BIOREF-iNTEG

SEVENTH FRAMEWORK PROGRAMME

Case 4: Oil refinery sector

Co-production of biofuels in existing refinery units

Rubén Miravalles Gutiérrez (Repsol, Spain)

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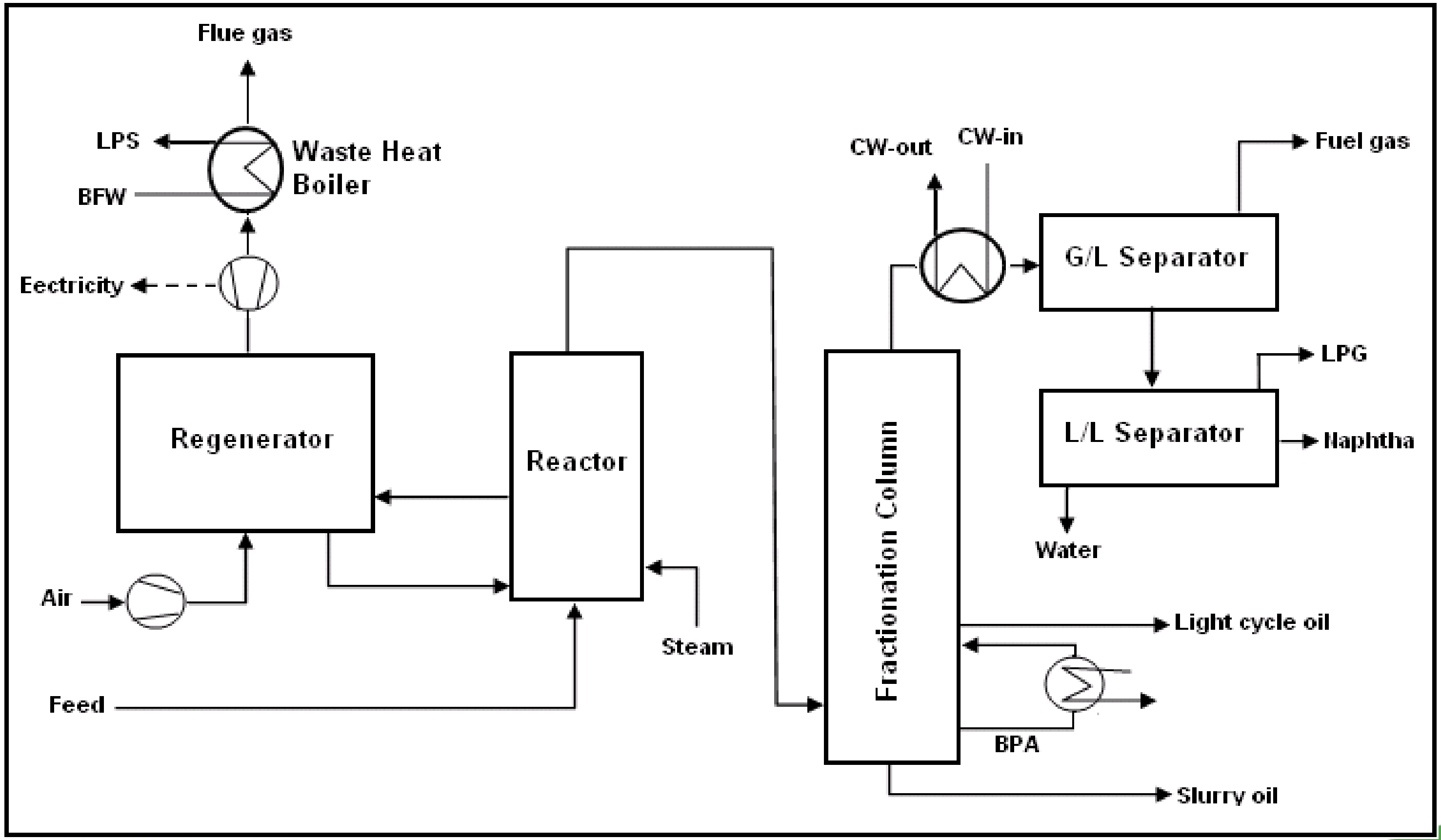
- Introduction:
  - Why biofuels?
    - To reduce European energy dependence on external sources
    - To reduce greenhouse gases (GHG) emissions
  - European Directives promoting the use of biofuels
    - EU Directive 2003/30/EC, promoting mandatory incorporation of biofuels in road transport fuels (5,75% energetic base in 2010).
    - Proposal for 2020: increase amount of biofuels from 5,75% to 10% (energetic base).
    - Fuel Quality Directive (2009/30/EC): obliges to reduce by 10% GHG between 2011 and 2020 (compared to emissions in 2010).

- Introduction:
  - On the other hand, fuels must comply European quality standards:
    - EN-228 (gasoline) / EN-590 (diesel)
    - Some specifications in these standards limit the incorporation of high volumes of conventional biofuels (bioethanol and biodiesel):
      - EN-228: maximum vapour pressure (60 kPa), oxygenated compounds (10% vol ethanol) and distillation curve in gasoline
      - EN-590: maximum 7%vol FAME in diesel
    - Not possible to comply a 10% participation (energy base) of biofuels only with bioethanol and biodiesel
      - 10% energy in diesel ≈ 10,7% vol FAME
      - 10% energy in gasoline ≈ 14,4% vol ethanol

- Reference cases (FCC unit):
  - Block scheme:

Objective: convert vacuum gasoil at low pressure (1-3 bar) and high temperature (490-550ºC) with an acid catalyst, into lighter molecules (LPG, naphtha, gasoil and heavy oil). Some by-products are also produced: fuel-gas, coke and H_2S.



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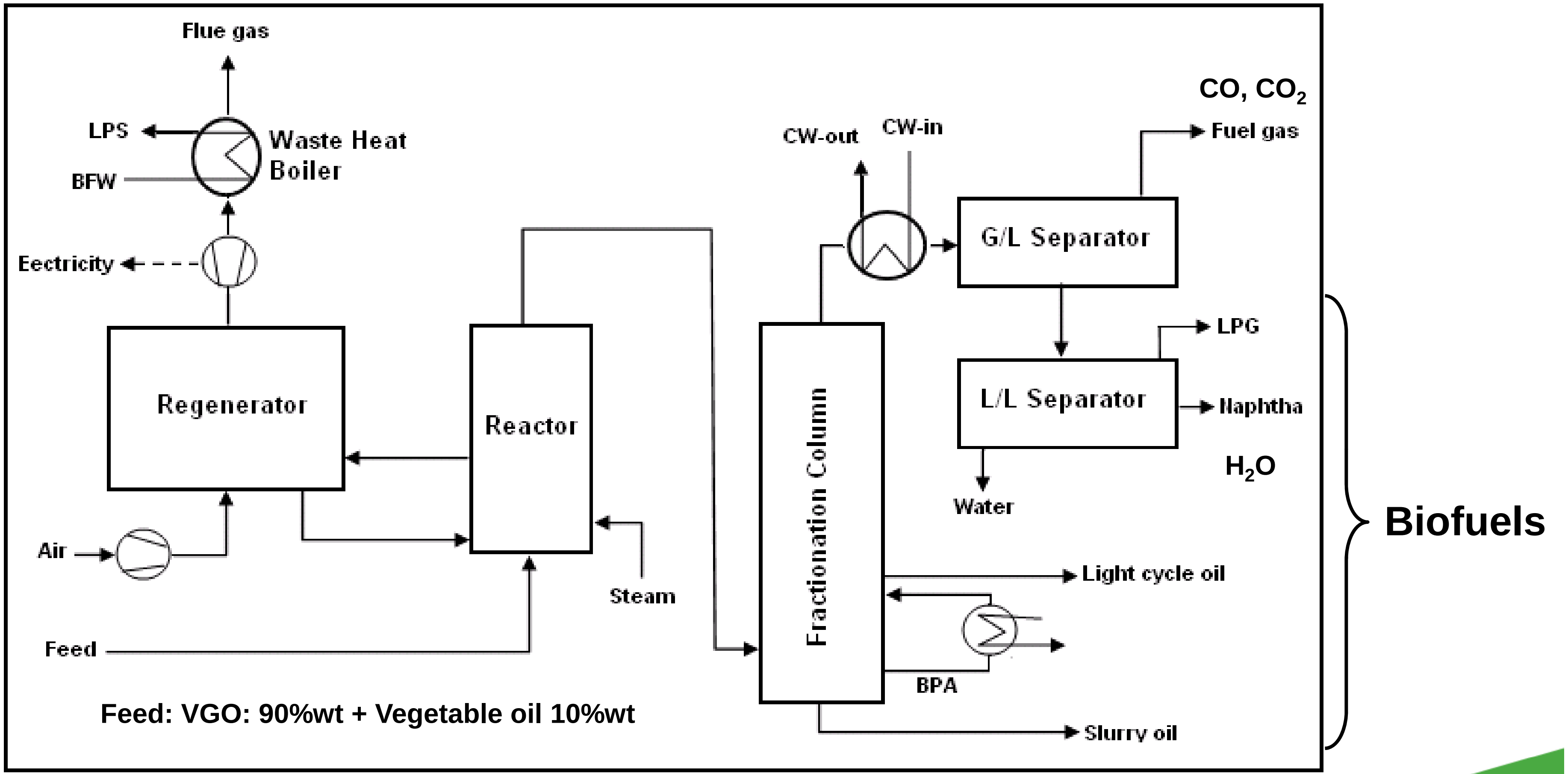
- Integrated biorefinery case (FCC unit):
  - Block scheme: Co-processing 10%wt vegetable oil



- Reference and integrated biorefinery case (FCC):
  - Mass balance:
    - Data obtained from studies carried out by Repsol at pilot plant scale, simulating commercial unit performance

	REFERENCE CASE	BIOREFINERY CASE
Component	**Input/Output (t/h)**	**Input/Output (t/h)**
Feed		
Vacuum gas oil	200	180.0
Vegetable oil - palm oil	0	20.0
Total sum	200	200.0
Products		
Liquefied petroleum gas (LPG)	187.6	184.6 (decrease in main products)
Naphta (GLN)		
Diesel (gas oil)		
Heavy oil		
Total amount of products	**187.6**	**184.6**
Byproducts		
Fuel gas	12.4	12.3 (same by-products)
Solid sulfur (from SH_2)		
Coke		
Water, CO and CO_2	0	**3.1**
Total amount of byproducts	**12.4**	**15.4**
Total sum	200.0	200.0

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- Results techno-economic assessment (FCC):
  - Mass balance and product properties:
    - Vegetable oil is cracked under the operating conditions of FCC unit.
    - Oxygen present in vegetable oil is converted to CO, CO_2 and H_2O.
      - Part of the feed go to non valuable products (impact in economics)
      - Slight increase in O&P costs due to the downstream processing of CO, CO_2 and H_2O
    - Minimum amount of oxygen (ppm) in final products: biofuels produced are very similar to fossil fuels. Even some properties are enhanced (higher octane in gasoline / higher cetane and lower density in diesel)
    - These biofuels could be used in current motors, even at higher percentages

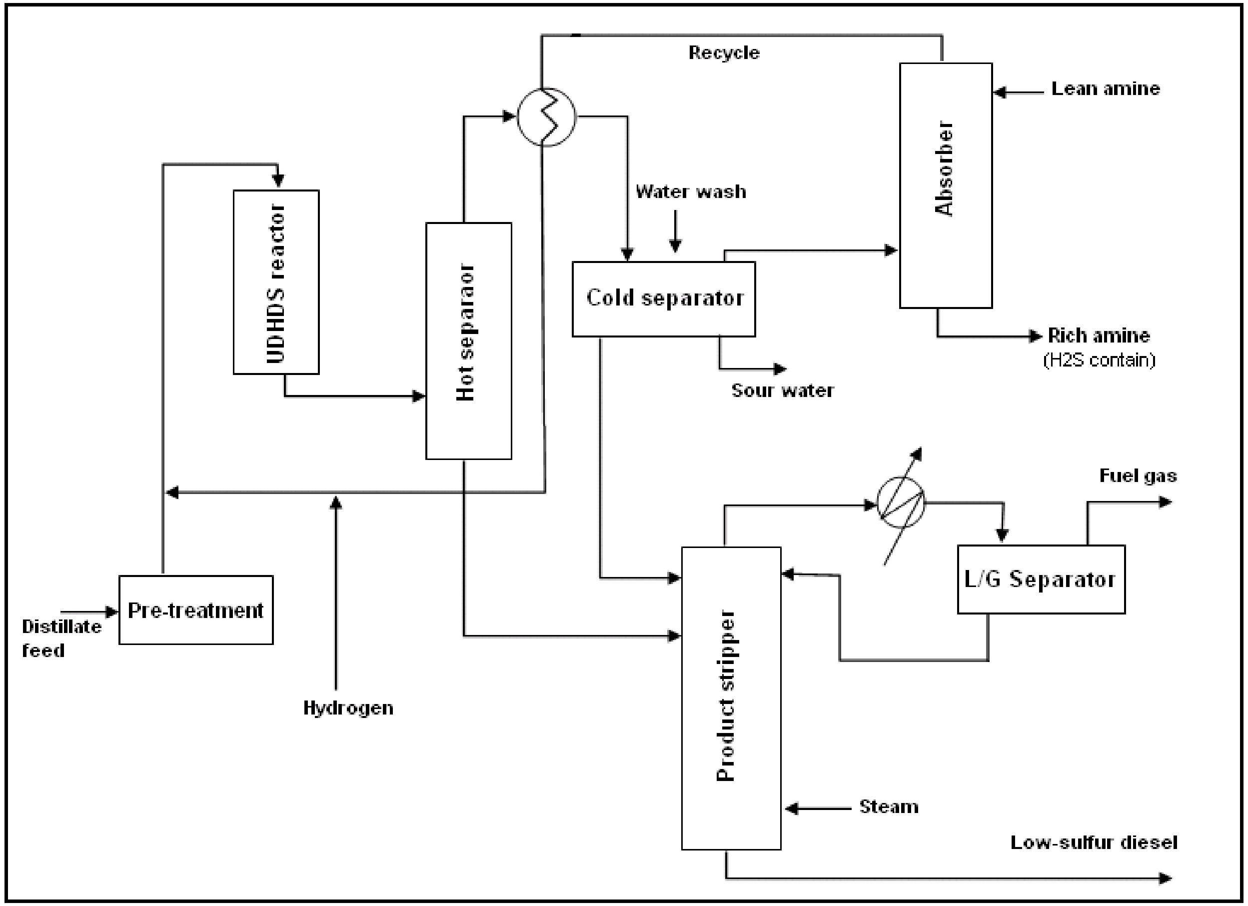
- Results techno-economic assessment (FCC):

  – Economics:

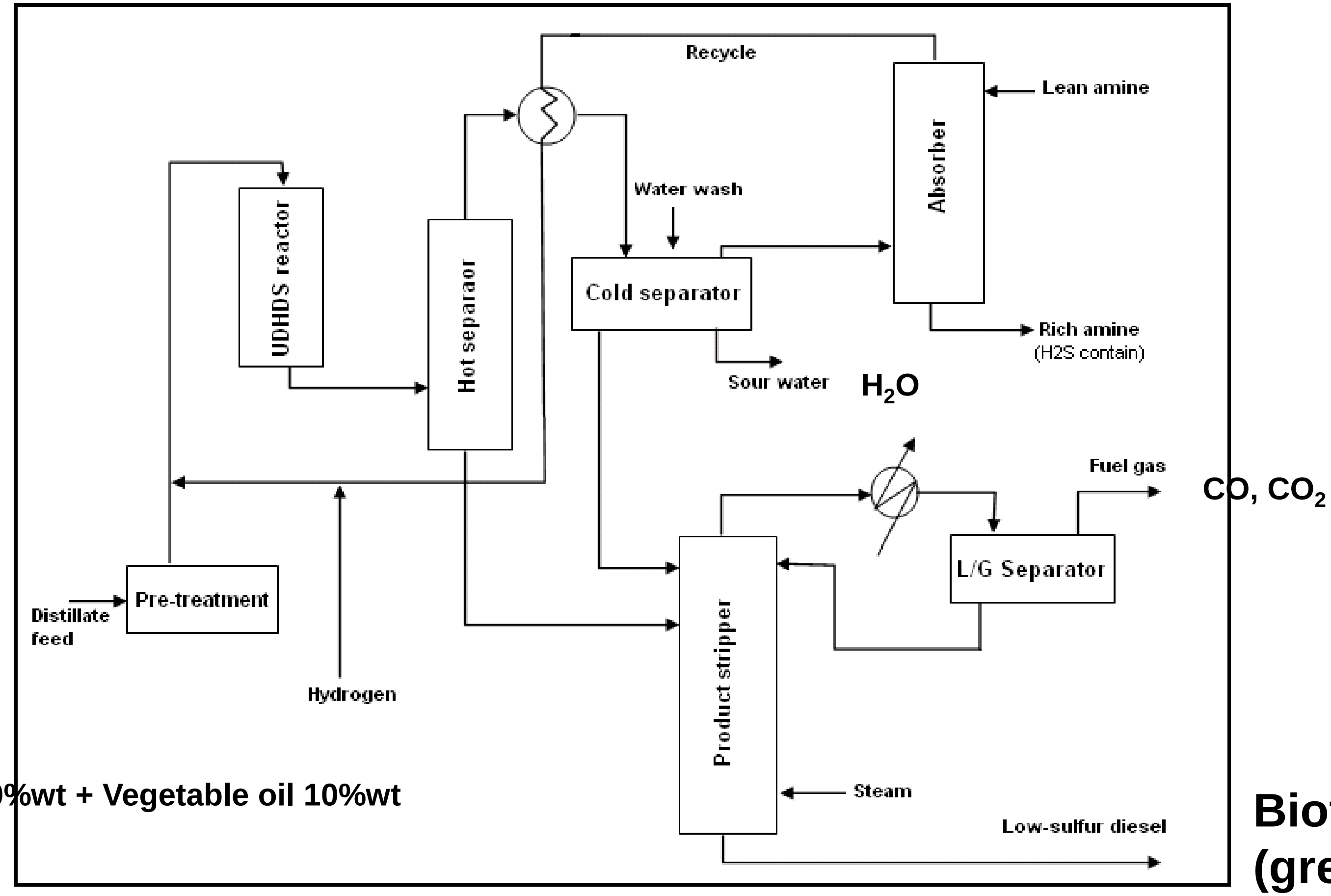
    - Advantage: no need for additional investment (existing units are used)
    - Disadvantage: important increase in production cost (loss of economic margin): + 10 and 20% compared with reference case, depending on feed cost
    - Two main factors affecting production cost are:
      - Differential price between cost of VGO and vegetable oil
      - Vegetable oil is partially cracked to non-valuable products: CO, CO_2 and water
    - Increase in operating costs is not significant compared with the feed cost (vegetable oil)

- Reference case (HDS unit):
  - Block scheme:

Objective: eliminate sulphur present in middle distillates (kerosene and diesel), using H_2 at high pressure, high temperature and a fix-bed catalyst, to fulfil the maximum amount of sulphur allowed in the end product.



- Integrated biorefinery cases (HDS unit):
  - Block scheme: Co-processing 10%wt vegetable oil



Feed:

Middle distillates: 90%wt + Vegetable oil 10%wt

Biofuels (green diesel)

- Reference and biorefinery case (HDS unit):
  - Mass balance :
    - Data obtained from studies carried out by Repsol at pilot plant scale, simulating industrial unit performance

	REFERENCE CASE	BIOREFINERY CASE
Component	**Input/Output (t/h)**	**Input/Output (t/h)**
Feed		
High sulphur gasoil	230.0	207.0
Vegetable oil - palm oil	0	23.0
Hydrogen	**1.6**	**2.1**
Total sum	231.6	232.1
Products		
Hydroteated middle distillates	**226.6**	**222.4** (decrease in main products)
Byproducts		
Fuel gas	5.0	6.1 (increase in C3)
LPG (C3)		
Solid sulfur (H_2S)		
Water, CO and CO_2	0.0	**3.5**
Total sum of byproducts	5.0	9.7
Total sum	231.6	232.1

- Results techno-economic assessment (HDS):

  – Mass balance and product properties:

  - Vegetable oil is completely deoxygenated under the operating conditions of HDS unit.

  - Oxygen in vegetable oil is converted to CO, CO_2 and H_2O.
    - Part of the feed go to non valuable products (impact in economics)
    - Higher H_2 consumption
    - Slight increase in O&P costs due to the downstream processing of CO, CO_2 and H_2O

  - The hydrotreating of vegetable oil produce parafins: biofuels produced are very similar to fossil fuels. Some properties are enhanced (higher cetane and lower density in diesel)

  - These biofuels could be used in current motors, even at higher percentages

- Results techno-economic assessment (HDS):

  – Economics:

  - Advantage: no need for additional investment (existing units are used)

  - Disadvantage: important increase in production cost (loss of economic margin): + 5 and 15% compared with reference case, depending on feed cost

  - Main factors affecting production cost are:
    - Differential price between cost of feedstock: middle distillate and vegetable oil
    - Higher H2 consumption
    - Vegetable oil partially converted to non-valuable products: CO, CO_2 and water

  - This alternative has a cost of production higher than incorporating FAME into diesel

- Technical feasibility

- Score above average: 85,7 (FCC) and 88,7 (HDS) > 71
- Technical feasibility demonstrated at industrial scale for both processes

Statement	Refinery	
	FCC	HDS
Process development		
The integrated concept does not require significant downstream processing	2,0	2,0
All steps of the integrated concept are well identified	1,7	1,7
Required technologies are already developed for the targeted products	1,7	2,0
Required technologies are proven on industrial scale for the targeted products	1,0	1,3
Process does not require toxic or hazardous auxiliaries	1,7	1,7
The integrated concept does not generate additional waste that has to be treated	1,3	1,3
Application development		
Most of the selected applications are already existing	2,0	2,0
Products can be used in most of the selected applications	2,0	2,0
Products are referenced in most of the selected applications	2,0	2,0
Secondary products are referenced in the applications	2,0	1,7
Technical feasibility	**85,7**	**88,7**
Standard deviation	12,7	7,6

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- # Commercial feasibility
  - Score below average: 63,7 (FCC) and 64,3 (HDS) < 71

Statement	Refinery	
	FCC	HDS
Project characteristics		
The integrated concept is leading to 1 new product	1,3	1,3
The product(s) can be used in several applications/markets	2,0	2,0
Market characteristics		
The integrated project addresses existing product/market combinations	2,0	2,0
The addressed markets are innovative (= open for new products/concepts)	1,0	1,3
The targeted markets are large enough to absorb the foreseen volumes	2,0	2,0
Competitive advantage		
Introduction of the new product(s) will lead to an economical benefit for the user	0,7	0,7
The new product(s) have functional benefits	0,7	0,7
There are specific benefits related to the integrated concept compared to the conventional processes	0,0	0,0
Social impact		
The new product(s) is an alternative to fossil-based products	2,0	2,0
The integrated concept is not in competition with food supply	0,7	0,7
The integrated concept does not require large quantities of fresh water	1,7	1,7
The integrated concept is leading to additional renewable energy production	1,7	1,7
The integrated concept is "LCA positive"	1,3	1,3
The integrated concept improves the European competitive position in a global market	1,7	1,7
Regulatory impact		
There are no regulatory barriers affecting the market introduction of the product(s)	1,0	1,0
There is a supporting EU directive promoting the integrated concept	1,7	1,7
Commercial feasibility	**63,7**	**64,3**
Standard deviation	12,4	11,9

• SWOT analysis: Vegetal oil in FCC and HDS unit

Strenght

- EU Directives on mandatory incorporation of biofuels (2003/30/EC) and on reduction of GHG
- No need for extra investment
- Technical feasibility demonstrated at industrial scale
- Biofuels produced are very similar to fossil fuels (some properties improved)
- No need to modify motors

Weaknesses

- Production cost is higher
  - Price of vegetable oil higher than fossil fuel feedstock
  - Cost in auxiliaries is slightly higher
  - There can be unpredictable costs in long term operation (catalyst life) for HDS
  - The production cost a lot of expensive hydrogen for HDS
- Need for downstream processing (CO, CO2 and water)
- Less cost-effective than conventional biofuels (biodiesel)
- Cold properties are worse than fossil diesel for HDS case

• SWOT analysis: Vegetal oil in FCC and HDS unit

Opportunities

- EU directive (Directive 2003/30/EC) promoting incorporation of biofuels
    - 5,75% energetic value in 2010
    - 10% energetic value in 2020 (not possible only blending biodiesel or bioethanol)
- EU directive (Fuel Quality Directive) that obliges to reduce by 10% GHG between 2011 and 2020
- Reduce energetic dependence from other countries outside EU (substitution of the fossil feedstock by a renewable)

Threats

- No mechanism to compensate higher production costs: need of tax exemption

• Summary and Conclusions

- Advantage: no need for extra investment

- Disadvantage: important increase in the cost of production:
  - Mainly due to the differential price between vegetable oil and fossil feedstock
  - Production of non valuable products (CO, CO_2 and water)
  - Cost of production could be lower if “residual feedstock” is used (animal fat and used cooking oil)
  - Biofuels produced by this route should have tax benefits

- Co-processing of vegetal oil in HDS unit is preferred by two main reasons:
  - Increase in production cost is lower
  - More focused in diesel production (deficit in Europe)

- This alternative do not compete with current biofuels. It is a complementary route
  - Production of biodiesel (FAME) is more cost effective than co-processing vegetable oil in HDS unit, but limited by EN590
  - 10% energetic value in 2020 not possible only blending biodiesel or bioethanol