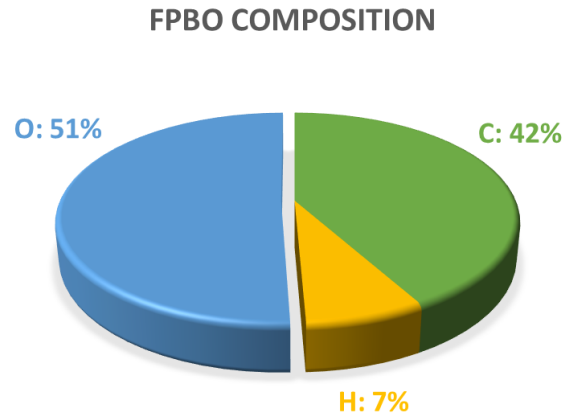
CO-REFINING OF FPBO; WHAT ABOUT YIELDS?

Co-processing up to 5wt% FPBO has limited/no impact on yields of the products:



Source: DOE Bioenergy Technologies Office (BETO) 2015 Project Peer Review
2.4.2.303 Brazil Bilateral: Petrobras-NREL CRADA

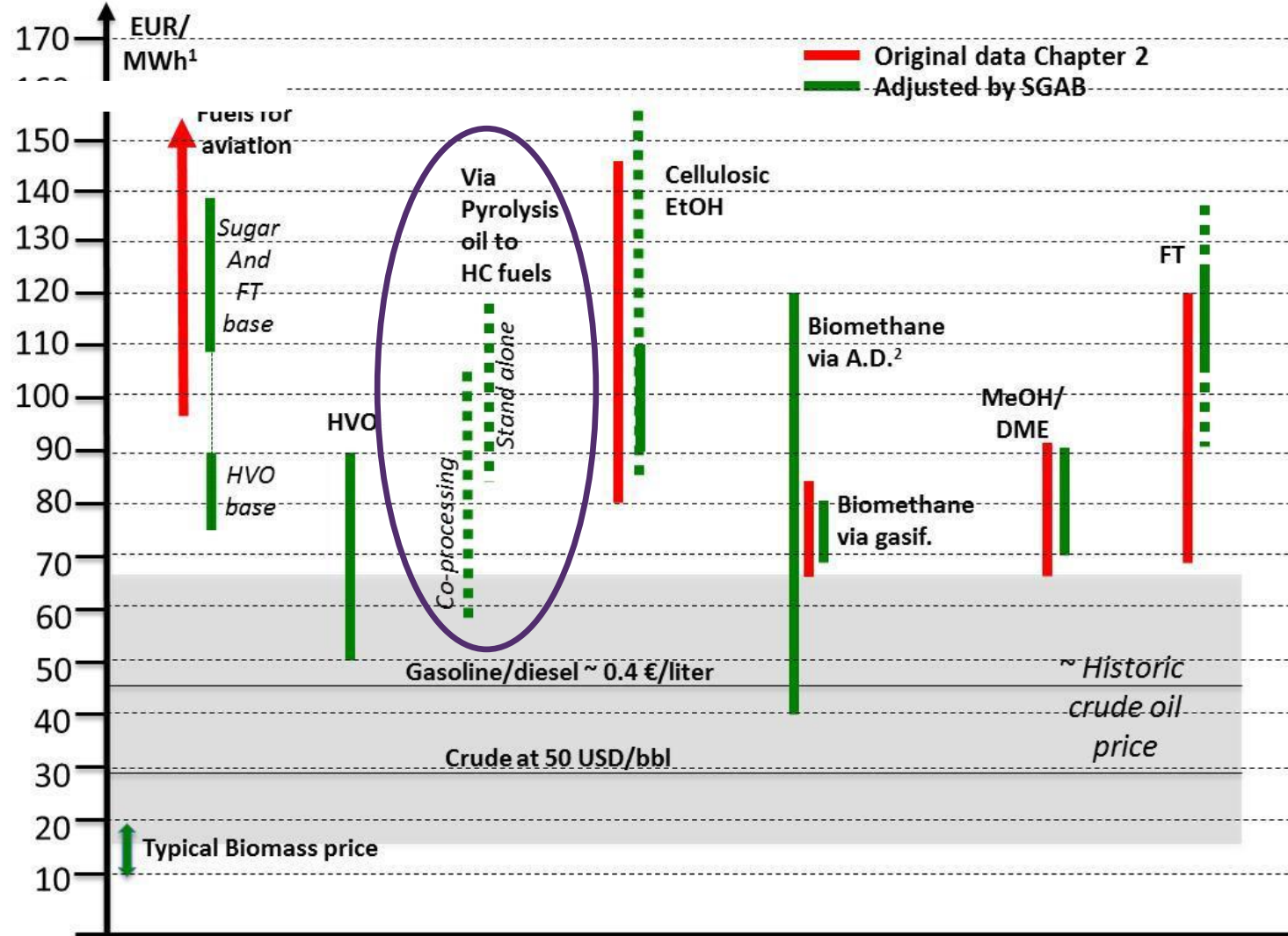
CO-REFINING OF FPBO; WHAT HAPPENS TO THE GREEN CARBON & HYDROGEN?



Data: Petrobras 2015, using FPBO in an FCC demo unit

- Half of the mass of FPBO comes from oxygen atoms, in water or oxygenates
- About 30% of the bio-Carbon becomes FCC-naphtha + LCO
- The rest of the bio-Carbon is not lost, and still reduces the use of crude oil for other products (e.g. LPG, olefins, etc.) and energy.
- Local EU legislation will determine how bio-credits are calculated for the different products.

BIOFUELS PRODUCTION COSTS



¹(EUR / MWh)/3.6 = €/MJ ²Anaerobe Digestion (large span due to very different feedstock costs)

Source: Sustainable Transport Forum, Sub Group on Advanced Biofuels, 2017, final report

SUMMARY

- Waste and residues based biofuels are being promoted in the EU biofuels policy
- EU mandate for Advanced Biofuels requires refiners to look at an alternative way to meet the obligations starting from 2020.
- Co-processing small quantities of crude FPBO has little to no impact on refinery operations.
- Co-processing of crude Fast Pyrolysis Bio-Oil in an (existing) FCC is a cost effective and efficient way to meet REDII.
- Co-processing with higher FPBO contribution may call for a mild hydrotreatment of FPBO.

PRC : EUROPE
: 2019

**THANK YOU FOR YOUR
ATTENTION!**

Jacco Kroeze

TechnipFMC Process Technology

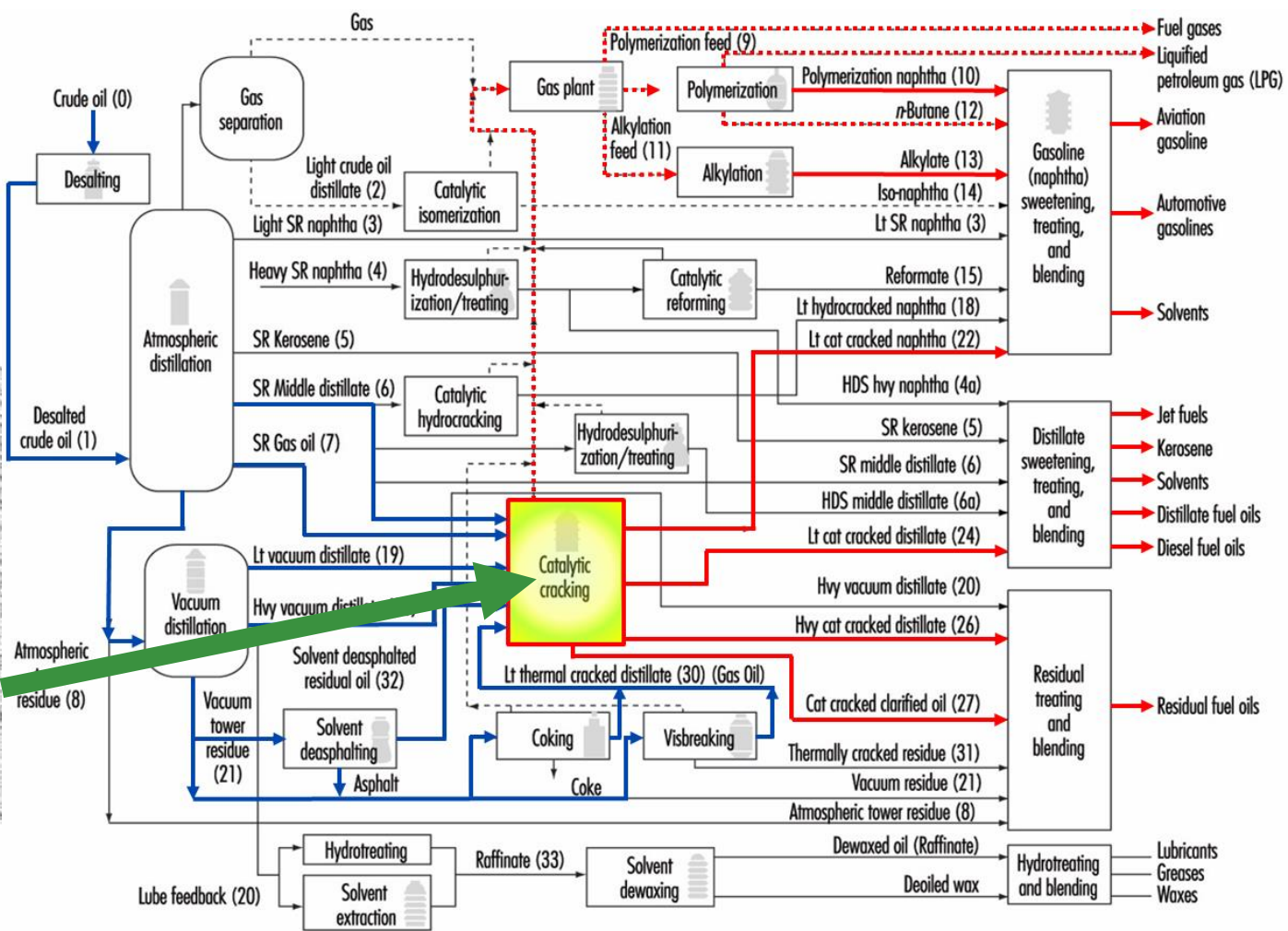
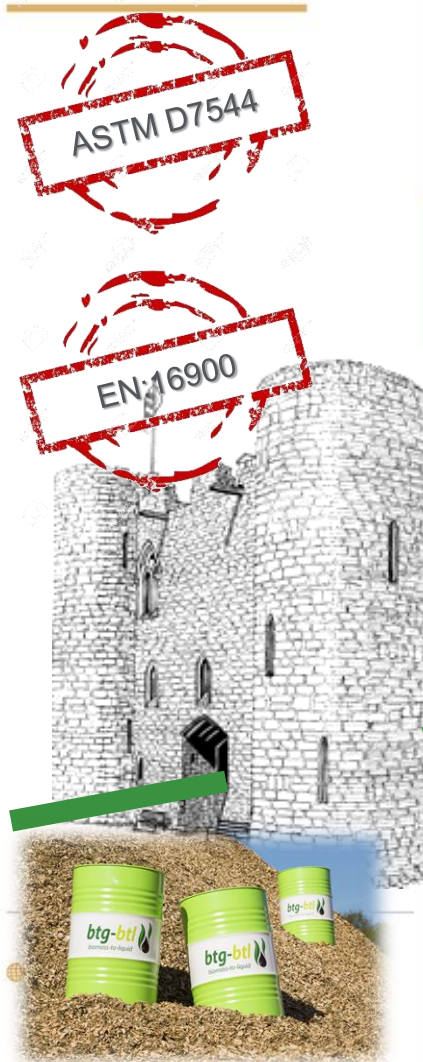
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FAST PYROLYSIS BIO-OIL IN A REFINERY



Note: Numbers in parentheses refer to typical product process flow routes.
Source: OSHA 1996.

Liquids ——— Gases - - - - -