Biomass and Coal To Liquid
BTL / CTL / B-XTL

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Agenda

- Introduction
- Biofuels via thermo conversion : Focus on indirect route BTL chain outlook and technical challenges
- CTL : Synergies between Direct and Indirect routes
- Advantages of Co processing : B-XTL
- Conclusions

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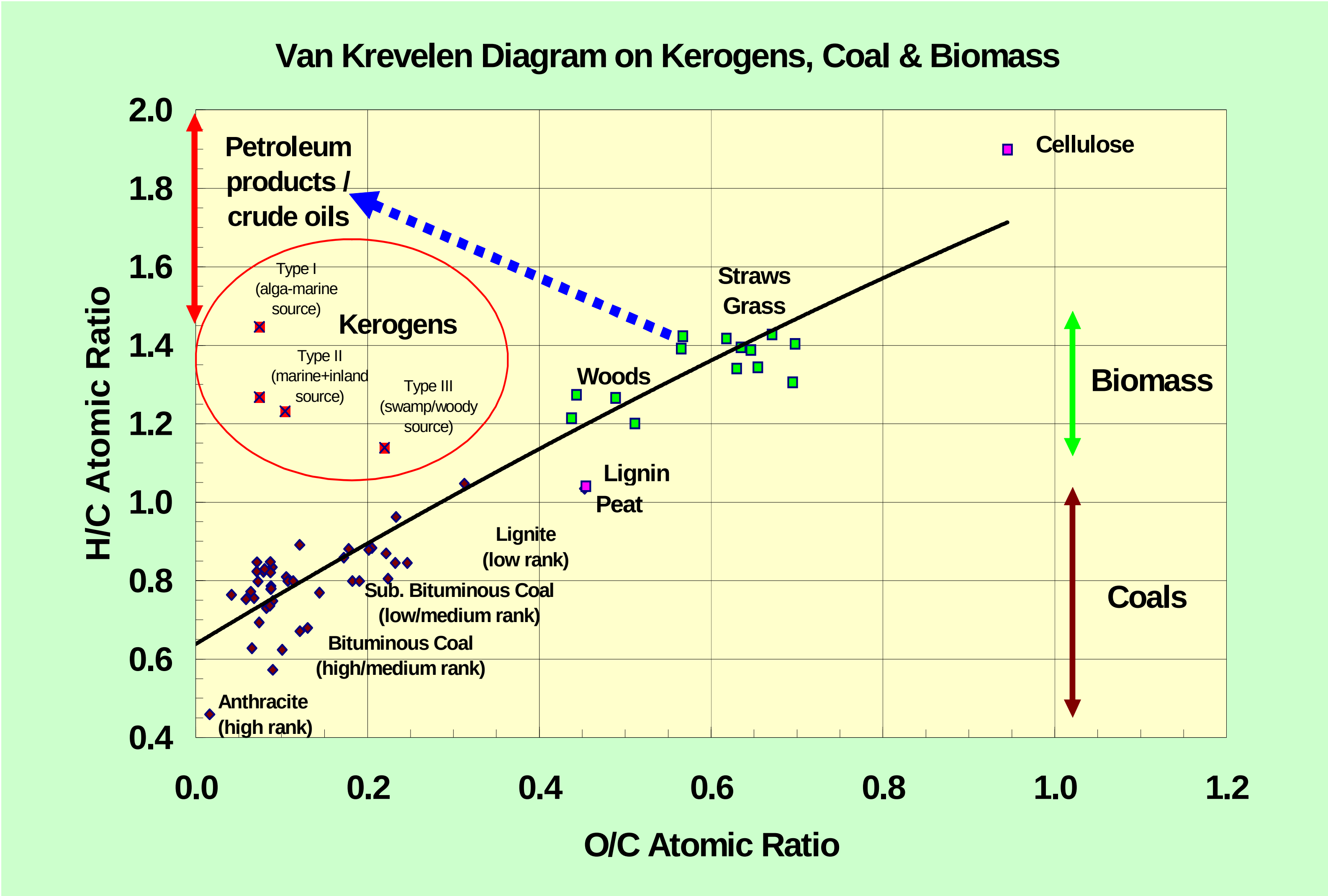
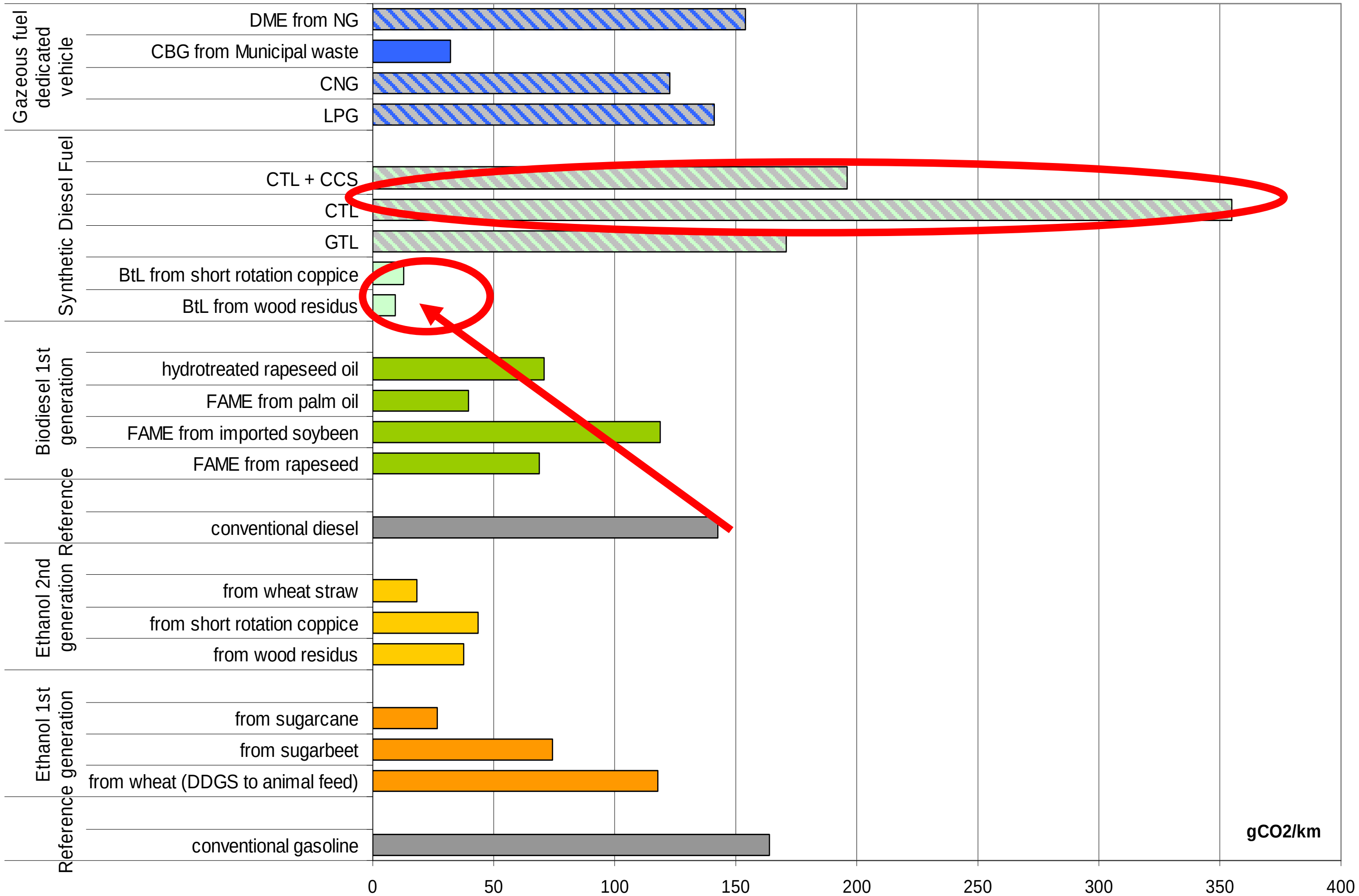
Introduction

Biomass compared to fossil resources



Introduction
BTL and CTL Life Cycle Analysis



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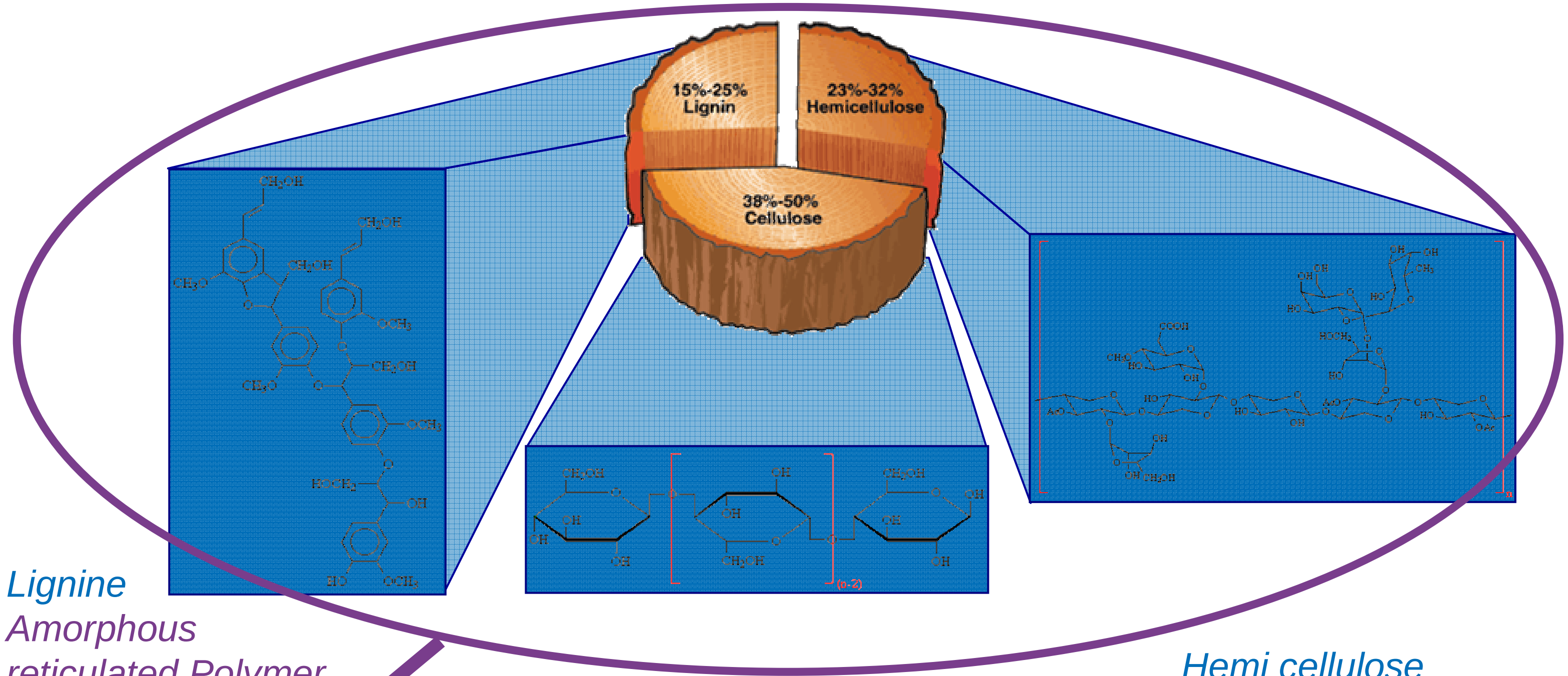
Biofuels via thermo conversion
Ligno cellulosic biomass



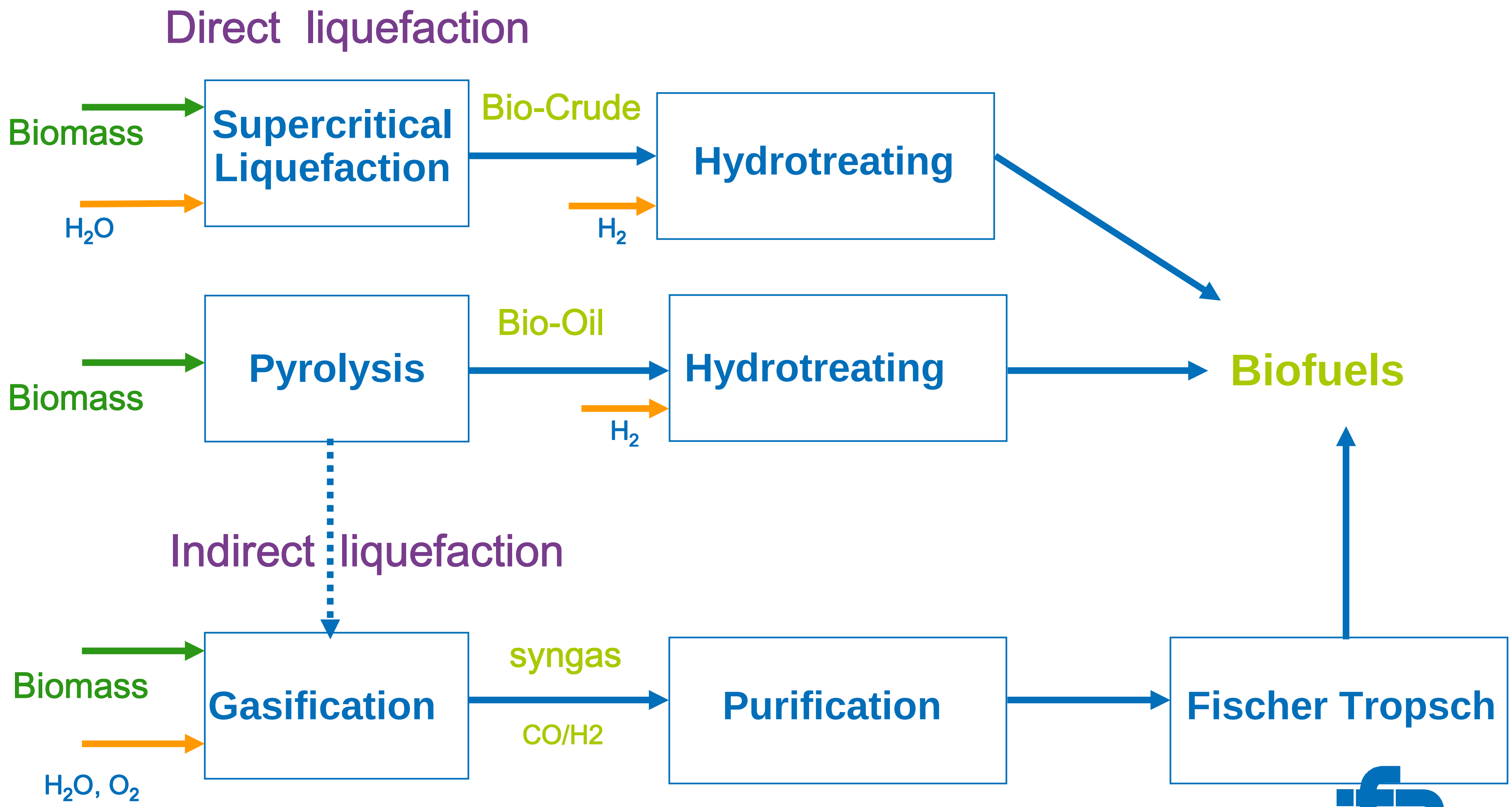
Lignine
Amorphous
reticulated Polymer

Cellulose $(C_6H_{10}O_5)_n$
Linear polysaccharide

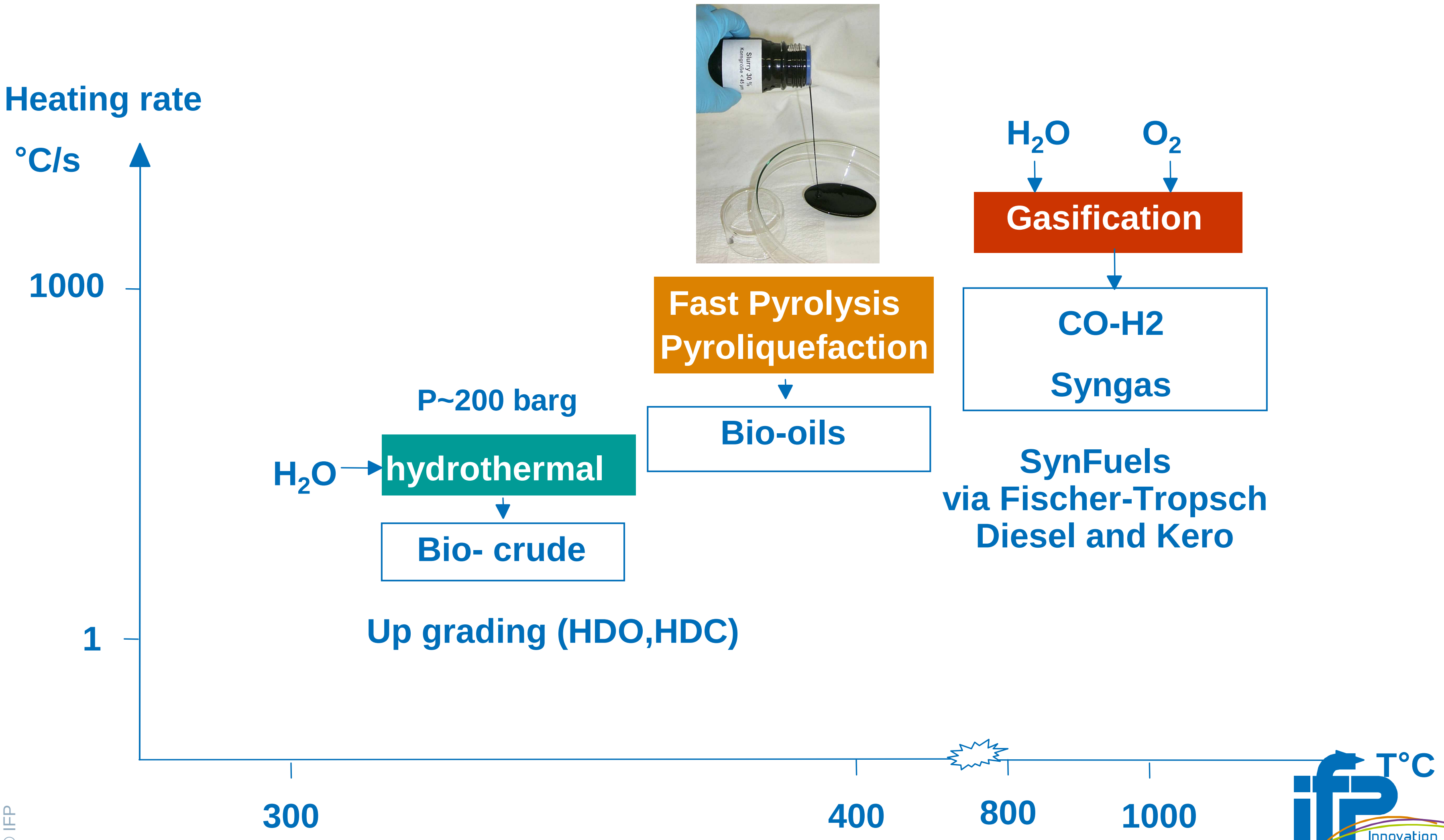
Hemi cellulose
Linear/ramified polysaccharide

Thermo chemical route :
- Pyrolysis
- Hydro liquefaction
- Gasification

Biofuels via thermo conversion
Main routes



Biofuels via thermo conversion
Heat treatment comparison



Direct Liquefaction hurdles

- ***Direct Liquefaction is a promising route with technical challenges :***
  - ***Instable products (polymerization) difficult to handle (transportation, process)***
  - ***Deep hydro treatment steps are necessary***
  - ***Needs of research to understand the chemical mechanisms needs of development of analytical tools***

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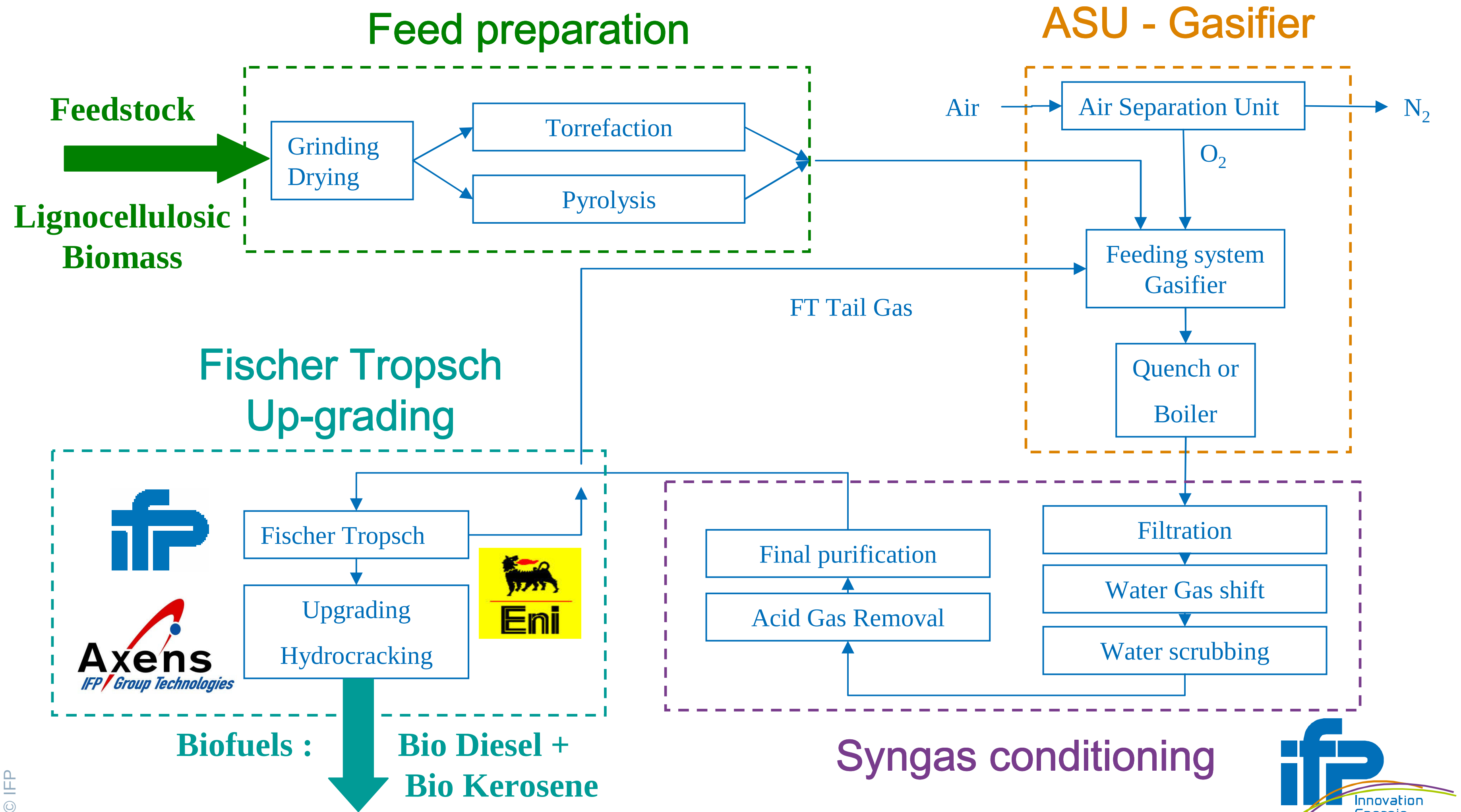
Focus on indirect route

BTL chain outlook



Focus on indirect route

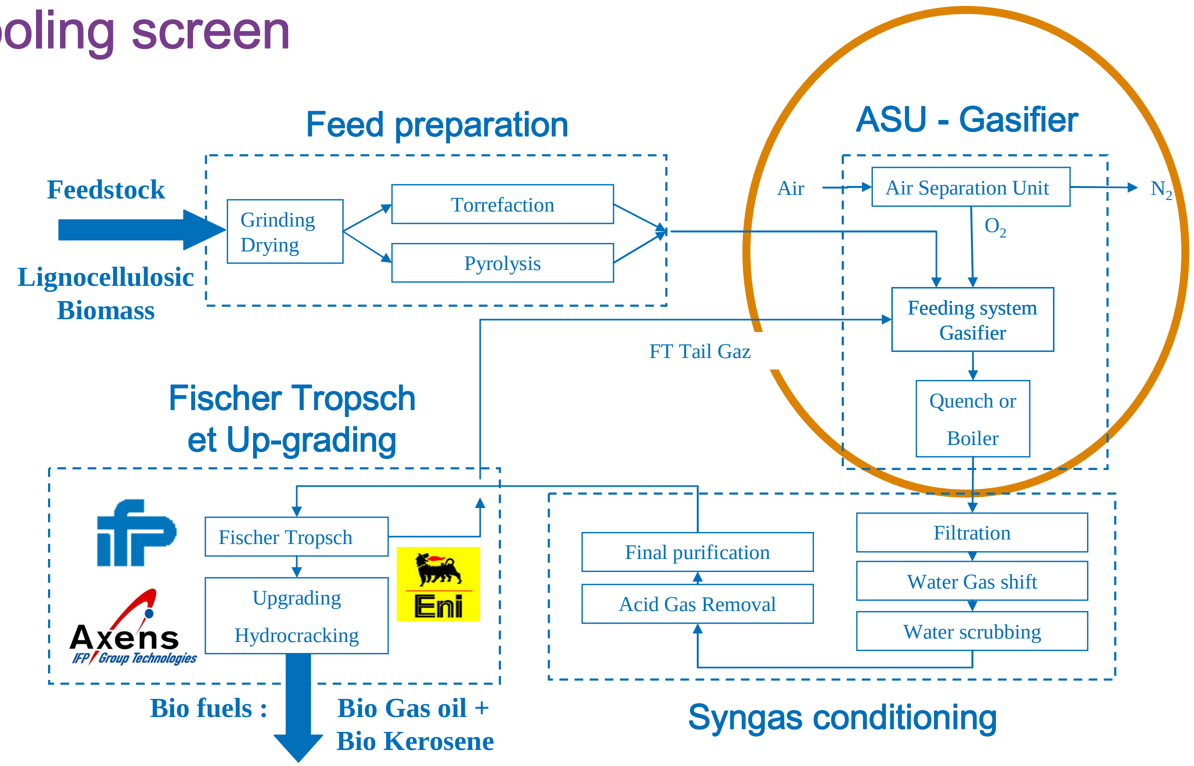
BTL chain challenges : Gasification step

Challenges	Constraints	Solutions
Avoid Tars and Chars	Carbon conversion in the gasifier > 99%	T gasification ~ 1200 / 1400°C
Costly gas compression step (FT op P = 20 – 30 barg)	High pressure Gasification	Pgasifier ~ 30 to 40 barg
Purification step size, CO_2 capture	No N_2 in the syngas	Pure O_2 fired gasification
Gasifier feeding	Constant feedstock flow-rate	Slurry or Dry feeding
Stream factor	Refractory weakness	Cooling screen

Focus on indirect route

BTL chain challenges : Gasification step

- Gasification : Already existing for coal gasification
  - Entrained Flow
  - Pure oxygen
  - Cooling screen
  - Dry : lock-hopper + pneumatic conveying



BTL chain challenges : Feed preparation

Challenges	Constraints	Solutions
Obtain a powder able to be handled by pneumatic conveying	For coal : 50-80 µm "round" particles	Heat treatment
	Grinding biomass leads to needle-shaped particles	
Minimize energy consumption	Biomass grinding to 50-100µm is very costly	
Minimize mass loss	Low temperature	Torrefaction under inert atmosphere

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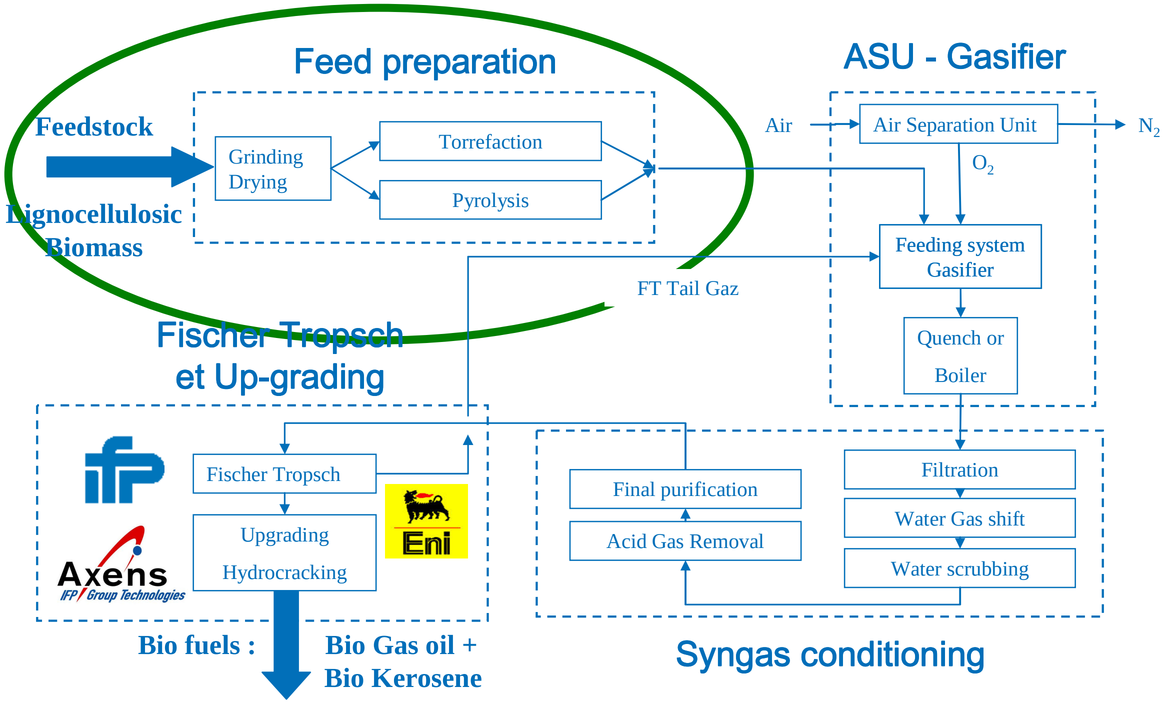
Focus on indirect route

BTL chain challenges : Feed preparation

- Torrefaction : has to adapted to biomass feedstock
  - Heat treatment at 220-280°C
  - Without oxygen (otherwise combustion)
  - Biomass becomes more brittle



Focus on indirect route

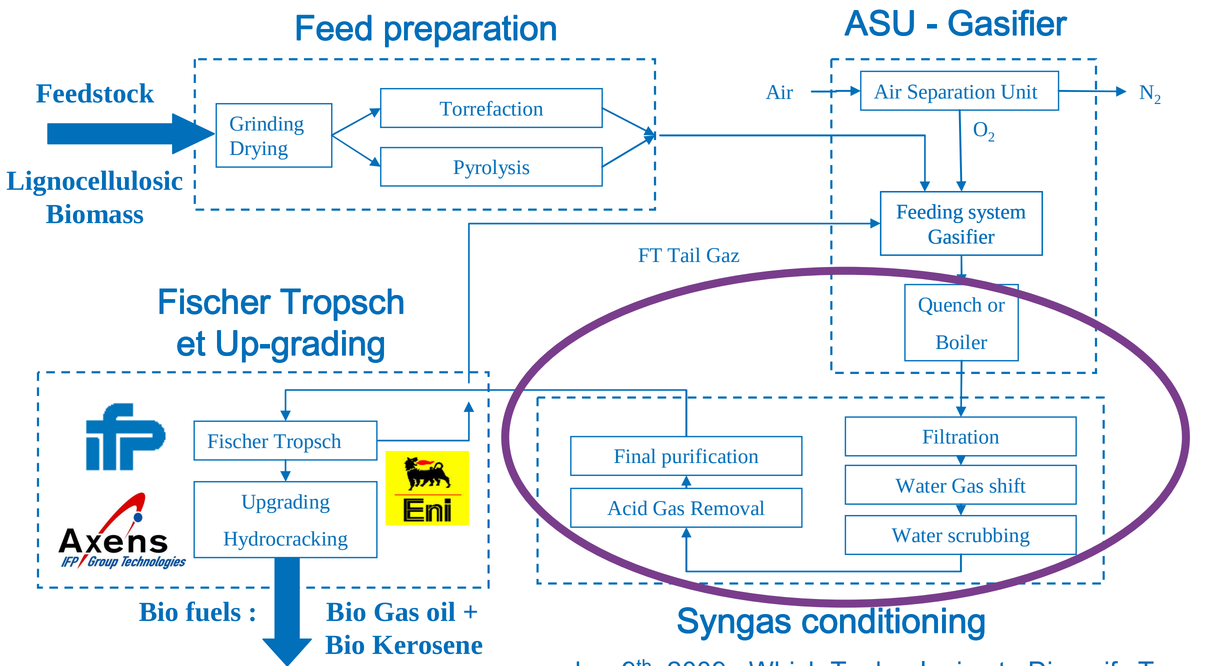
BTL chain challenges : Syngas conditioning

Challenges	Constraints	Solutions
Adjust H_2/CO	FT (Co) catalyst : $H_2/CO \approx 2$	Water Gas Shift
Entrained particles removal (plugging)	FT (Co) catalyst : Particles ~ 0	Filtration
Inert as low as possible to reduce FT size	CO_2 from Gasifier and WGS	Acid Gas Removal
FT (Co) catalyst sensibility towards impurities	Remove halogen compounds (HCl, HBr, HF,…) + HCN&NH_3.	Water scrubbing
	«S», HCN , NOx, «Cl», Metals, alkaline : some ppb	Catalytic final purification step

Focus on indirect route

BTL chain challenges : Syngas conditioning

- Syngas conditioning : define optimal purification chain able to cop with biomass impurities
  - Filtration
  - WGS : S compounds
  - Water scrubbing
  - AGR
  - Final purification : catalytic step



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- **CTL : Synergies between Indirect and Direct routes**
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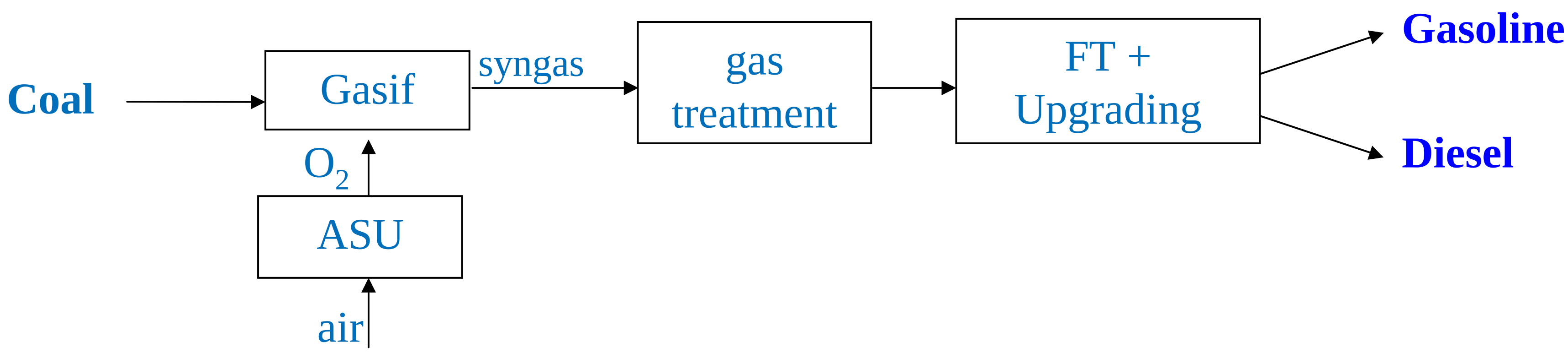
CTL

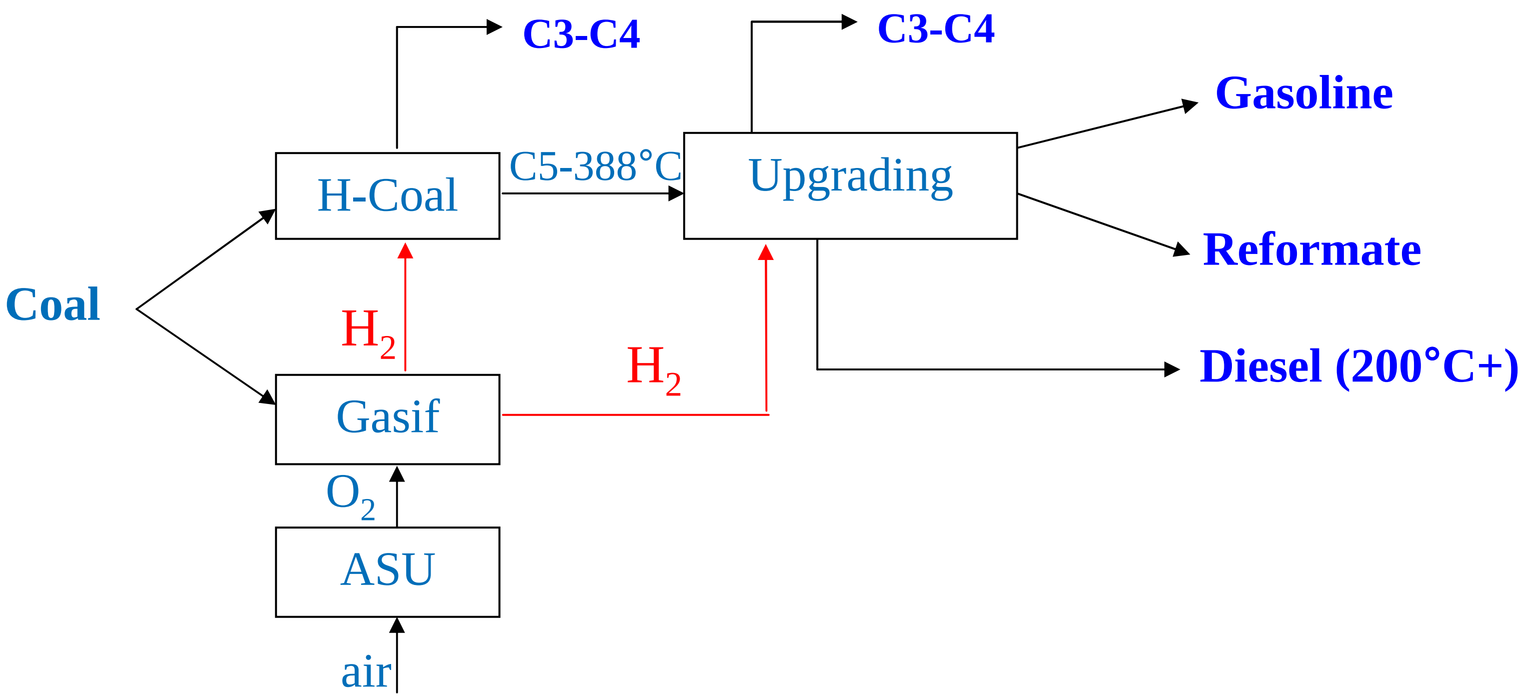
ICL route



<u>Yield :</u>

⇒ 2,5 bbl/tons without external H_2 (WGS)

CTL
DCL route



Yield :

⇒ 3,5 bbl/tons of coal if H_2 is produced with coal

⇒ 5 bbl/tons if H2 is imported

CTL

Coal classification

Type	Chemical composition C (% pds)	H (% pds)	O (% pds)	H/C ato	O/C ato	Vitrinite reflectance (%)	Calorific value (kcal/kg)
Anthracite	> 90	3	1,5	0,38	0,01	> 2	7800 -8500
Bituminous	80-90	4	5-10	0,55-0,8	0,05-0,1	0,5 - 2	6500 -7800
Lignite	70	5	20	0,85	0,2	< 0,5	3000-6500

Influence on the liquefaction reactivity :

- Indirect : no influence
- Direct : required
  - high H/C
  - low O/C
  - high rank

Compromise :
Sub. Bituminous, Bituminous

CTL
Objectives

- Identify synergies between Direct and Indirect CTL routes
  - Possibility to share a large number of process operations
    - coal handling and preparation
    - coal gasification to produce syngas or hydrogen
    - gas purification...
  - Potential blending of very different, but complementary, products of these two routes

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CTL
Comparison Direct / Indirect CTL by products

Naphtha / Gasoline	Indirect route raw products	Direct route raw products	Targets Commercial
Chemical structures	**•Olefins content is much higher than allowed •Aromatics much lower •Linear paraffins •Some oxygenates to be eliminated**	**•Naphtenic- Aromatic structures •Very few paraffins, some olefins**	•Olefins (max 18% vol) •Aromatics (max : 35% vol), Benzene < 1% vol •Oxygenates (2.7 % wt as O)
Octane number	**Very low due to n-paraffins and linear a-olefins**	**Low 60-70 but 80% naphthenic structure for Reforming/ Aromizing**	•Eu : 95 RON/85 MON •US : AKI (MON+RON)/2 : 87 to 91
Density range	**Low density (≈ 700)**	**High density (≈ 800 -850)**	720-775
Heteroatoms	**No S, No N Some oxygenates (aldehydes, ketones…)**	**Very high Nitrogen, Sulfur, High Oxygenates**	S < 30 (US) or 10 (Eu) ppm
Needs	***↗Octane : branched molecules and aromatics***	***Heteroatom removal - severe HDT ↗Octane : but with aromatics content limitation***	**≠ Targets: Automotive Gasoline/ Petrochemical Bases**

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CTL

Comparison Direct / Indirect CTL by products

Diesel	Indirect route	Direct route	Targets (Euro-4)
Chemical structures	**Paraffinic**	**•Naphtenic- Aromatic (mainly mono) structures. mainly condensed napthenes** **•Very few paraffins, some olefins**	
Cetane number	**Excellent > 70**	**Very Low : 25-30**	Eu:51, USA: 40-45
Density range- Cold flow properties	**•Low density (LTFT) : 770-780**	**•Very high density (≈ 900-950)** **•Excellent cold flow properties**	•Eu: 820-845 kg/m3 US: no specs •CFPP / Pour pt : depends on geographical area & seasons
Heteroatoms	**Free of S & N**	**Very high N, S, O**	S < 15 (US) or 10 (Eu) ppm
Needs	*↗ density*	*Heteroatom removal + deep HDT/HCK* *➩cetane ⇒ ➩n- P but not iP ???* *↙ density*	

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CTL

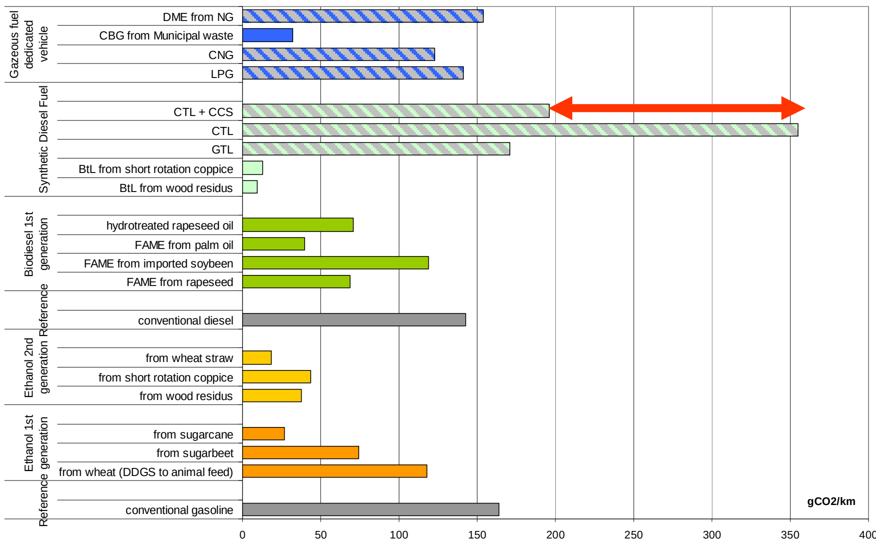
Comparison Direct / Indirect CTL by products

- CTL :
  - Different products properties but complementary for diesel oil

↳Hybrid route

  - Possibility of process integration (coal preparation, gasification, gas purification...)

⇨CO_2 capture is required to reduce GHG footprint



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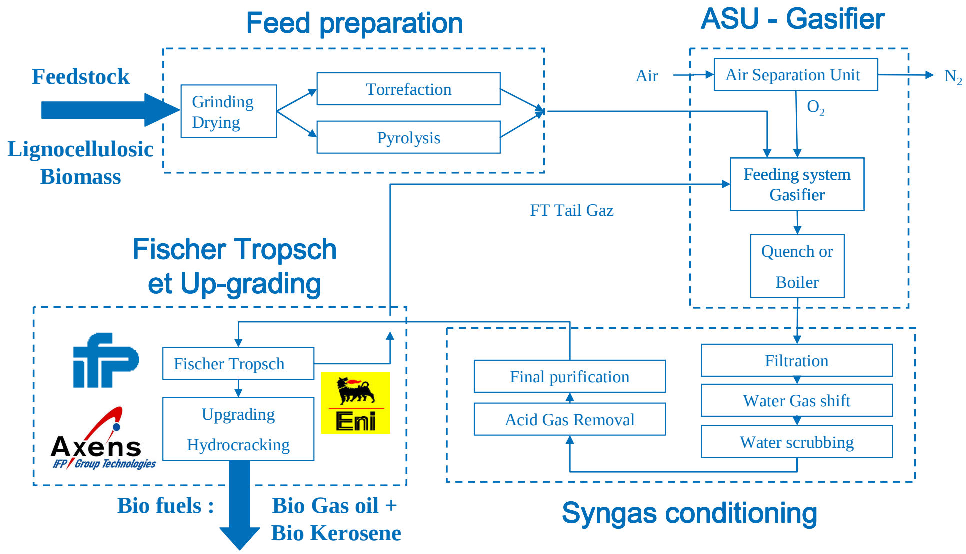
Advantages of B-XTL
Summary of BTL chain status

- State of the art :
  - Complex process unit chain
  - Mass yield ~ 15-20%
  - High Capex and Opex



- Challenges :
  - Process integration to improve η_{mat} / $\eta_{éner}$
  - Scale factor to limit production cost : Huge amount biomass
  - Flexibility towards feedstock

Advantages of B-XTL

BTL scale & industrialization

French case :

Reasonable LC biomass capacity ≈ 540 kT/y (dry)

(collection radius = 250 km max.)

BTL: 100% biomass feedstock

540 kT/y dry biomass

↓

2000 bpd liquid FT C5+

XTL :

75-50 % biomass + 25-50 % fossil feedstock

540 kT/y dry biomass + 181-540 kT/y fossil

↓

4300 bpd - 6500 liquid FT C5+

Refinery

optimization & integration

Advantages of B-XTL

Production cost

Case	Capacity kt/y	Product bpd	Production Cost for 1 liter C5+
100% Biomass	544	2000	100
75% Biomass 25% Fossil	544 181	4300	60 - 70
50% Biomass 50% Fossil	544 544	6500	50 - 60

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Conclusions

- BTL Direct Liquefaction : promising and more prospective
  - Process hurdles
  - Further development needed
- BTL Indirect Liquefaction :
  - Complex process chain / High Capex and Opex
  - Process integration to improve η_{mat} / $\eta_{\acute{e}ner}$
  - 100% biomass feedstock → favorable economy of scale ?
  - *IFP : strong involvement in BTL*
  - *FT Cobalt catalyst technology (developed with ENI)*
  - *R&D efforts on biomass pretreatment and syngas conditioning*

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Conclusions

- CTL :
  - Hybrid route
  - Products properties are different but may be complementary
  - Possibility to share a number of unit operation (coal preparation, gasification, gas purification...) to optimize Capex
  - CO_2 capture to reduce GHG footprint

Conclusions

- IFP believes in B-XTL :
  - Refinery optimization matches with BTL integration
  - Interesting economy of scale to reduce production cost
  - Production of a blend of biofuels and conventional fuels

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