

## *Supplementary Material*

A. Integrated Process Flow Diagram (PFD) & stream results

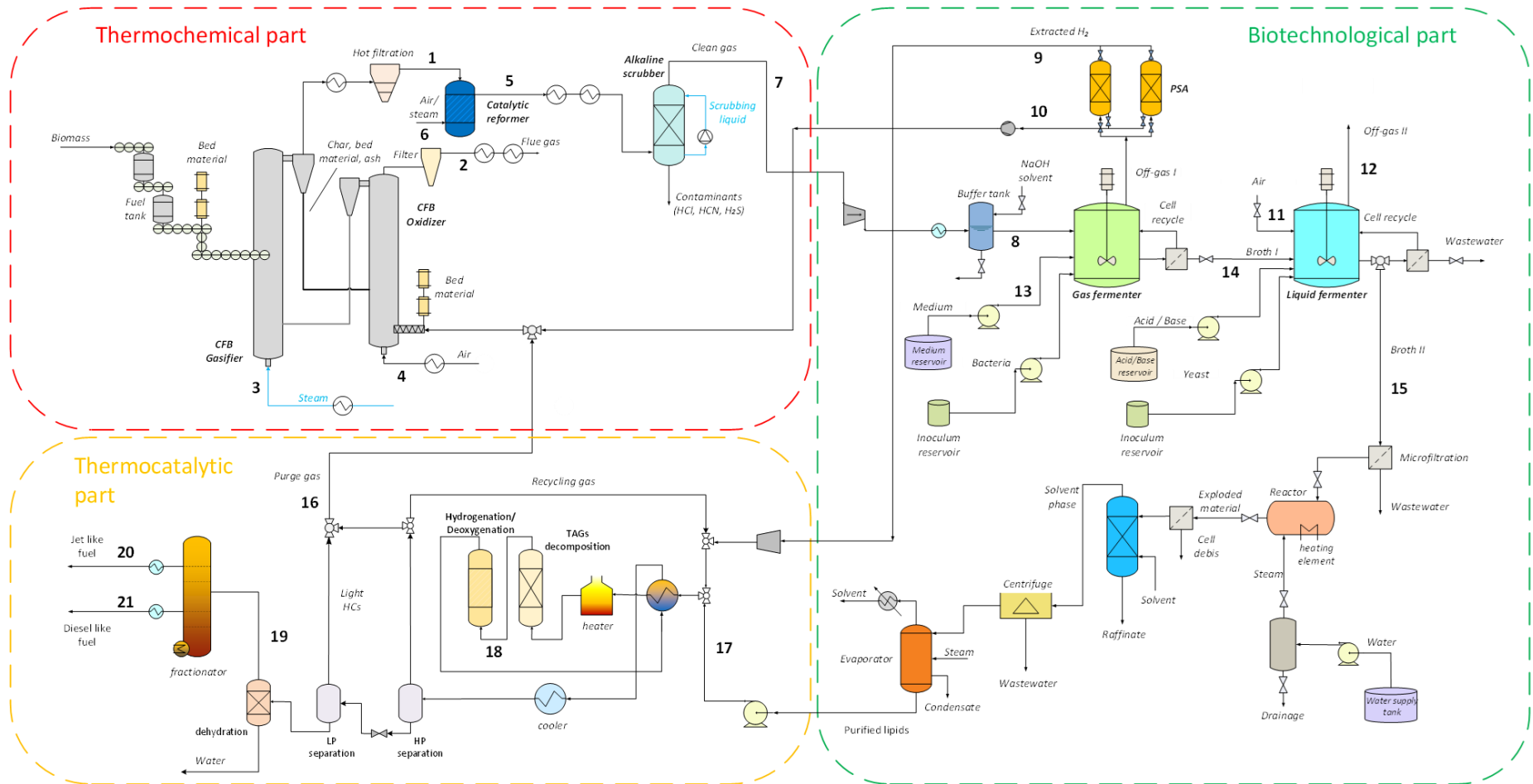


Figure S1. Integrated PFD of the BtL concept

Table S1. Stream results for the thermochemical part

Stream No	1 Syngas after filtration	2 Flue gas after filtration	3 Pre-heated steam	4 Pre-heated air	5 Reformed syngas (ATR)	6 Air (ATR)	7 Cooled syngas
Mass flow (kg/s)	16.99	35.86	7.92	25.40	24.19	7.21	19.19
Temp (°C)	780	880	350	400	900	400	35
Press (bar)	1.3	1.1	1.5	1.5	1.1	1.5	1.1
Composition (vol. %)							
H <sub>2</sub>	30.89	-	-	-	32.61	-	41.53
CO	12.79	-	-	-	15.33	-	20.34
CO <sub>2</sub>	14.58	14.20	-	-	13.15	-	15.86
H <sub>2</sub> O	31.95	8.04	100	-	22.73	-	1.71
N <sub>2</sub>	2.04	73.71	-	79.00	15.38	79.00	19.58
H <sub>2</sub> S	178 ppm	-	-	-	127 ppm	-	21 ppm
CH <sub>4</sub>	5.26	-	-	-	0.75	-	0.96
NH <sub>3</sub>	0.19	-	-	-	273 ppm	-	84 ppm
HCN	12 ppm	-	-	-	-	-	-
COS	10 ppm	-	-	-	7 ppm	-	7 ppm
C <sub>2</sub> H <sub>4</sub>	1.74	-	-	-	-	-	-
C <sub>6</sub> H <sub>6</sub>	0.37	-	-	-	27 ppm	-	27 ppm
C <sub>10</sub> H <sub>8</sub>	0.17	-	-	-	-	-	-
O <sub>2</sub>	-	4.05	-	21.00	-	21.00	-

Table S2. Stream results for the biological part

Stream No	8 Gas prior fermenter	9 Purge H <sub>2</sub>	10 Gas fermenter off-gas	11 Air	12 Liquid fermenter off-gas	13 Medium	14 Broth-I	15 Broth-II
Mass flow (kg/s)	19.18	0.10	9.50	109.9	115.2	236.5	245.7	14.07
Temp (°C)	55	15	55	28	28	55	55	28
Press (bar)	5	100	5	1	1	5	5	1
Composition (vol. %)						Composition (wt. %)		
H <sub>2</sub>	41.53	100	15.02	-	-	-	-	-
CO	23.34	-	6.56	-	-	-	-	-
CO <sub>2</sub>	12.86	-	18.31	-	3.28	-	0.15	0.10
H <sub>2</sub> O	1.71	-	2.65	-	3.74	100	96.74	87.05
N <sub>2</sub>	19.58	-	54.85	79.00	75.16	-	-	0.10
H <sub>2</sub> S	10 ppm	-	44 ppm	-	-	-	-	-
CH <sub>4</sub>	0.96	-	2.69	-	-	-	-	-
NH <sub>3</sub>	88 ppm	-	330 ppm	-	-	-	-	-
C <sub>6</sub> H <sub>6</sub>	27 ppm	-	51 ppm	-	-	-	-	-
O <sub>2</sub>	-	-	-	21.00	17.81	-	-	-
Acetic acid	-	-	-	-	-	-	3.11	-
Tripalmitin	-	-	-	-	-	-	-	3.15
Triolein	-	-	-	-	-	-	-	5.93
Trilinolein	-	-	-	-	-	-	-	1.65
Tristearin	-	-	-	-	-	-	-	1.99

Table S3. Stream results for the thermocatalytic part

Stream No	16 Light gases	17 Purified TAGs	18 Fatty acids/ propane	19 Jet/Diesel paraffins	20 Jet-like fuel	21 Diesel-like fuel
Mass flow (kg/s)	0.29	1.82	1.92	1.51	1.21	0.30
Temp (°C)	30	50	370	30	30	30
Press (bar)	1	100	100	1	1	1
Composition (vol. %)		Composition (wt. %)				
Tripalmitin	-	24.76	-	-	-	-
Triolein	-	46.63	-	-	-	-
Trilinolein	-	12.99	-	-	-	-
Tristearin	-	15.62	-	-	-	-
Palmitic acid	-	-	22.36	-	-	-
Oleic acid	-	-	42.29	-	-	-
Linoleic acid	-	-	11.78	-	-	-
Stearic acid	-	-	14.17	-	-	-
H <sub>2</sub>	78.08	-	4.58	-	-	-
CO	4.59	-	-	-	-	-
CO <sub>2</sub>	8.41	-	-	-	-	-
Propane	4.97	-	4.83	-	-	-
Methane	3.95	-	-	-	-	-
C <sub>9</sub> H <sub>20</sub>	-	-	-	4.03	8.52	-
C <sub>10</sub> H <sub>22</sub>	-	-	-	7.03	14.87	-
C <sub>11</sub> H <sub>24</sub>	-	-	-	4.36	9.23	-
C <sub>12</sub> H <sub>26</sub>	-	-	-	3.68	7.78	-
C <sub>13</sub> H <sub>28</sub>	-	-	-	3.52	7.44	-
C <sub>14</sub> H <sub>30</sub>	-	-	-	22.92	47.15	1.21
C <sub>15</sub> H <sub>32</sub>	-	-	-	6.90	3.11	10.29
C <sub>16</sub> H <sub>34</sub>	-	-	-	6.59	1.90	10.80
C <sub>17</sub> H <sub>36</sub>	-	-	-	28.34	-	53.74
C <sub>18</sub> H <sub>38</sub>	-	-	-	12.64	-	23.96

B. Main feedstock (crushed bark) specifications

Table S4. Feedstock (crushed bark) properties involved in the process simulations

Mass flow a.r. (kg/s)				11.24		
Net Calorific Value LHV a.r. (MJ/kg)				17.79		
Proximate Analysis (%)						
Moisture		Fixed Carbon		Volatile Matter		Ash
8.4		18.5		77.8		3.7
Ultimate Analysis (%)						
Ash	Carbon	Hydrogen	Nitrogen	Chlorine	Sulfur	Oxygen
3.7	51.5	5.8	0.3	-	0.06	38.64

C. Critical equipment list

Table S5. Main equipment considered for the industrial layout of the concept

Equipment type	Additional information
Thermochemical part	
Biomass feeding system	-
Gasifier	CFB reactor + hot gas ducts including refractories
Oxidizer (combustor)	CFB reactor + hot gas ducts including refractories
Air, steam, and nitrogen systems	Pre-heating and auxiliaries
Ash systems	Ash handling and storage
Hot gas filters	-
Gas coolers	-
Catalytic tar reformer	Air/steam driven autothermal reformer (ATR)
Alkaline scrubber	NaOH solvent feeding mode
Gas compression system	-
Biological part	
Media preparation	Substrate/powder handling, chemical dosing for pH-correction, dissolving, sterilisation
15 x gas fermenters (acetic acid)	CSTR (500 m3) including agitators and circulation pumps
3 x seed fermenters (acetic acid)	CSTR (250 m3) including agitators and circulation pumps, 10% inoculation ratio
15 x liquid fermenters (TAGs)	CSTR (500 m3) including agitators and circulation pumps
3 x seed fermenters (TAGs)	CSTR (25 m3) including agitators and circulation pumps, 1% inoculation ratio
Microfiltration	DSP train for TAGs purification
Steam explosion	
Solvent extraction	
Centrifugation	
Evaporation	
Thermocatalytic part	
Hydrotreating reactor	Hydrogenation/hydrocracking, deoxygenation
Fractionating column	Jet/diesel fraction separation
Flash tanks	High pressure and low pressure liquid (paraffins)/ gas (unreacted hydrogen, light hydrocarbons) separation
Reactor feed-effluent heat exchanger	-
Reactor feed heater	-
Reactor effluent air-blown cooler	-
PSA hydrogen unit	-

D. Microbial Oil Business case

Table S6. Capital Expenditures (CapEx) of the BtL plant (microbial oil scenario)

Dual Fluidized Bed Gasification	80,000,000 €
Catalytic Reformer	8,500,000 €
Gas Conditioning (coolers, alkaline scrubber)	10,500,000 €
Gas Compression	5,000,000 €
Gas Fermentation	80,000,000 €
Liquid Fermentation	64,000,000 €
Downstream Processing (TAGs recovery)	16,000,000 €
Hydrotreatment/ Hydrocracking	-
Utilities & Storage	8,000,000 €
<b>Total installed costs (direct costs)</b>	<b>272,000,000 €</b>
Indirect costs	163,200,000 €
Total direct & indirect costs	435,200,000 €
Contingency	43,520,000 €
<b>Fixed Capital Investment (FCI)</b>	<b>478,720,000 €</b>
Working Capital	47,872,000 €
<b>Total Capital Investment (TCI)</b>	<b>526,592,000 €</b>

Table S7. Annual Operational Expenditures (OpEx) of the BtL plant (microbial oil scenario)

Feedstock costs	21,090,646 €/year
Electricity	5,361,120 €/year
Maintenance	9,574,400 €/year
Labor costs	3,500,000 €/year
Nutrients & chemicals	1,054,532 €/year
Property Insurance	3,351,040 €/year
Solvent make-up	2,959,338 €/year
Wastewater discharge	1,858,164 €/year
<b>Annual operational expenses</b>	<b>48,749,240 €/year</b>
Income from diesel	-
Income from cellular biomass	6,288,716 €/year
<b>Annual revenue streams (by-product credits)</b>	<b>6,288,716 €/year</b>



E. Discounted cash flow analysis

Table S8. Discounted cash flow analysis for the calculation of MJSP (jet fuel scenario)

Year	Total Capital Investment (TCI)	Income*	Operational Expenses	Cash flow	Discount factor $1/(1+i)^{\text{year}}$	Net Present Values	Discounted payback
-1	€ 230,771,200.00			-€ 230,771,200.00	1.00	-€ 230,771,200.00	
0	€ 346,156,800.00			-€ 346,156,800.00	1.00	-€ 346,156,800.00	
1		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.94	€ 42,576,588.76	-€ 534,351,411.24
2		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.89	€ 40,166,593.17	-€ 494,184,818.07
3		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.84	€ 37,893,012.42	-€ 456,291,805.65
4		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.79	€ 35,748,124.93	-€ 420,543,680.72
5		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.75	€ 33,724,646.16	-€ 386,819,034.56
6		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.70	€ 31,815,703.92	-€ 355,003,330.64
7		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.67	€ 30,014,815.02	-€ 324,988,515.62
8		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.63	€ 28,315,863.23	-€ 296,672,652.39
9		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.59	€ 26,713,078.52	-€ 269,959,573.87
10		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.56	€ 25,201,017.47	-€ 244,758,556.40
11		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.53	€ 23,774,544.78	-€ 220,984,011.62
12		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.50	€ 22,428,815.83	-€ 198,555,195.79
13		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.47	€ 21,159,260.22	-€ 177,395,935.57
14		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.44	€ 19,961,566.24	-€ 157,434,369.33
15		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.42	€ 18,831,666.27	-€ 138,602,703.06
16		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.39	€ 17,765,722.89	-€ 120,836,980.16
17		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.37	€ 16,760,115.94	-€ 104,076,864.22
18		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.35	€ 15,811,430.13	-€ 88,265,434.09
19		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.33	€ 14,916,443.52	-€ 73,348,990.57
20		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.31	€ 14,072,116.53	-€ 59,276,874.05
21		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.29	€ 13,275,581.63	-€ 46,001,292.42
22		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.28	€ 12,524,133.61	-€ 33,477,158.80
23		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.26	€ 11,815,220.39	-€ 21,661,938.41
24		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.25	€ 11,146,434.33	-€ 10,515,504.08
25		€ 95,115,944.90	€ 49,984,760.82	€ 45,131,184.08	0.23	€ 10,515,504.08	€ 0.00
*(jet fuel + diesel + yeast biomass)					NPV	€ 0.00	MJSP = 1.83 €/l

Table S9. Discounted cash flow analysis for the calculation of MOSP (microbial oil scenario)

Year	Total Capital Investment (TCI)	Income*	Operational Expenses	Cash flow	Discount factor $1/(1+i)^{\text{year}}$	Net Present Values	Discounted payback
-1	€ 210,636,800.00			-€ 210,636,800.00	1.00	-€ 210,636,800.00	
0	€ 315,955,200.00			-€ 315,955,200.00	1.00	-€ 315,955,200.00	
1		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.94	€ 38,861,852.83	-€ 487,730,147.17
2		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.89	€ 36,662,125.31	-€ 451,068,021.86
3		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.84	€ 34,586,910.67	-€ 416,481,111.20
4		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.79	€ 32,629,161.01	-€ 383,851,950.19
5		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.75	€ 30,782,227.37	-€ 353,069,722.82
6		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.70	€ 29,039,837.14	-€ 324,029,885.68
7		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.67	€ 27,396,072.77	-€ 296,633,812.91
8		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.63	€ 25,845,351.67	-€ 270,788,461.24
9		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.59	€ 24,382,407.24	-€ 246,406,054.00
10		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.56	€ 23,002,270.98	-€ 223,403,783.03
11		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.53	€ 21,700,255.64	-€ 201,703,527.39
12		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.50	€ 20,471,939.28	-€ 181,231,588.10
13		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.47	€ 19,313,150.27	-€ 161,918,437.84
14		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.44	€ 18,219,953.08	-€ 143,698,484.75
15		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.42	€ 17,188,634.98	-€ 126,509,849.77
16		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.39	€ 16,215,693.38	-€ 110,294,156.39
17		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.37	€ 15,297,823.94	-€ 94,996,332.45
18		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.35	€ 14,431,909.38	-€ 80,564,423.07
19		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.33	€ 13,615,008.85	-€ 66,949,414.22
20		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.31	€ 12,844,347.97	-€ 54,105,066.24
21		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.29	€ 12,117,309.41	-€ 41,987,756.84
22		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.28	€ 11,431,423.97	-€ 30,556,332.87
23		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.26	€ 10,784,362.23	-€ 19,771,970.63
24		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.25	€ 10,173,926.64	-€ 9,598,044.00
25		€ 89,942,804.81	€ 48,749,240.82	€ 41,193,564.00	0.23	€ 9,598,044.00	€ 0.00
*(microbial oil + yeast biomass)					<b>NPV</b>	<b>€ 0.00</b>	<b>MOSP = 1.32 €/l</b>