Tomorrow's biorefineries in Europe

Biobased Aviation Fuels. Creation of a new value chain from lignocellulosic materials

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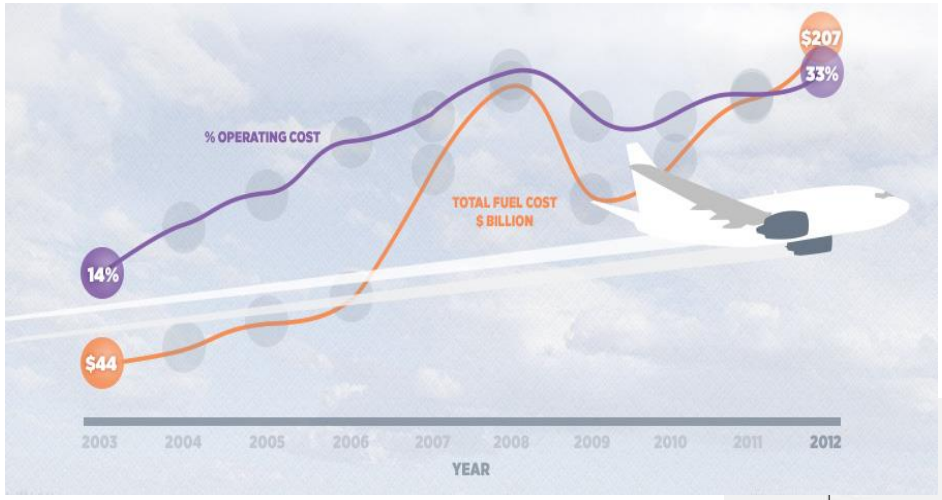
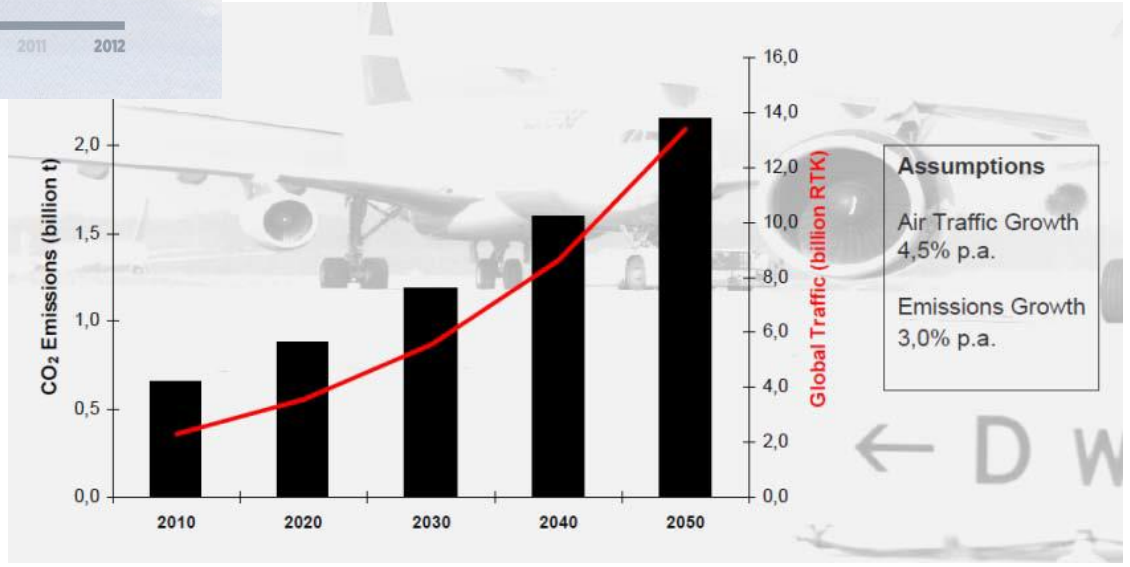
Bio-based aviation Fuels

A challenge for Economy and Environment

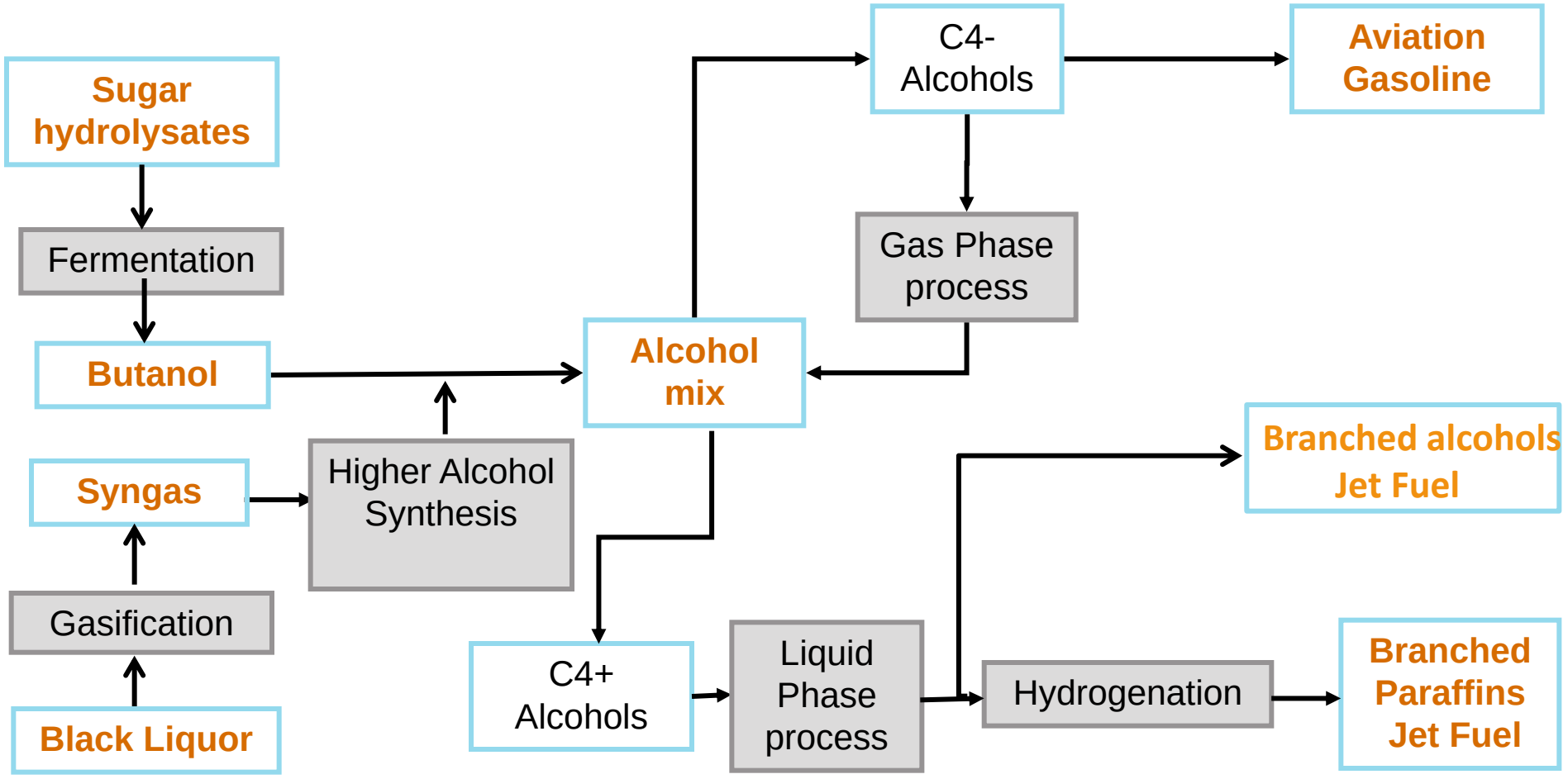




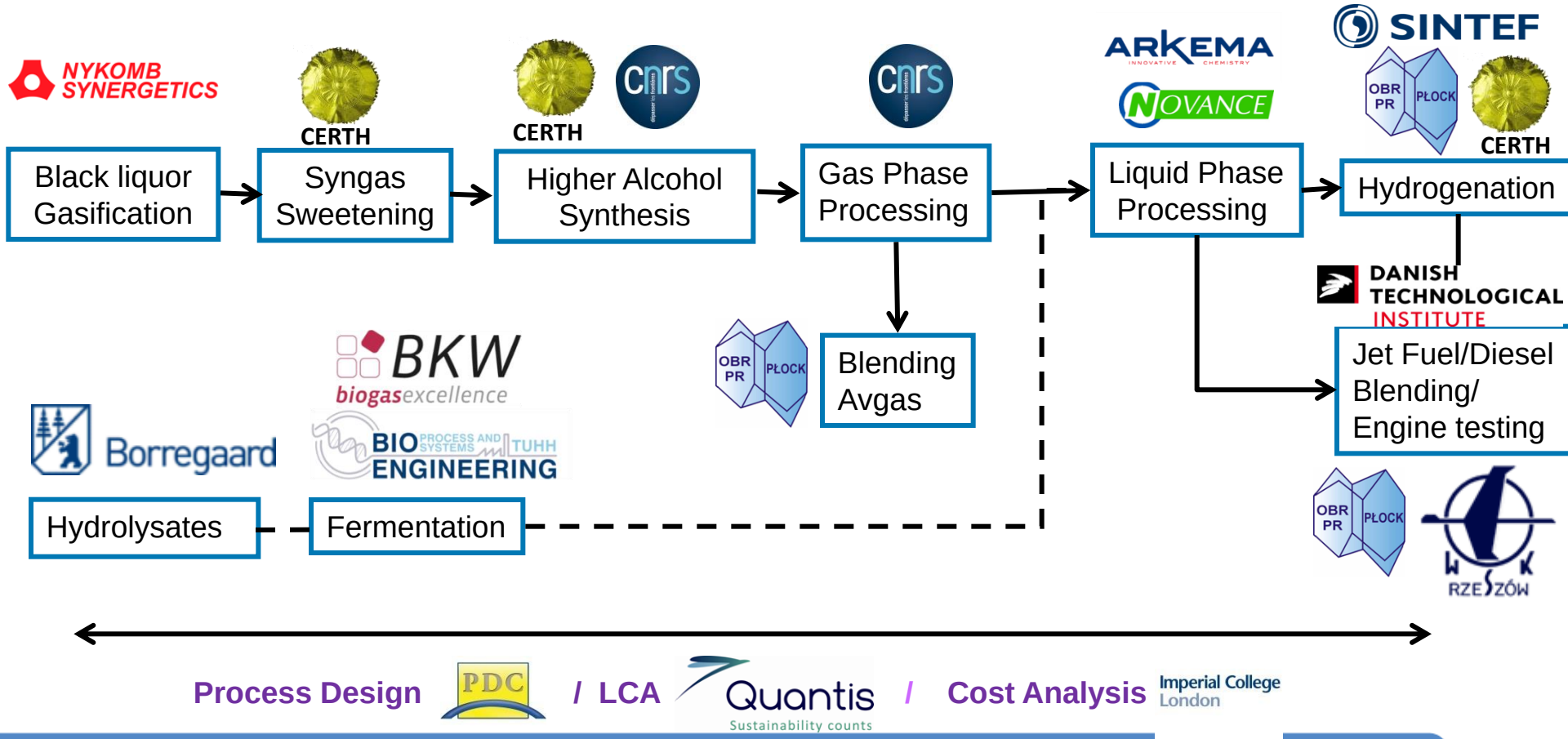
http://renewablejetfuels.org/

General Description of the Alcohols to Fuels Value Chain

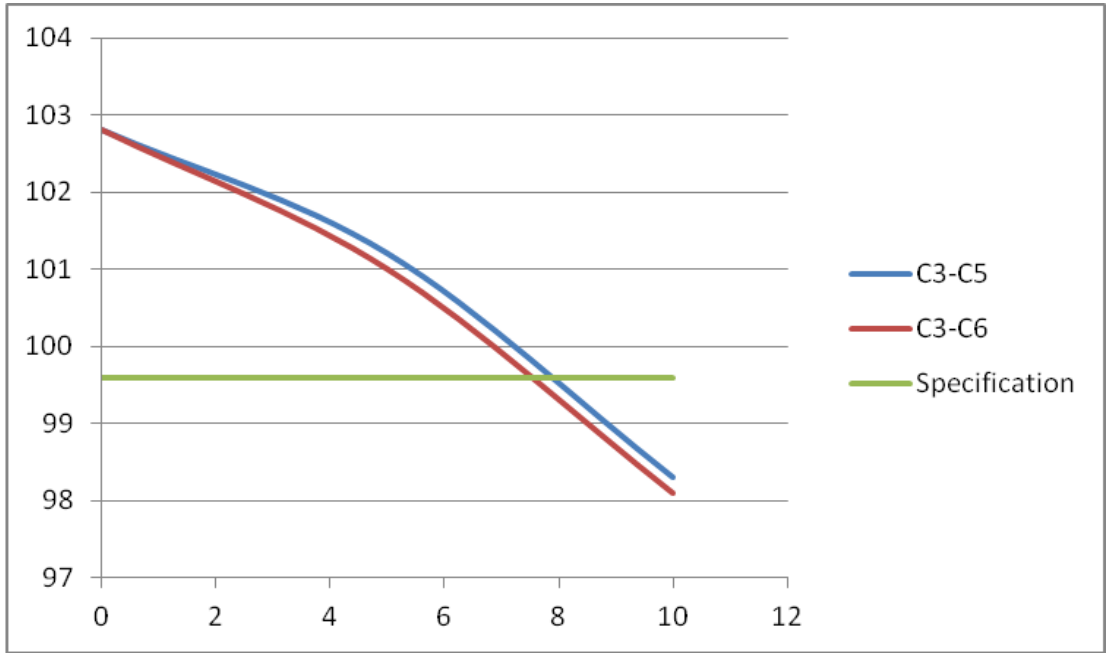
The ATF Biorefinery



Partners' position in the value chain



Evaluation of bio-components addition to AVGAS



Octane rating

% added bio-component to AVGAS100LL

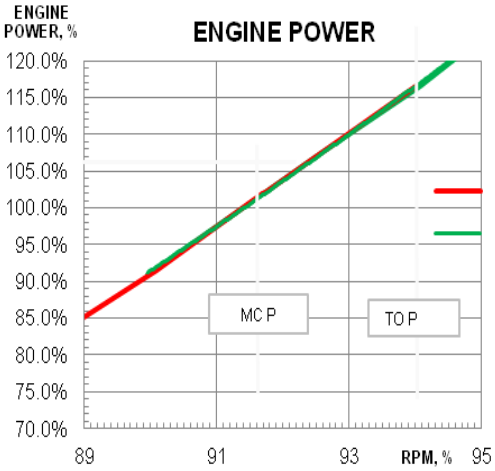
- Alcohols C3-C6 affect negatively the octane rating
- Limitation for max concentration 8%

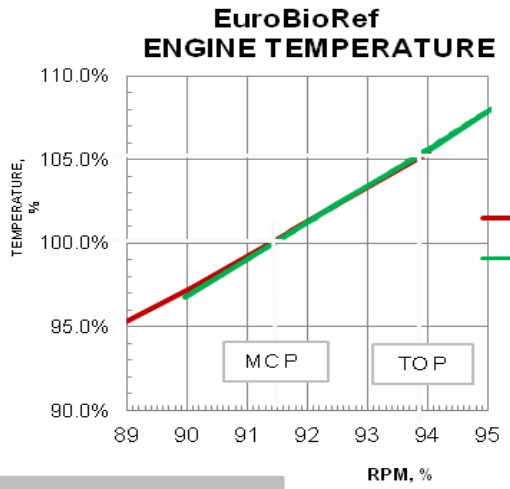
Blending of Eurobioref product with Jet A1

Properties	DEF STAN 91-91	Jet A1	10% Eurobioref product in Jet A1
Density (15^{o}C), Kg/m^{3}	Min 775.0 Max 840.0	792.9	796.6
Freezing point, ^{o}C	< -47	< -60	< -60
Heating value, MJ/Kg	Min 42,800	43,313	42,982
Electrical Conductivity, pS/m	Min 50 Max 600	40	90
Acid number, mgKOH/g	Max 0.015	<0.01	<0.01

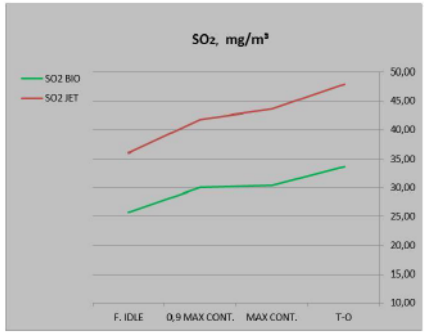
- EuroBioRef Fuel matches regular fuels

Product engine test





Jet A1
EuroBioRef Blend



✓ EuroBioRef Fuel Blend (at 10 %) matches performance of regular Jet Fuel with improved emissions

Market Assessment

- Competing final products
- Competing technologies

Competing final products (jet fuels)

- 100% fossil-based jet fuel
- synthetic jet fuel produced from Fischer-Tropsch
- hydrogenated oils
- drop-in jet fuels produced from isobutanol (GEVO)

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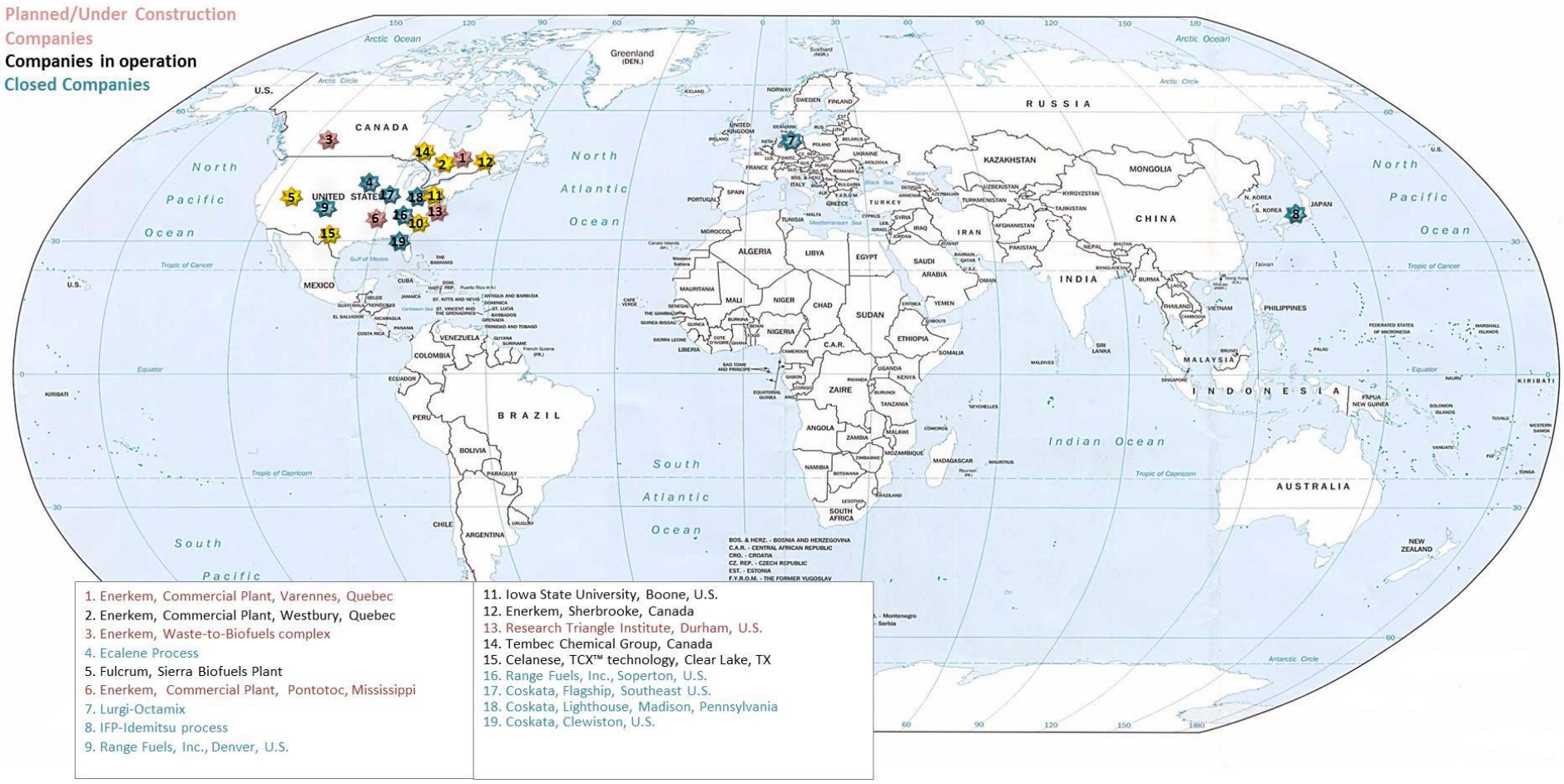
Competing companies for jet-fuel production

	Technology	Process	Feedstock	Product
	Oil Companies	Refining	Petroleum	Jet fuel, gasoline, diesel
UOP A Honeywell Company	UOP/Eni (Ecofining process)	Hydrotreating and isomerization	Triglycerides and/or free fatty acids	Green diesel and jet fuel
HALDOR TOPSØE CATALYSING YOUR BUSINESS	Haldor Topsøe	Hydrotreating	Raw tall oil	Green diesel and jet fuel
NESTE OIL	The Neste Oil. (NExBTL process)	Hydrotreating	Palm oil and waste animal fat	Green diesel
Syntroleum	Syntroleum Corporation	Hydrotreating	Animal fats	Green diesel and jet fuel
sasol	Sasol	FT synthesis	Coal, natural gas	Green diesel and jet fuel
Shell	Shell	FT synthesis	Natural gas	Green diesel and jet fuel
gevo	Gevo	Dehydration, oligomerization	Isobutanol from biomass fermenation	Jet fuels

Competition in the higher alcohol synthesis process step



Technology Assessment

- SWOT
- IP-Score
- Mass and Energy balance
- CAPEX-Cost analysis
- LCA
- Jobs

SWOT ANALYSIS

Strength

- IP on the potential use of branched alcohols and paraffins as blending components of jet fuel
- Products have an additive value
- The target products are high volume and value
- Partners know how on process steps
- Sustainable production

Weaknesses

- Catalyst cost for some of the steps
- Relatively low selectivity in the syngas to alcohol step
- Low productivity in hydrolysates to butanol step
- The fuel to be produced will have to go through certification processes
- **High CAPEX**

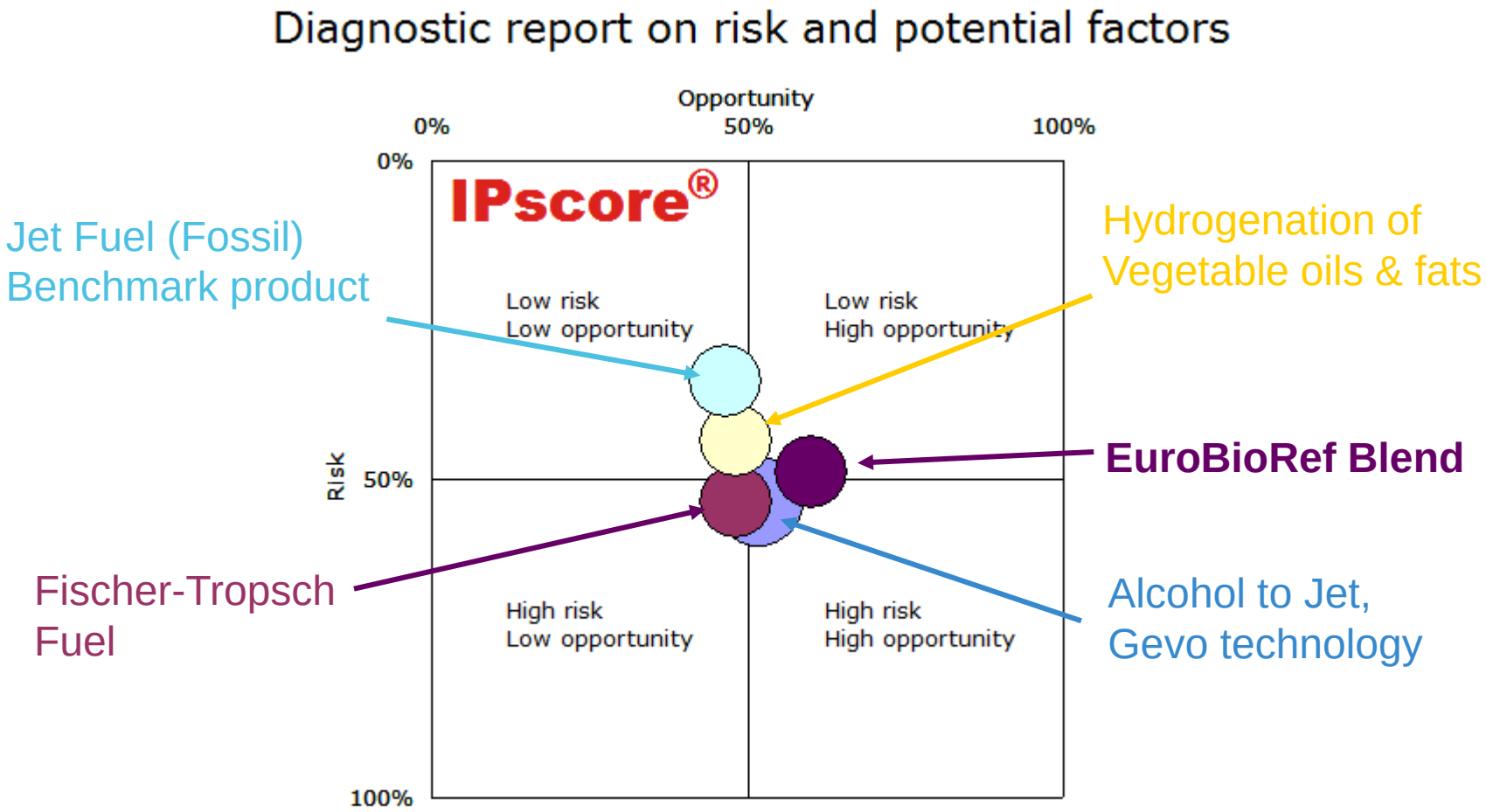
Opportunities

- Tax reduction for (partly) sustainable fuel, increase of CO_2 emission prices, future (company) directives for a minimum sustainable fraction.
- Parts of the technologies developed do not rely exclusively on biomass.
- New business for jet fuel producing companies

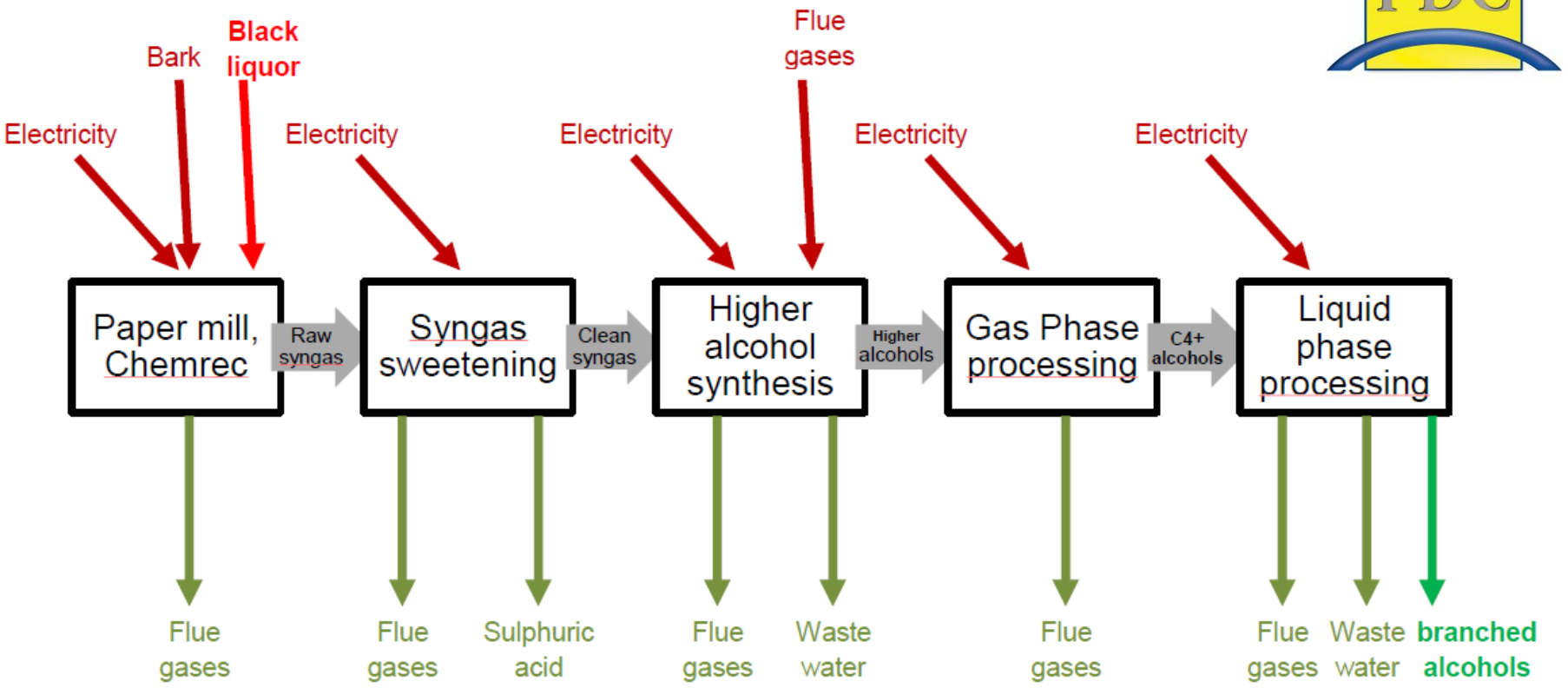
Threats

- Costs
- Competing technologies in the syngas to alcohol step via thermochemical an/or biochemical routes
- Several products or mix of products could compete
- Alternative technologies (FT, NexBTL, Ecofining, Gevo) producing synthetic and bio-jet fuel

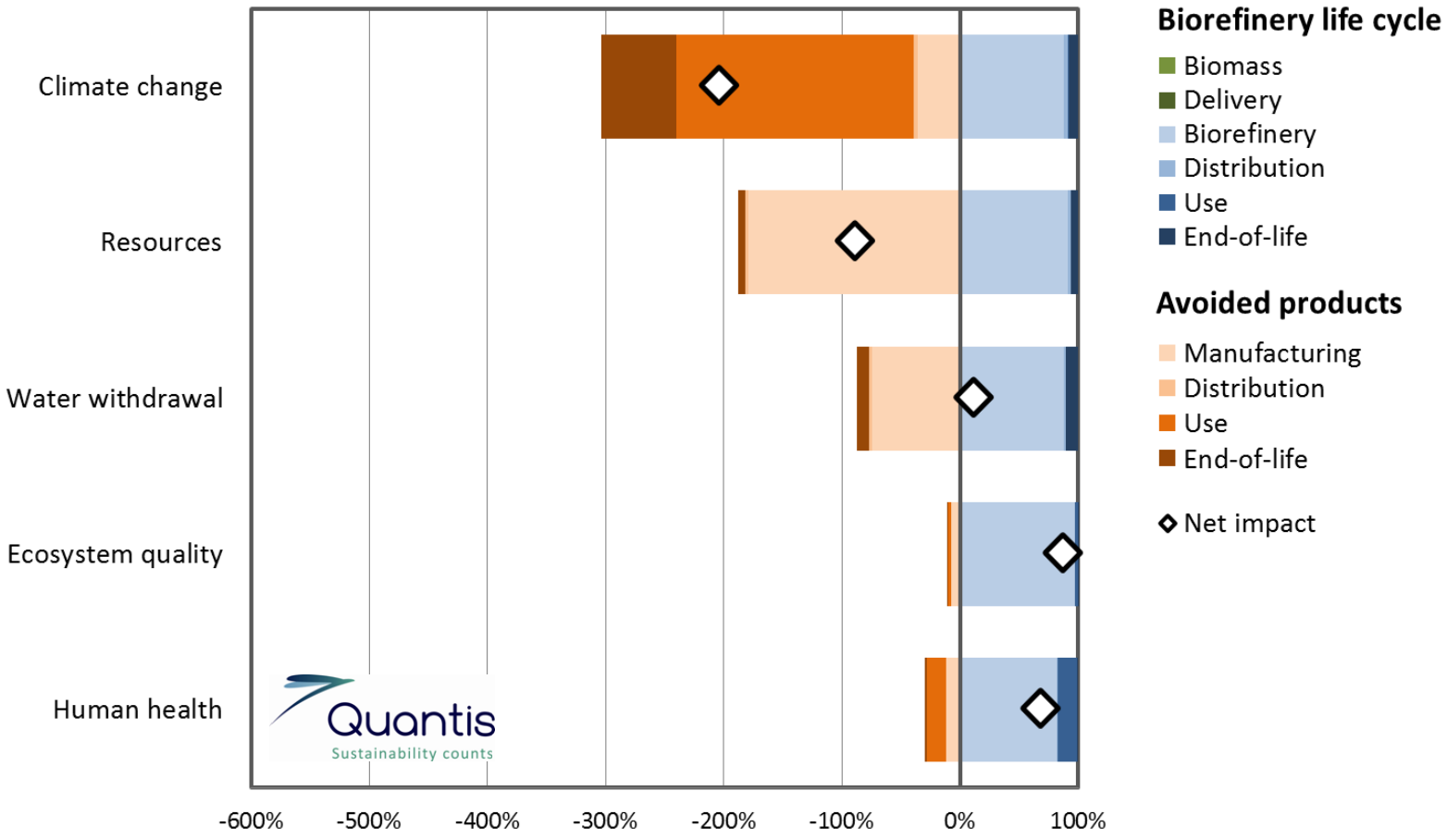
Competition benchmark- IP score



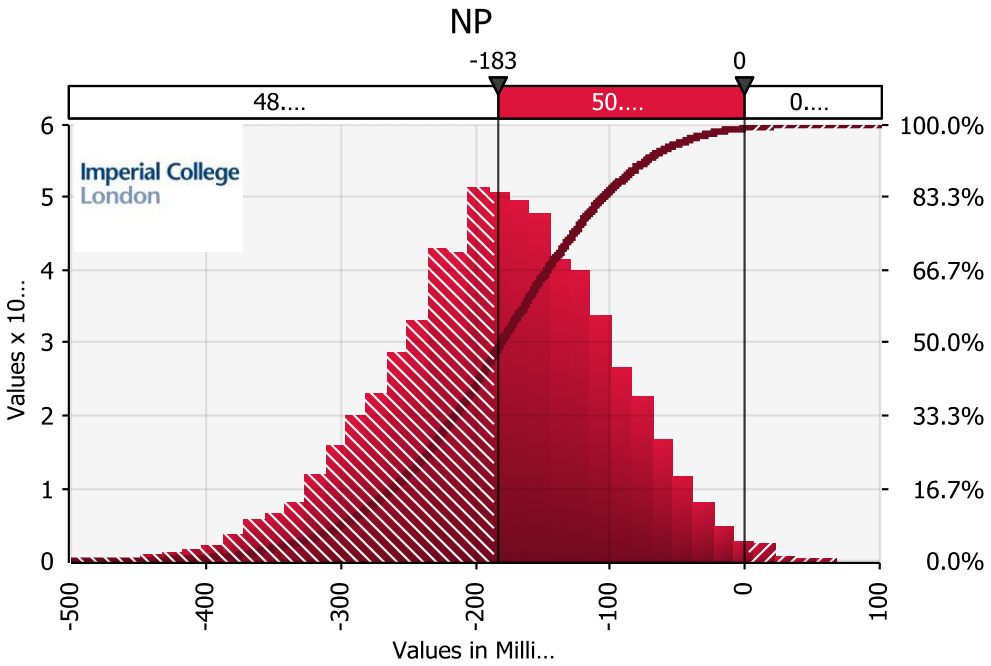
Main process steps - Mass and energy balance



LCA results as per IMPACT 2002+ for VC3: Overview



Cost analysis – Black liquor to higher alcohols

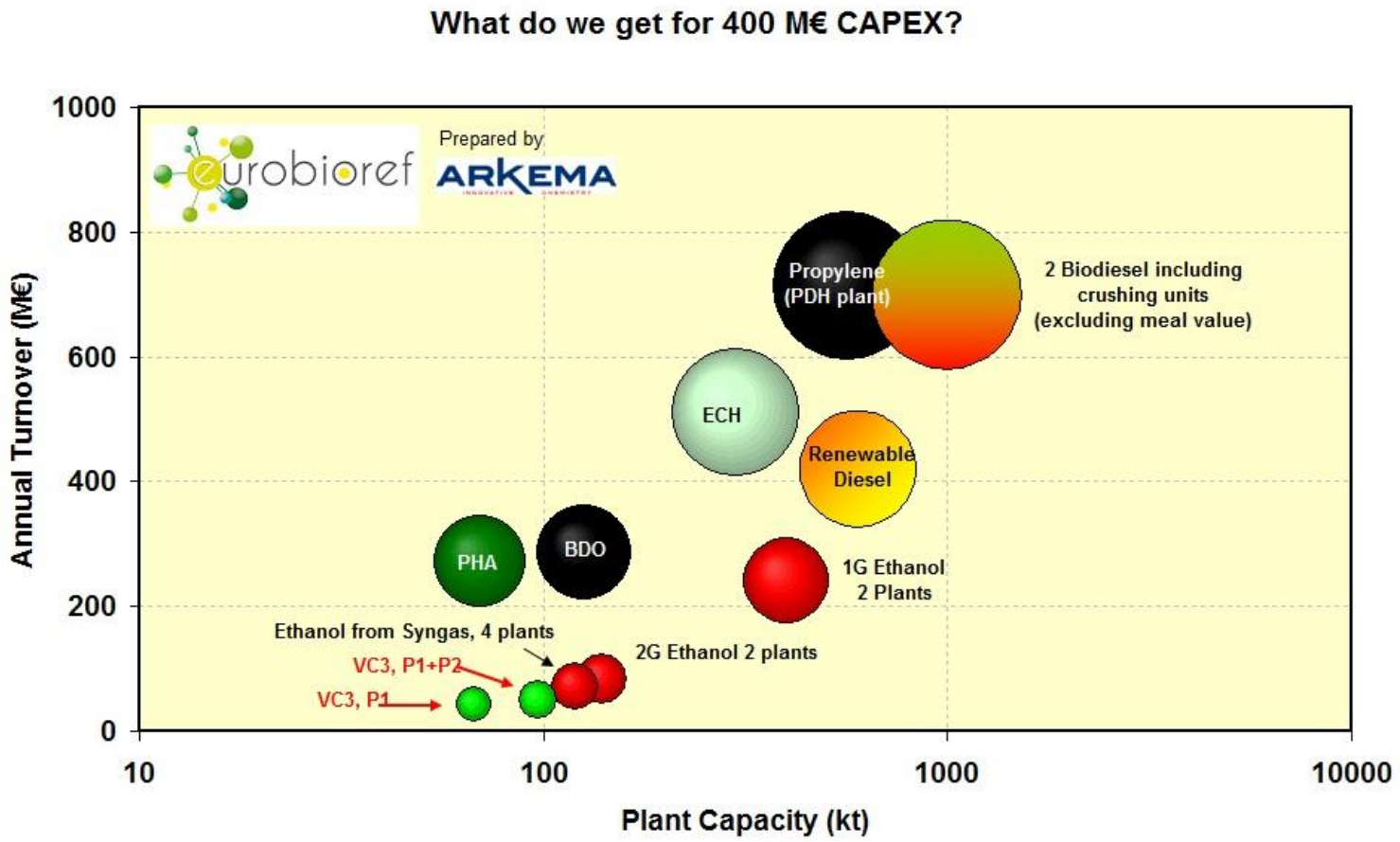


Net present value – higher alcohol production

- Best case: Slightly negative NPV assuming:
  - very low wood cost
  - 40% of capital cost offset against recovery boiler cost
- Capital cost dominate VC performance
- A subsidy or green premium is necessary for being profitable
- A higher value chemical products than fuels would improve economics

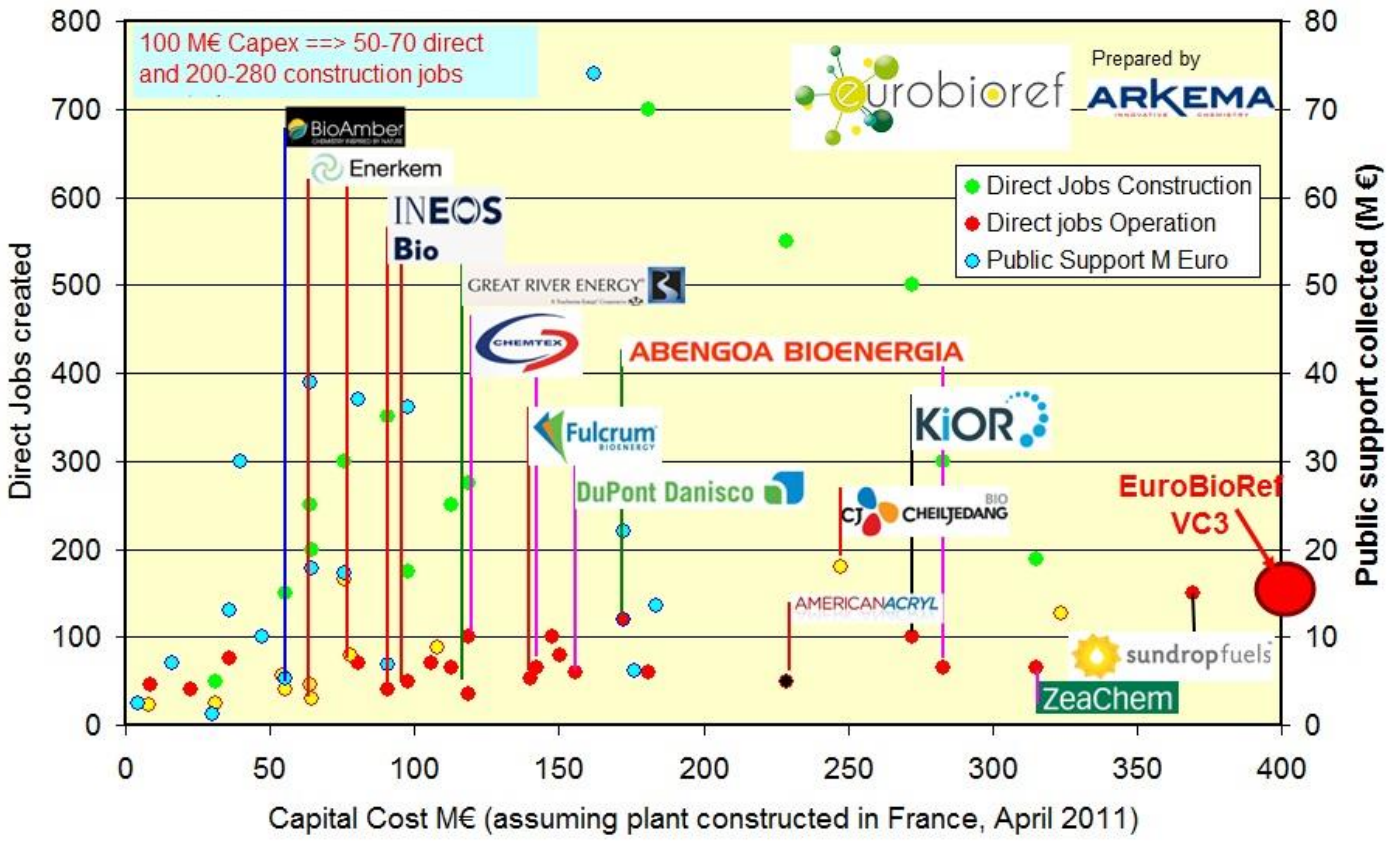
Capital Cost impact

What else could we make for the same Capital cost

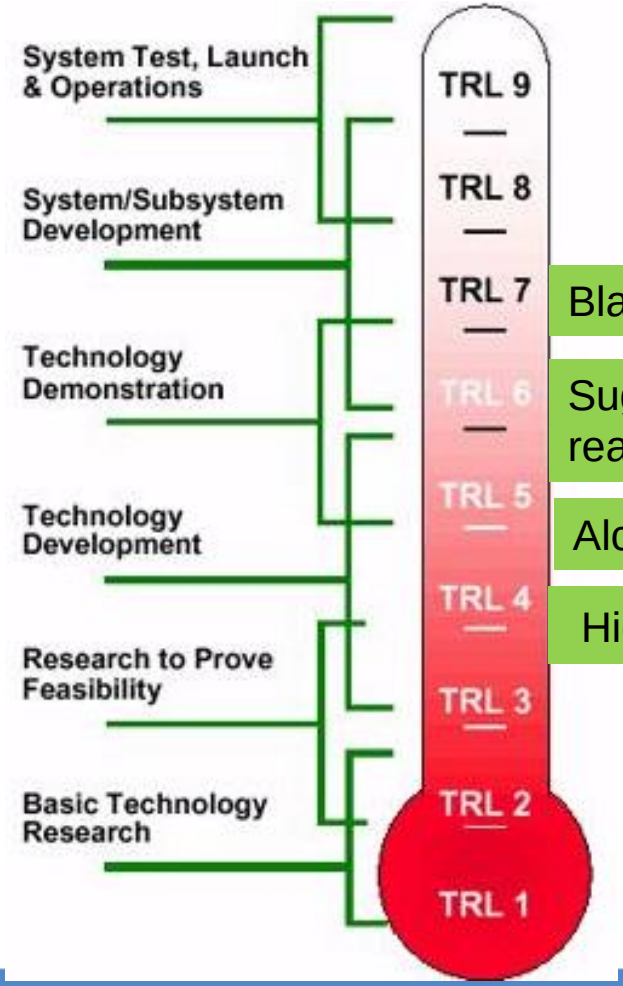


Plant assumed to be built in France, overnight in 2011, Data based on plants announced in literature
Extrapolation factors assumed to be 0.65 for Chemical plants and 0.85 for Fermentation processes

Jobs Creation



Technology Readiness Level



Black liquor gasification

Sugar hydrolysates fermentation, Liquid phase processing, Fuel readiness level

Alcohols Hydrogenation

Higher alcohol synthesis, Gas phase processing

Summarising: Aviation Fuels Biorefinery

Need, Market Opportunity & Impact

- **Need:** Aviation fuels (mostly jet fuels) based on renewable resources.
  Renewable alcohols may have a market in chemical industry

- **Value to the customer:** Green fuels are attractive to the customers – minimum carbon footprintIt is expected but the price that the customers will pay for this product will be over 1 €/liter

- **Market Opportunity:** Tax reduction for (partly) sustainable fuel, increase of CO_2 emission prices, future mandates for a minimum sustainable fraction.

- **Impact:** Bio-alcohols currently find application as octane boosters in gasoline (ethanol), gasoline substitutes (ethanol, butanol), boosters or substitutes of AVGAS and jet fuels

Technology and sponsorship

- **Technology description:** **B**lack liquor gasification to syngas –
  syngas sweetening –
  higher alcohol synthesis-
  C4-gas phase processing-
  C4+liquid phase processing to **Branched Alcohols**
  Hydrogenation to **Branched paraffins**

  Alternative route: hydrolysates fermentation to butanol –
  Liquid phase processing-
  Branched alcohols

- **Project sponsorship:** EuroBioRef is providing support-FP7

Technology Development Milestone (T.R.L.)

- 2 process steps at TRL 4
- 1 process step at TRL 5
- 2 process steps at TRL 6
- 1 process step at TRL7

Company/Team & Business Model

- **Commercial Applications:**
  Black liquor gasification (Borregaard), HAS from Syngas (CERTH/Nykomb),
  Liquid phase process (ARKEMA), Gas phase process (CNRS-UCCS)
  Fermentation of sugars hydrolysates (TUHH), Hydrogenation (Sintef/OBR/CERTH),
  Blending and testing of aviation fuels (OBR,WKRZ)

- **Energy Applications:** Branched alcohols and paraffins blended to Jet fuel and AVGAS

- **Business Model:** Upstream based on the CHEMREC black liquor gasification,
  Alternatively, the HAS unit should be located near a biomass fermentation unit where butanol and other alcohols will be readily available.

- **Objective:** To produce air-transport biofuels with lower carbon footprint at competitive price.

- **Partners / expertise needed in following areas:** Fuel company / Air transportation company.

Take-home messages

✓ A new value chain for the production of aviation fuels blending components from biomass has been proposed, experimentally proved and fully evaluated in terms of technical, cost and environmental impact

✓ Blending of the alcohols up to 10% with conventional jet A1 presents satifactory performance in jet engine with improved emissions

✓ The high capital cost, especially in the step of higher alcohols synthesis strongly affect the profitability of the whole VC.

✓ A cost of ~1200 euros per tonne for the heavy alcohols is the minimum threshold for positive NPV.The price of the envisaged jet fuel blended with the eurobioref product will eventually be affected by only 10%.

✓ If the product mixture is to target chemicals the feasibility will be largely improved due to the much higher market value

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  And all the VC3 contributors

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