The bioCRACK Process

– a refinery integrated biomass-to-liquid concept to produce diesel from biogenic feedstock

Edgar AHN, CSO
BDI - BioEnergy International AG

BDI bioCRACK BDI BioDiesel BDI BioGas BDI RetroFit

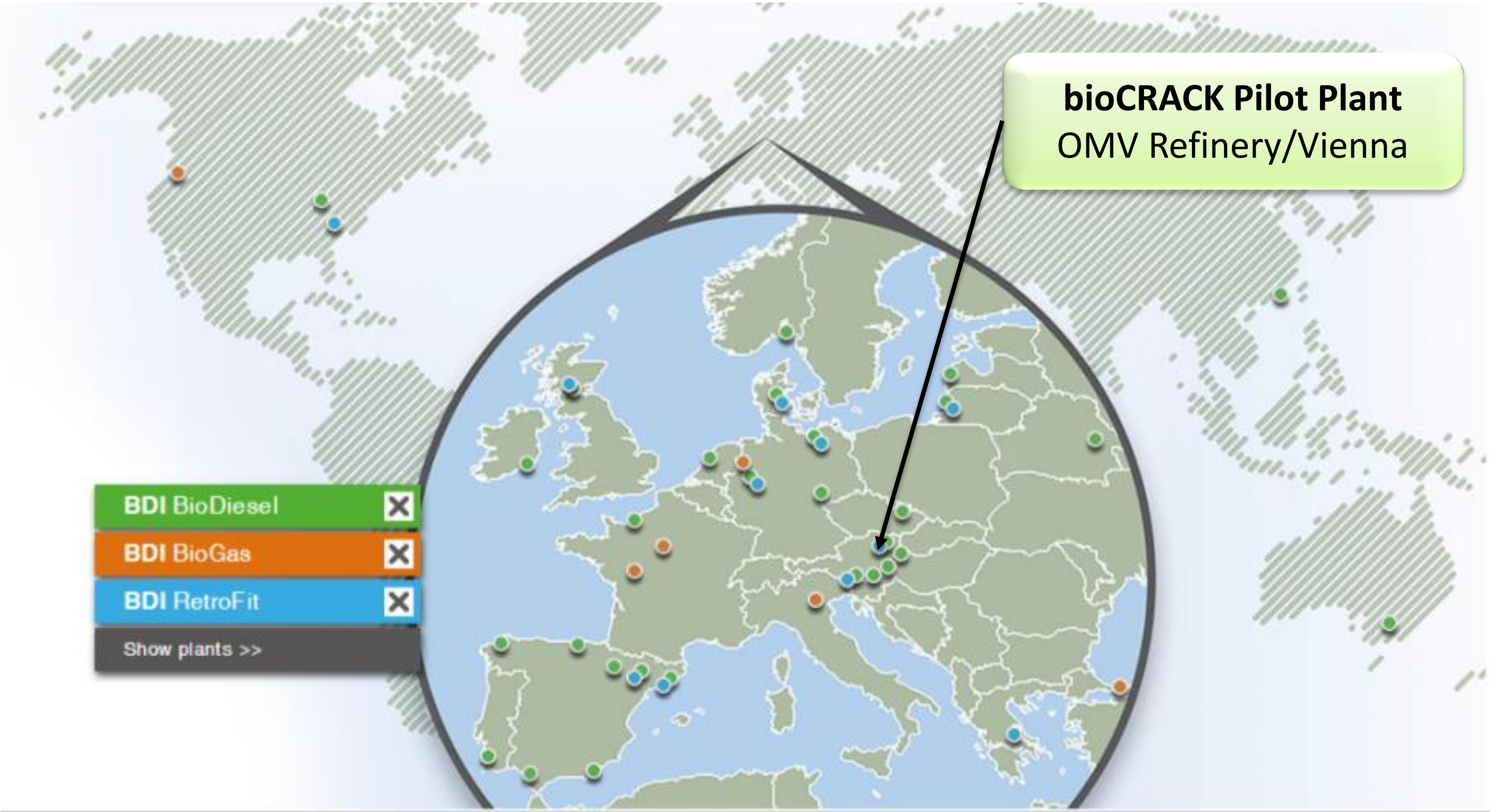
Outline

- BDI at a glance
- Motivation
- bioCRACK Concept
- Pilot Plant
- Experimental Results
- Outlook / Summary

BDI at a glance

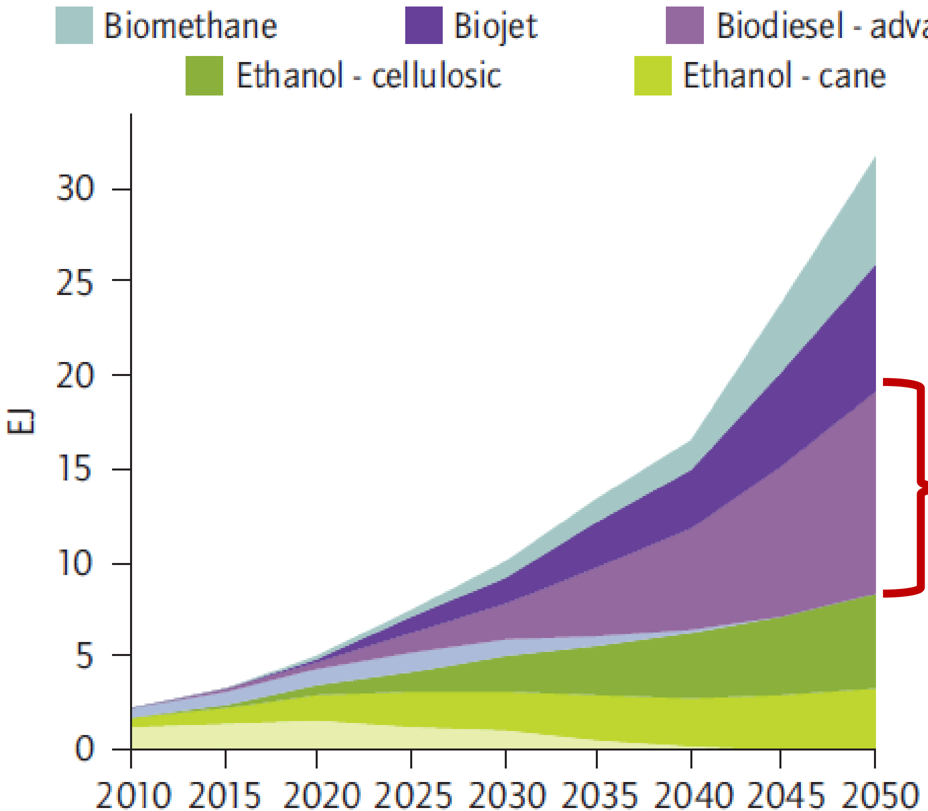
- Austrian based, highly professional plant engineering and construction company
- Tailor-made turn-key solutions
- Own biodiesel & biogas technologies “from waste to value“
- More than 40 reference plants on 4 continents, since 1991
- Strong in-house r & d (5 – 10% of annual revenue)

Global Player



bioCRACK - Motivation

IEA projected global biofuels demand



Huge projected global demand on biofuels especially on advanced (Bio)Diesel

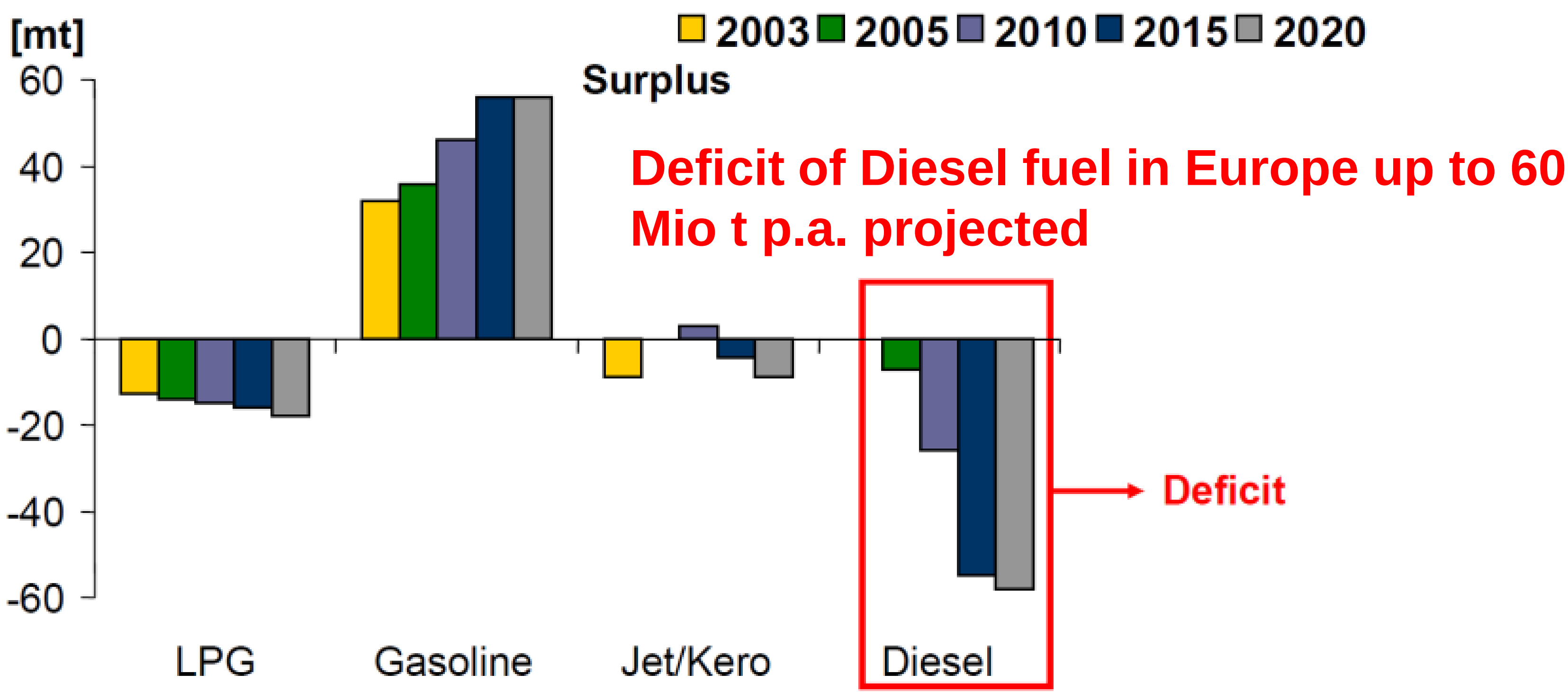
EU RED:
10% renewable energy in transport (2020), Lignocellulosic-biofuels preferred (double counting)

US Renewable Fuel Standard (RFS2):
36 billion gallons renewable fuels, of which 21 bgal advanced biofuels (2022)

Source: IEA Technology Roadmap - Biofuels for Transport 2011 1 exajoule ~ 23-24 Mio t Oil

bioCRACK - Motivation

Europe oil product balances



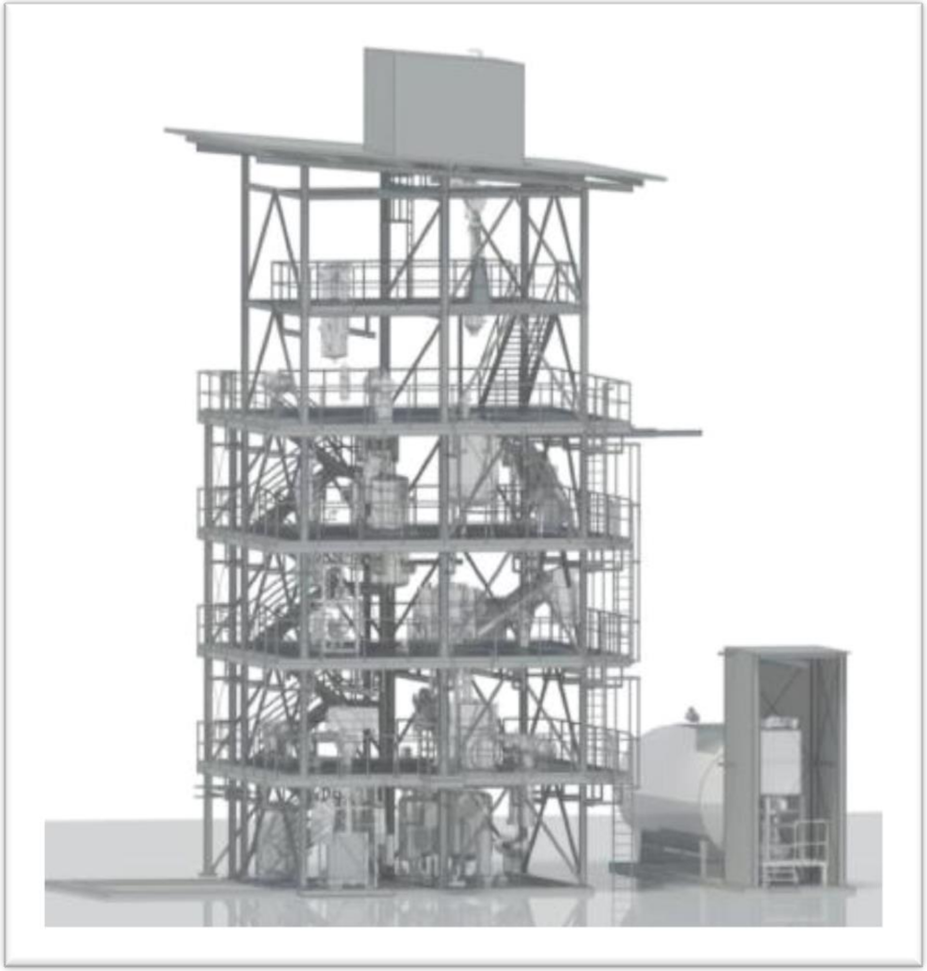
Source (by OMV): Refining Capacity Study, EUROPIA Strategy Council

bioCRACK - Motivation

- Continuous development of **Benchmark-Technologies for Biofuel production**
- Technically simple process for the production of **Next Generation Biofuel**
- Conversion of **biogenic waste & residues** from „non-food“ areas into high-quality Biofuel

bioCRACK - Project Goals

- Compliance of current quality standards in final fuel product
- Useable side-products, no waste streams
- Integrable in conventional process of mineral oil refining
- Liquid phase pyrolysis (liquefaction of solid biomass)
- Co-processing of intermediate product in refinery (heavy ends) and solid Biomass



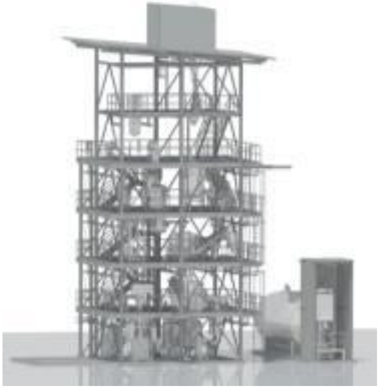
bioCRACK History

Start basic research of liquid phase pyrolysis

2007

Start-up of test plant (6kg/h); Test trials

2008/9



Start Coop. with OMV, Engineering pilot plant Construction & start-up

2010/11/12

Continuous test runs (24h/5d)

2013/14

bioCRACK Partners

BDI – BioEnergy International AG

OMV Refining and Marketing GmbH

Institute of Chemical Engineering and Environmental Technology

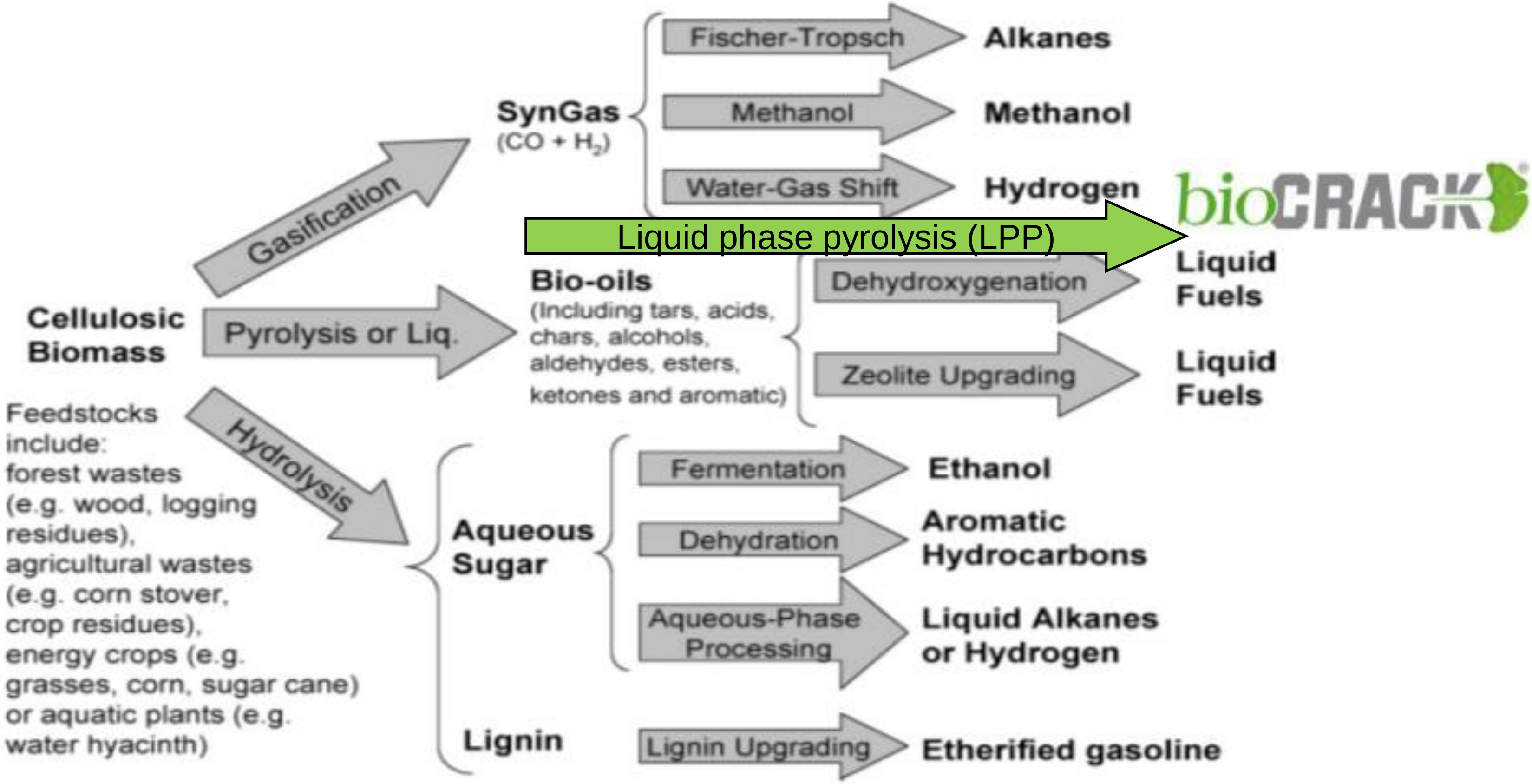
Prof. Dr. M. Siebenhofer

Austrian Climate & Energy Fund

"New Energies 2020"

bioCRACK - Concept

Typical pathways from lignocellulosis to biofuel



Source: Chem.Rev.2006,106,4044ff

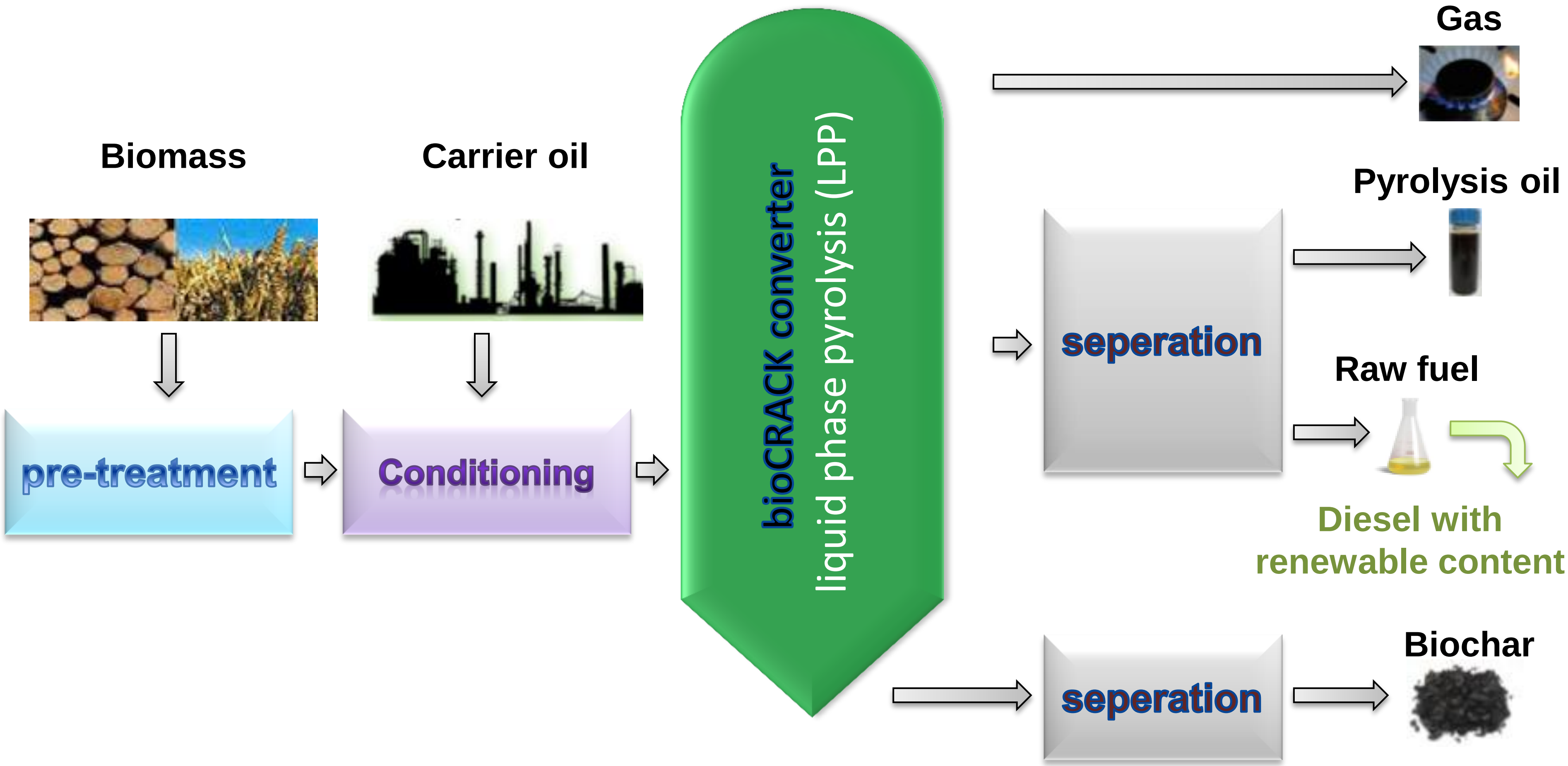
bioCRACK - Concept

In liquid phase pyrolysis (LPP) a hot liquid is used as heat carrier

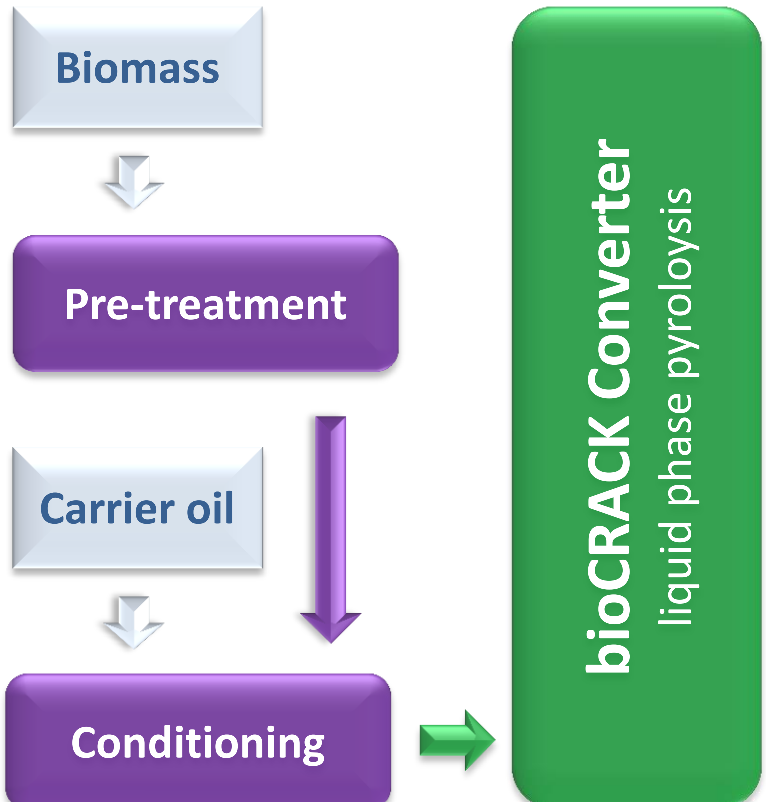
Pro:	Contra:
• Moderate process conditions (ambient pressure, temperature <450°C) • Compared to other technologies simple concept • Heat recovery possible • Usage of standard industrial equipment • Time to market short • Direct conversion from solid biomass to liquid hydrocarbon	• Limitation in maximum temperature • Limited conversion from solid to fuel • Challenging separation task solid/liquid • Utilisation of by-products necessary • Cracking of the heat carrier oil **Chance for integrated process in standard refinery**

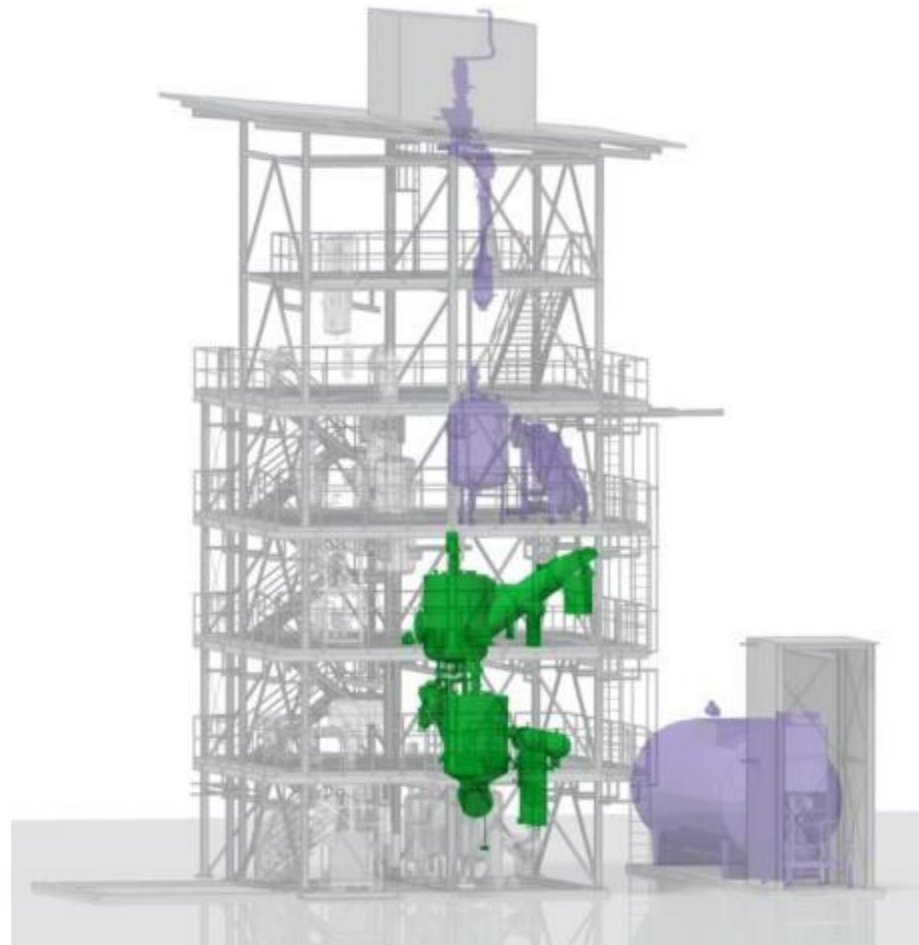
To succeed with LPP one need to use a heat carrier oil where cracking is desired!

bioCRACK - Process Scheme

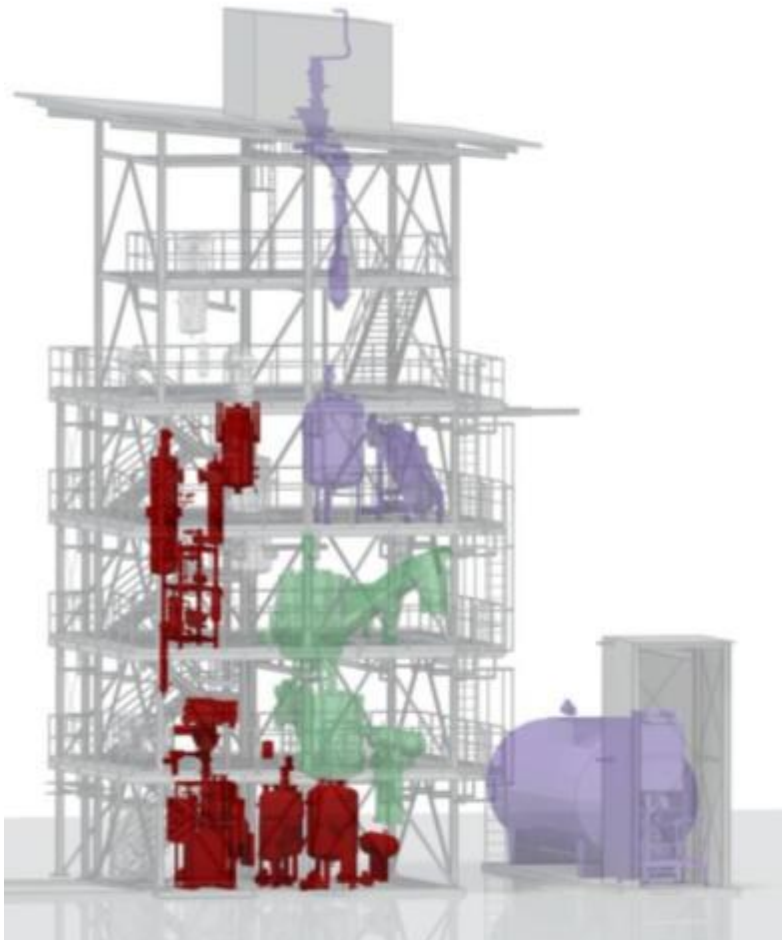


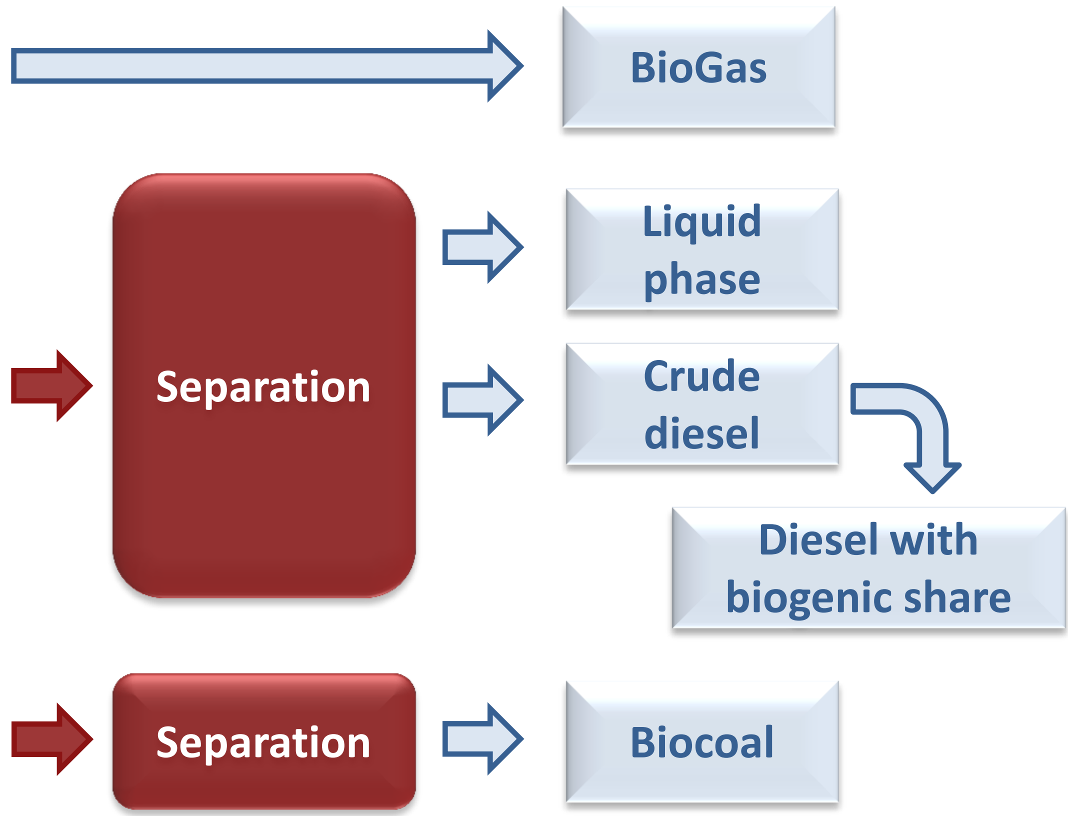
bioCRACK - Pilot Plant



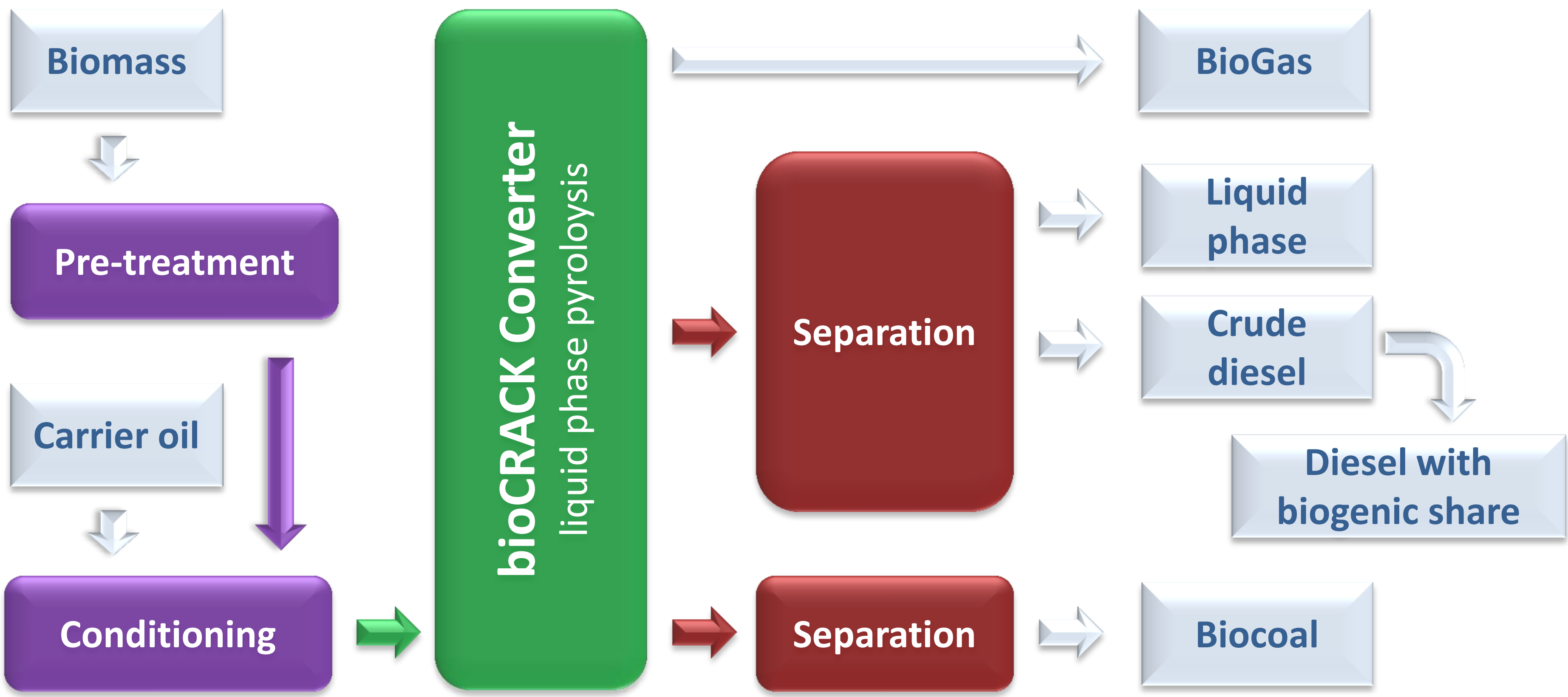


bioCRACK - Pilot Plant

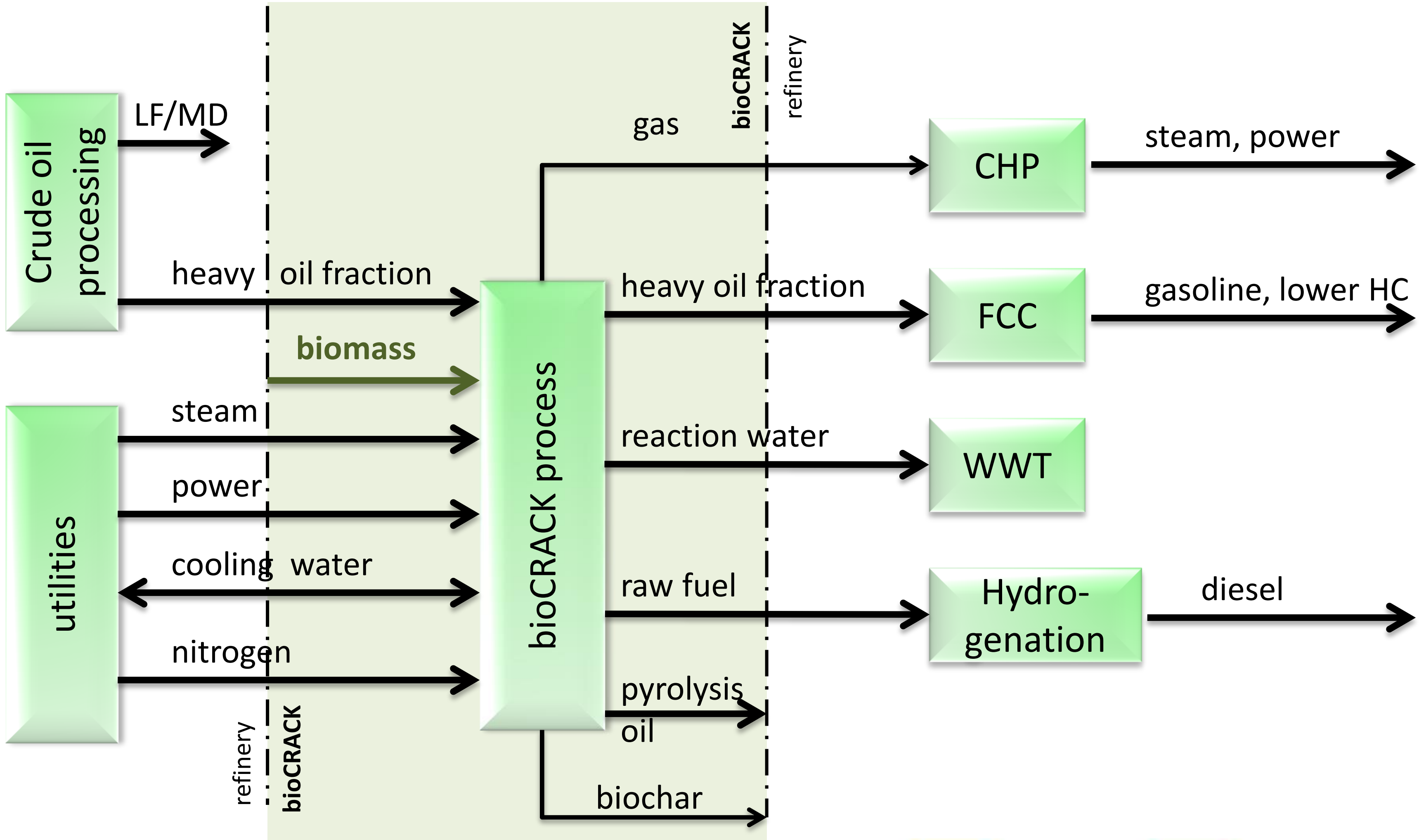




bioCRACK - Pilot Plant



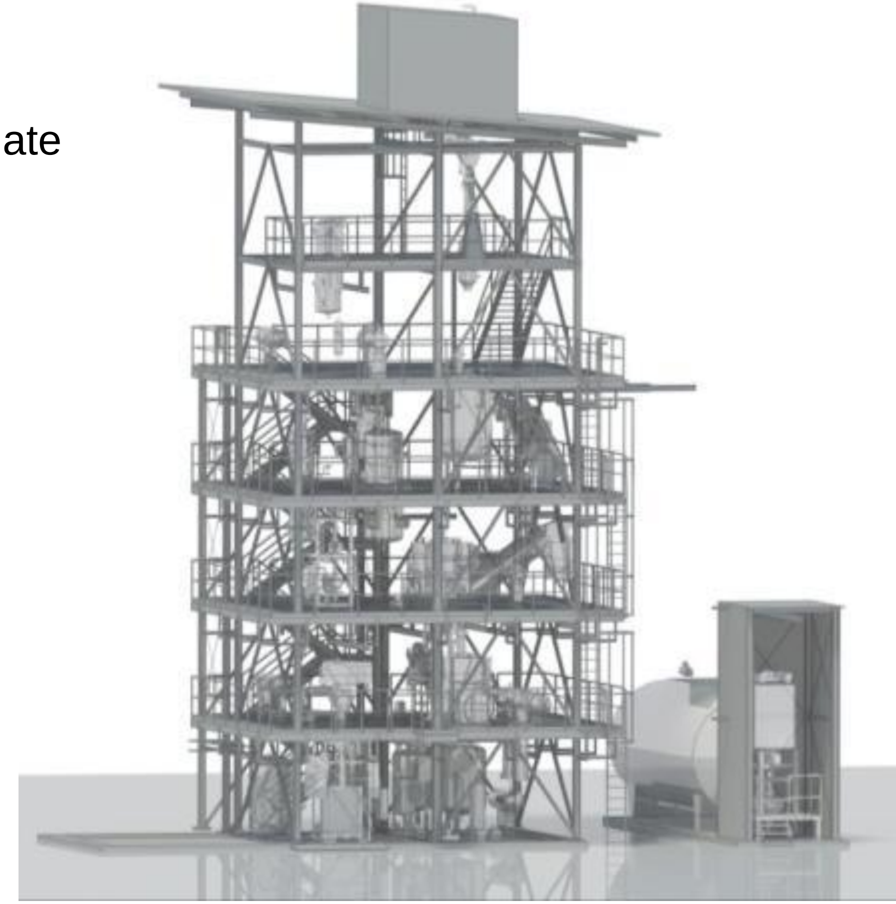
bioCRACK - Refinery Integration



bioCRACK Pilot Plant

Facts and figures

- Project duration: April 2010 - 2014
- Project cost: € 7 Mio (Grand by Austrian Climate and Energy Fund: € 2,0 Mio.)
- Dimensions: basis: 7,5x7m, height: 21,5m
- Steelwork: 60 tons
- Pipes: >2.000 m
- I/O: > 700
- Engineering demand: ~ 17.000 hours
- Feed capacity: 100 kg/h biomass and 1000 kg/h heavy oil
- Pressure: atmospheric
- Temperature: up to 400°C



bioCRACK Pilot Plant

Integrated pilot plant at the OMV refinery Schwechat/Austria*

***Dismantled End 2015**

bioCRACK - Feedstock

Ideal biomass for bioCRACK is renewable lignocelluloses

+ Low water content
+ Low nitrogen, chlorine, toxics
+ Fine particle size (<5mm) possible

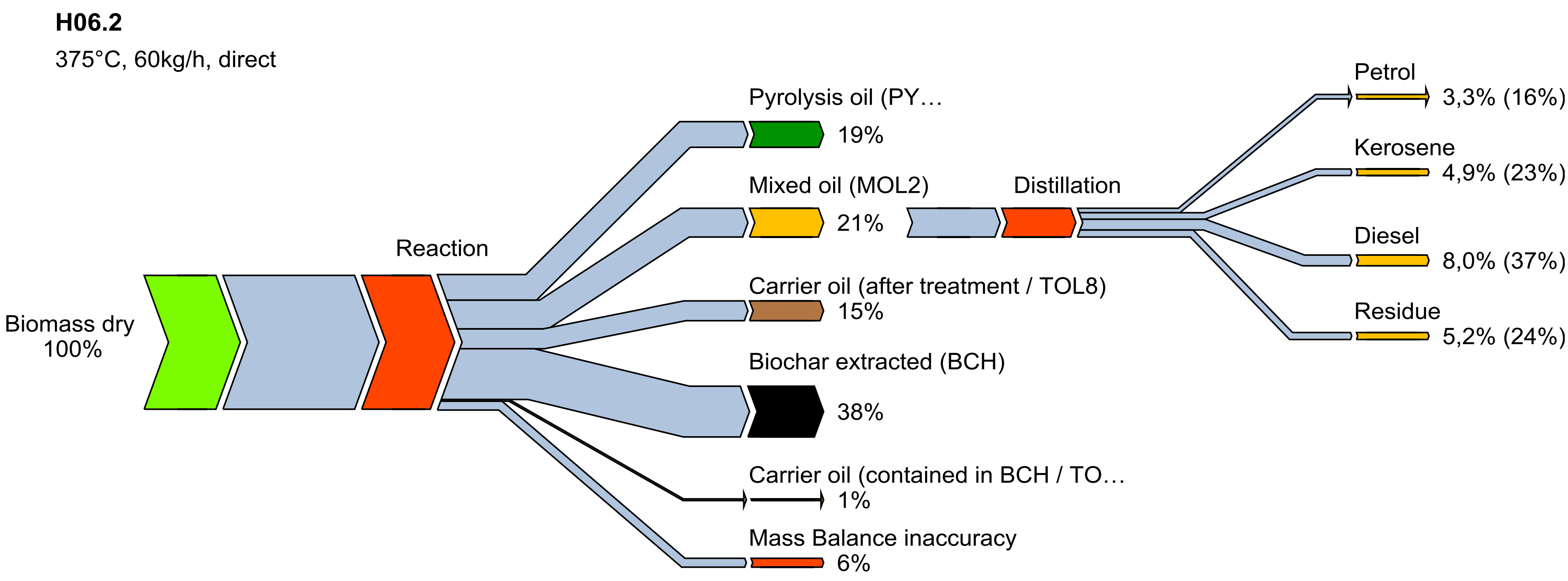
Examples:

- Wood chips (soft and hard wood)
- Forestry residues
- Chopped straw/agricultural residue
- …..

Biomass contains up to 50% oxygen in complex molecular structure. Oxygen is unwanted element in liquid fuels and has to be removed to reach requested fuel quality!

bioCRACK - detailed C14 Balance

Bio-carbon transfer in streams (H06, 375°C)



Results from bioCRACK pilot plant Schwechat
Feedstock: spruce

bioCRACK - Diesel Fuel

Upgrading of raw diesel to EN590 quality is possible

Parameter	Untreated raw diesel	After hydro treatment	EN 590
Density (15°C)	868 kg/m³	**833 kg/m³**	820 - 845 kg/m³
Viscosity (40°C)	2,53 mm²/s	**n.a.**	2 - 4,5 mm²/s
Cetan	44	**53**	> 51
C/H/O	85/13/2 wt.%	**86/14/0 wt.%**	n.a.
Volatile <350°C	83 wt.%	**86 wt.%**	> 85 % (v/v)
Sulfur	177 mg/kg	**3 mg/kg**	< 10 mg/kg

Results from bioCRACK pilot plant and hydrogenation at OMV/Schwechat
Feedstock: spruce

bioCRACK - Biochar

Analysis of biomass (spruce) and biochar

		Biomass (spruce)	Biochar
Carbon	[wt.%]	50	81
Hydrogen	[wt.%]	6.3	5.4
Nitrogen	[wt.%]	0.0	0.3
Rest (Oxygen + Ash)	[wt.%]	44.2	13.4

Utilisation:

- ✓ Renewable solid fuel for combustion
- ✓ Additive in steel industry, construction material,....
- ✓ Fertilizer and carbon sink
- ✓ Further upgrading to transportation fuel

bioCRACK - Pyrolysis Oil

Dehydration of bioCRACK pyrolysis oil is possible

		Pyrolysis Oil	Pyrolysis Oil dehydrated	Crude Oil[1]
Water Content	[wt.%]	50	8	0.1
Lower Calorific Value	[kJ/kg]	8700	29000	43100
Carbon	[wt.%]	22	72	83 - 86
Hydrogen	[wt.%]	10	9	11 - 14
Oxygen	[wt.%]	68	19	<1
Nitrogen	[wt.%]	<1	<1	<1

[1]Mortensen et al., Applied Catalysis A: General, 407 (2011)

Utilisation:
- ✓ Renewable liquid fuel for combustion
- ✓ Source for chemicals
- ✓ Further upgrading to transportation fuel

GHG Calculation according to EU-Directive

Source: EU-Directive on Renewable Energy, Brussel 5. June 2009

$$E = e_{ec} + e_l + e_p + e_{td} + e_u - e_{sca} - e_{ccs} - e_{ccr} - e_{ee} \ [g\ CO_2\text{-eq}/MJ_{biofuel}]$$

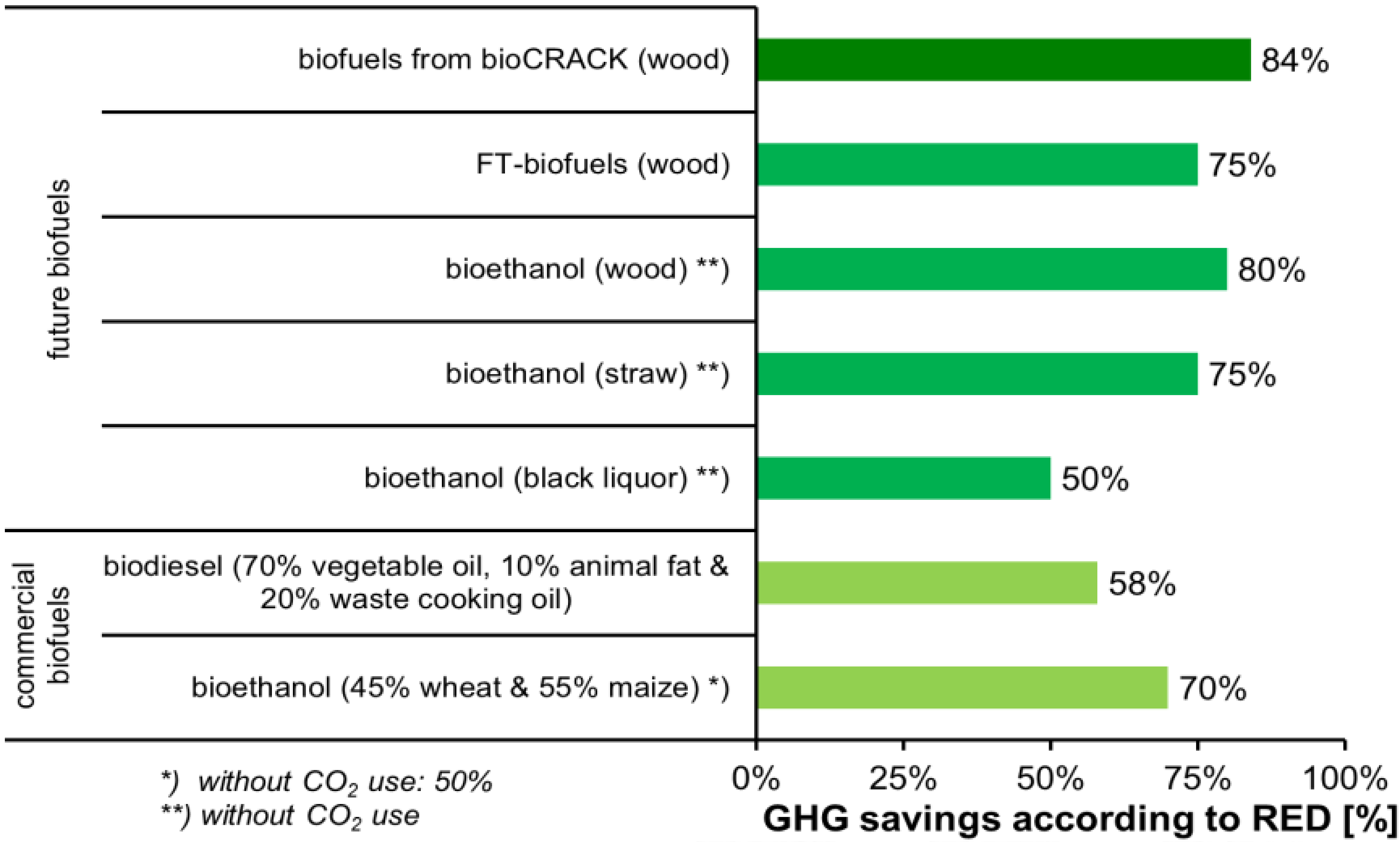
$$E = (E_{fossil} - E_{biofuel}) / E_{fossil} \ [\%]$$

E > 35% (2017: > 50%; 2018*): > 60%) *) *new biofuel plants*

- E = total emissions from the use of the biofuel;
- e_{ec} = emissions from the extraction or cultivation of raw materials;
- e_l = annualized emissions from carbon stock changes caused by land-use change;
- e_p = emissions from processing;
- e_{td} = emissions from transport and distribution;
- e_u = emissions from the fuel in use;
- e_{sca} = emission saving from soil carbon accumulation via improved agricult. management;
- e_{ccs} = emission saving from carbon capture and geological storage;
- e_{ccr} = emission saving from carbon capture and replacement; and
- e_{ee} = emission saving from excess electricity from cogeneration.

Emissions from the manufacture of machinery and equipment shall not be taken into account

Comparison to Other Biofuels in Austria



Source: JOANNEUM RESEARCH (2008 – 2014)

bioCRACK Industrial Scale - Layout

- **Capacity:**
  400.000 to/y BM
  ➔ 60.000 to/y biofuels
- Total Area: 235.000m^2
- **Area I:**
  Multi-Feedstock biomass feedstock preparation,
- **Area II:**
  bioCrack Refining 1-4, Product treatment (BCO, FCO, PYO), TOL Conditioning
- **Area III:**
  Energy central station, bioChar treatment

bioCRACK – Added Value

Estimated added Value of the conversion products from wood:

Stream	Annual Demand t	Price per t	Cost/Revenue p.a
Wood	360.000	€ 100	€ 36.000.000
bio Naptha	19.000	€ 850	€ 16.150.000
bio Gasoil	44.000	€ 1.100	€ 48.400.000
bio Char	100.000	€ 60	€ 6.000.000
Pyrolysis Oil raw	137.000	€ 90	€ 12.330.000
Gases	60.000	€ -	€ -
Added Value p.a.			**€ 46.880.000**

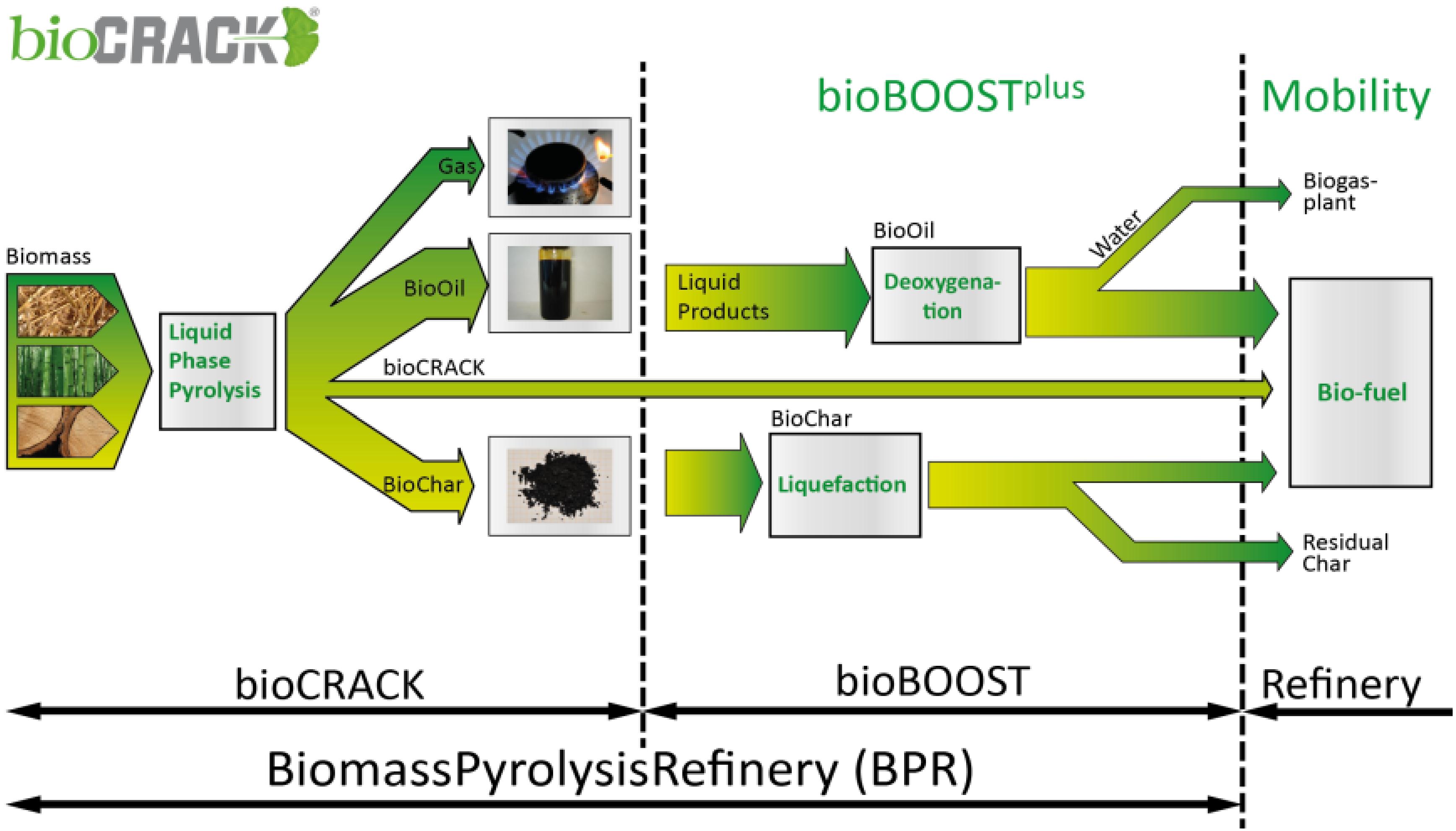
Example integration bioCRACK in OMV refinery concept:

- general increase of fuel production from VGO by + 5%
- Shift in fuel distribution from petrol (-11%) to diesel (+25%) and kerosene (+15%)

Estimated Capex 400.000 t p.a. biomass: 200 - 300 Mio €

Preliminary estimated data in cooperation OMV and Joanneum Research

Ongoing Research & Development



bioCRACK Outlook

- Completion of r&d project: 2015
- After successful completion:
  - Up-scaling to demonstration plant
    ➔ financing (VC, EU-NER300, ?)
  - GHG-saving potential
  - Profitable implementation in refineries
  - Licensing
- Extension project „bioBOOST“:
  value-adding utilization of
  side-product streams

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