ECONOMIC ANALYSIS ON BIO-BUTANOL PRODUCTION PLANT

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Executive Summary

The objective of this study is to critically analyse the costs associated with developing and operating a chemical plant for producing 100 000 t y^{-1} of bio-butanol by use of ABE fermentation. Operating and capital costs relevant to the plant estimated at the FEED stage were used to assess the viability of the design and decide whether to proceed to the next detailed design phase.

Based on this analysis, the conversion of wheat to butanol via ABE fermentation does not appear to be a viable process under current market pricing conditions. The proposed design produces butanol at a yield of 20 % by use of the bacterium *Clostridium acetobutylicum*.

The economic analysis presented in table 1 shows 2 scenarios. Scenario 1 represents the associated costs of the design prior to cost reduction recommendations whereas scenario 2 takes them into account. The analysis clearly demonstrates that, in both scenarios, the total annual revenue is significantly less than the total annual operating costs.

Table 1: Economic summary for scenarios 1 and 2

Economics Summary	Scenario 1	Scenario 2
Plant Operating lifetime (years)	15	15
Total Capital Investment (£ million)	268	216
Total Revenue (£ million/year)	125	125
Total Operating Costs (£ million/year)	387	347
Net Loss (£ million/year)	-266	-226
Cash Flow (£ million/year)	-301	-251
DCFRR (%)	N/A	N/A
Cash Flow Payback Period (years)	N/A	N/A
Return on Investment (%)	N/A	N/A
Net Present Value of Plant (£ million) - i = 10%	-3 532	-3 048

2 Plant-wide cost summary

For an expected plant service life of 15 years, the total capital investment for scenario 1 is £ 268 million. This includes fixed capital of £ 215 million and working capital of £ 53 million. The proposed plant design has the capacity to produce 100 000 t y^{-1} of butanol, 10 692 t y^{-1} of ethanol and 47 136 t y^{-1} of acetone. These combined quantities amount to an annual revenue of

£ 125 million. Variable costs including raw material and utility costs amount to £ 305 million per year. Fixed costs for the plant include annual operating expenses, overheads, and depreciation. Depreciation was calculated using straight line depreciation over a period of 10 years with no salvage nor scrap value.

Annual indirect costs amount to £ 31 million and include general overheads and sales expenses.

The main components of the total capital costs where estimated using Lang factors as detailed in figure 5 in appendix 6.4. The method employed in estimating all other relevant components of the total operating costs can be found in figure 6 in appendix 6.4. Equipment, and utility costs for each Area of the plant can be found in tables 4 & 5 of appendix 6.1.

Tables 2 and 3 below list the overall capital and operating costs associated with the bio-butanol production plant.

Table 2: Plant-wide cost summary of CAPEX

CAPEX	£ millions	% to total
Fixed capital		
Equipment cost	72	34%
Equipment erection and structural work	33	15%
Piping insulation and painting	33	15%
Instrumentation and control equipment	11	5%
Electrical power and lighting	7	3%
Process buildings and structures	7	3%
Land	3	1%
Design and engineering costs	41	19%
Contractor's fees	8	4%
Total fixed capital	**215**	**100%**
Working capital		
Start-up	3	6%
Initial catalyst charges	1	3%
Raw materials and intermediates in the process	22	40%
Finished product inventories	11	20%
Contingency allowance	17	31%
Funds to cover outstanding accounts from customers	0	0%
Total working capital	**53**	**100%**
Total capital investment	**268**	

Table 3: Plant-wide cost summary of OPEX

OPEX	£ millions	% to total
Variable costs		
Raw materials	164	54%
Miscellaneous materials	2	0%
Utilities	139	46%
Total variable costs	**305**	**100%**
Fixed costs		
Maintenance	15	29%
Operating labour	15	30%

Laboratory costs	3	6%
Supervision	2	4%
Plant overheads	8	15%
Capital charges - buildings	1	1%
Capital charges - equipment	7	14%
Tax – gaseous emissions	0	0%
Tax – corporation tax	0	0%
Total fixed costs	**51**	**100%**
Total variable & fixed costs	**356**	
Indirect costs		
Sales expense	15	49%
Insurance	4	14%
Royalties and licence fees	2	8%
General overheads	9	29%
R&D	0	0%
Total indirect costs	**31**	**100%**
Total operating costs	**387**	

3 Profitability analysis on bio-butanol production plant

3.1 Information relevant to the analysis

Revenue and variable costs are the key factors that determine the plant's economic performance. The largest capital and operating costs associated with the production plant were identified in scenario 1. In terms of capital costs, these include the process equipment in Areas 3 & 4 which account for 27 % and 60 % of total process equipment cost, respectively. The major components of variable costs include the annual electricity cost which accounts for 58 % of the total utility costs, and 21 % of total operating costs and the annual cost of wheat which accounts for 96 % of the raw material requirements of the plant and 41 % of total operating costs. These details can be found in tables 8 & 9 of appendix 6.3.

Revenue mainly comes from the sale of butanol which accounts for 81.6 % of total revenue and by-products produced by the plant, ethanol, acetone, and hydrogen which account for the remaining 18.4 %. Annual revenue from sales based on market prices (University of Cambridge Design Project 2020, In: Project brief, p.4-5) totals £ 125 million whereas annual purchases of wheat total £ 158 million. Clearly this indicates that the yield of butanol achieved by the process of 20 % is sub-optimal.

The price and cost profiles used to estimate the market over the lifetime of the plant are consistent and represent the most likely market trends. The variable and fixed costs associated with the plant were inflated over its operating lifetime by assuming annual inflation rates of 4 % and 6 %, respectively. The selling prices of the plant's products were also inflated over this time-period by assuming an annual inflation rate of 5 % (www.accaglobal.com/uk/specific inflation, accessed 01/06/2020).

3.2 DCF, NPV and Breakeven analyses

Tables 6 and 7 which can be found in appendix 6.2, list the discounted cash flows for scenarios 1 & 2, respectively. In both circumstances, the working capital was assumed to be employed at the end of year 0 and as a result, was included in the year 1 net cash flow.

The detailed cash flows for each of the 15 years of plant operation for both scenarios 1 & 2 can be found in figures 7 & 8 of appendix 6.5, respectively.

Under both scenarios 1 & 2, the bio-butanol plant is not profitable. On the contrary, it is generating billions of GBP in losses. For an annual discount rate of 10 %, the $NPV_{t=0}$ of scenario 1 is £ -3.532 billion whereas that of scenario 2 is £ -3.048 billion.

In performing the calculations, capital allowances were ignored since, huge losses are generated each year. In addition, even though, subsidies of up to £ 500 million are available in the area (Department for Business, Energy & Industrial Strategy, In: Industrial clusters in England, 2017 p. 60) where the plant will be located, these were also ignored for the purposes of the preliminary design phase. They should both however be considered in the case that it proceeds to the next design stage.

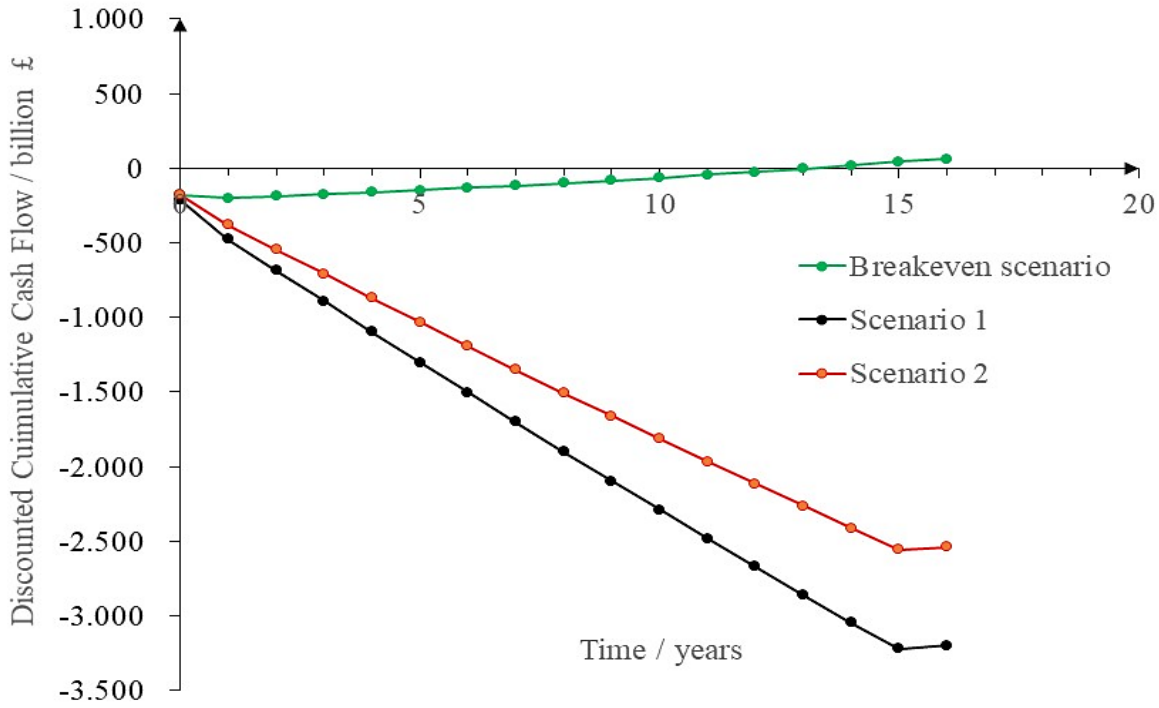

Figure 1: Discounted cumulative cash flow against time for scenarios 1 & 2. A breakeven scenario is also included

In figure 1, neither scenarios 1 nor 2 demonstrate a breakeven point. The cumulative cash flow in each case declines consistently up to the point where the plant reaches the end of its operating lifetime. Figure 1 reinforces the notion that the plant is not profitable.

The breakeven scenario as depicted in figure 1, has been estimated by computing a set of parametric values of product prices that result in the $NPV_{t=0}$ of revenues equalling the $NPV_{t=0}$

of costs. In this scenario, the plant demonstrates a breakeven point after 14 years of operation. A detailed cash flow for the breakeven scenario can be found in figure 9 in appendix 6.6.

All product prices have been increased by a factor of 2.5. Moreover, the annual electricity requirement was reduced by 50 %. Annual requirements of towns water and low-pressure steam were also reduced by 15 and 10 %, respectively. These reductions were made relative to the relevant utility and raw material requirements of scenario 1. The utility and raw material requirement alterations are feasible whereas the assumed change in product selling prices is less likely to occur at any point during the operating lifetime of the plant.

4 Sensitivity analysis on the economic performance of the plant

The sensitivity analysis was performed to comprehend how sensitive the plant's profitability is to changes in the parameters that drive cost and revenue identified so far. This analysis focused on butanol yield and utility requirements as the main plant parameters as well as the selling prices of the products as the main market parameters.

The effect the yield of butanol produced by the process has on the economics of the plant was examined. Figures 2 and 3 depict the influence that changes in the plant's annual wheat requirement have on the total operating costs and $NPV_{t=0}$ associated with the plant. An overall decrease in wheat requirement of 25 % corresponding to an increase in butanol yield of approximately 20 %, reduced the total operating costs from £ 382 million to approximately £ 340 million. The effects of this reduction are clearer in figure 3, which demonstrates that the overall $NPV_{t=0}$ increased by approximately 18 %. Even though this is a significant increase in absolute terms, under current market pricing conditions it is still not sufficient to make the plant profitable, other things being equal.

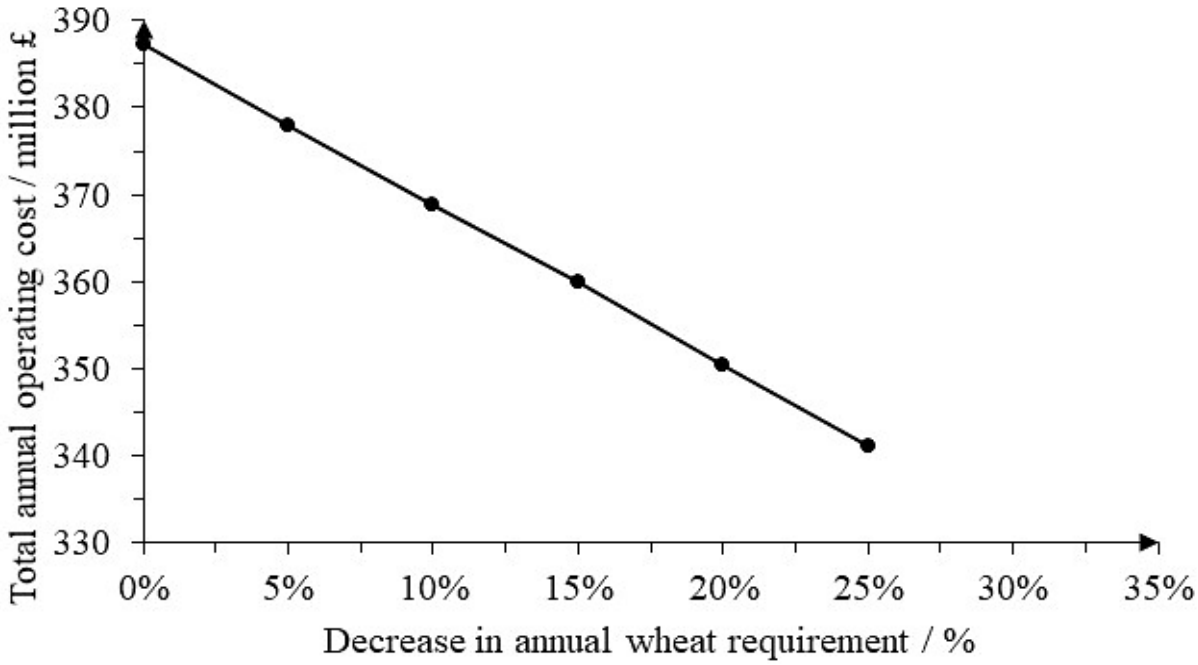

Figure 2: Total operating costs against % reduction in annual wheat requirement for scenario 1

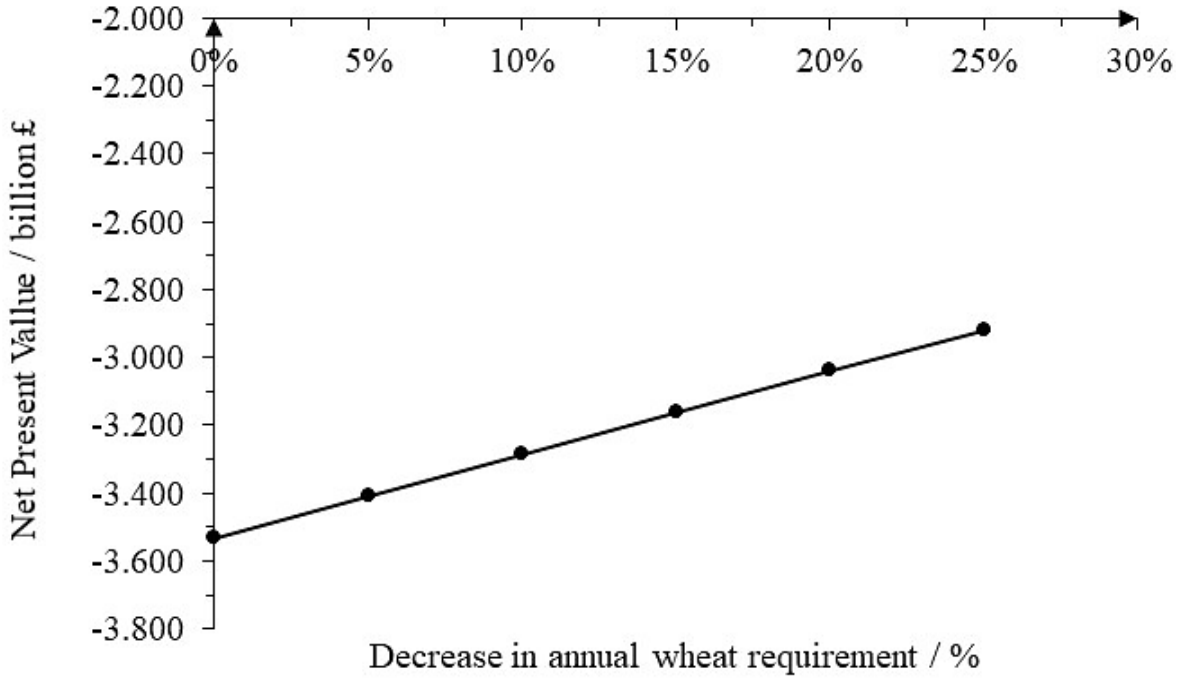

Figure 3: Net Present Value at a discount rate of 10 % against % reduction in annual wheat requirement for scenario 1

The effects the selling prices of ethanol and butanol have on the plant economic performance are demonstrated in figure 4. A decrease in selling prices of 20 %, reduced the $NPV_{t=0}$ by 7 %. A corresponding 20 % increase in product selling prices, increased the $NPV_{t=0}$ by approximately 10 %. According to figures 2, 3 & 4, the plant parameter that affects the plant's economic performance the most is the yield of butanol.

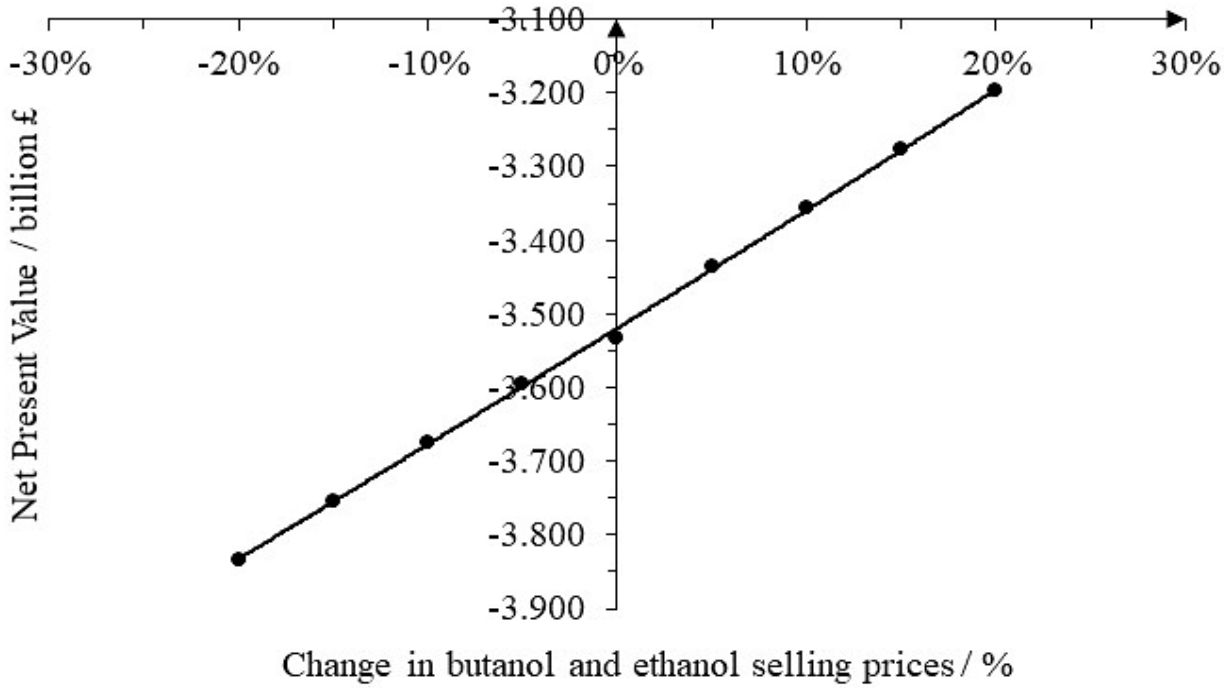

Figure 4: Net Present Value at a discount rate of 10 % against % change in butanol and ethanol selling prices for scenario 1

The major economic risks to the plant include, increases in the purchase price of wheat (https://ahdb.org.uk/news/usda-forecast-big-stocks-on-the-horizon-grain-market-daily) and loss in product purity. Loss in product purity will render the product wholly unsaleable and will thus generate even larger financial losses.

In addition, mainland competition in the biofuels industry by companies such as DuPont and BP which are also heavily investing in processes that produce bio-butanol will also pose a major economic threat to the plant. Its local market share will be at risk because of this competition. And while ethanol refining facilities far outnumber those for biobutanol, and as refinements continue with genetically modified microorganisms, the possibility of retrofitting ethanol plants to biobutanol is feasible.

5 Revisions and recommendations on cost reduction

In the design review meeting, a strategy on reducing the costs associated with the design was devised without compromising its inherent and engineered safety aspects.

Capital cost reductions discussed during the meeting include, the fermenters in Area 4 and the liquefaction as well as saccharification reactors in Area 3. These reactors were overdesigned and with excess storage volume. In addition, it was decided to eliminate a heat exchanger from Area 3 since, the required duty could be more than met by the overdesigned liquefaction reactors which include external heating jackets.

As far as operating costs are concerned, potential reductions in electricity requirements in Areas 2 and 3 were discussed. These reductions are possible since, the Area 3 engineer overestimated the electricity requirement by assuming a motor efficiency of 0.1 for the agitation units of the reactors.

Cost reduction recommendations stemming from the design review meeting include, a 24 % decrease in overall electricity consumption and a 15 % decrease in low pressure steam consumption, as far as total operating costs are concerned. In addition, a 17 % decrease in total process equipment cost is recommended prior to engaging in process revision 2. The recommendations were accounted for in scenario 2.

6 Appendix

6.1 Total process equipment and annual utility costs estimated for scenario 1

Table 4: Associated process equipment costs for scenario 1

AREA	PROCESS EQUIPMENT	No. of units	Total cost £
Area 1	Storage silo	2	518 000
	Wheat tempering unit	20	78 400
	Water pump	1	3 000
	Air blower	50	25 000
	Screw conveyor	2	24 350

	Bucket elevator	8	296 000
	Magnetic separator	4	16 000
	Aspiration channel	5	10 000
	Combi cleaner	5	150 000
	Scourer	5	100 000
	Breaker roller	145	2 175 000
	Reduction roller	145	1 450 000
	Cyclone separator	50	88 250
	Rotary sifter	290	3 100
		SUB TOTAL	**4.937.100**
Area 2	Positive displacement pump	4	129.015
	Mixing vessel	1	114.800
	Mixing vessel	1	149.240
		SUB TOTAL	**457.595**
Area 3	Centrifugal pump	4	57 007
	Centrifugal pump	4	64 654
	Heat exchanger	2	143 645
	Liquefaction reactors	4	4 970 000
	Saccharification reactors	16	14 400 000
		SUB TOTAL	**19 635 307**
Area 4	Heat exchanger	20	2 600 000
	Heat exchanger	10	550 000
	Heat exchanger	1	630 990
	Centrifugal pump	21	121 730
	Fermenter reactors	50	36 610 410
	Vessel	6	1 584 370
	Separator decanter	1	164 200
	Centrifuge	5	1 166 500
		SUB TOTAL =	**43 428 200**
Area 5	Centrifugal pump	2	54 000
	Stirred tank mixer vessel	1	38 000
	Continuous gravity decanter	1	226 000
	Distillation column	2	1 718 000
	Reboiler absorber column	1	628 000
	Kettle reboiler	3	524 000
	Condenser	2	260 000
		SUB TOTAL =	**3 448 000**
Area 6	Heat exchanger	2	14 850
	Sieve plate column	2	52 750
	Condenser	2	21 100
	Reboiler	2	79 300
	Centrifugal pump	4	4 640
	Reflux drum	2	12 800
	Acetone storage unit	1	70 000
	Ethanol storage unit	1	54 000
	Slop cut storage unit	1	12 400

		SUB TOTAL =	**321 840**
		TOTAL =	**72 228 042**

Table 5: Associated utility costs per annum for scenario 1

AREA	**UTILITY**	**ANNUAL COST £**
Area 1	Towns water, 20 ºC	91.679
	Electricity	13.581.228
	SUB TOTAL =	**13 672 907**
Area 2	Towns water, 20 ºC	2 550 000
	LPS, 131 ºC	1.830.000
	Electricity	29 100 000
	SUB TOTAL =	**33 480 000**
Area 3	Towns water, 20 ºC	10 362 816
	Cooling water, 18 ºC	886.000
	LPS, 131 ºC	7 970 000
	Electricity	28 458 900
	SUB TOTAL =	**47 677 716**
Area 4	LPS, 131 ºC	1 728 000
	Nitrogen	10 408 000
	Aqueous effluent disposal	17 924 961
	Electricity	9 450 127
	SUB TOTAL =	**39 511 088**
Area 5	Cooling water, 18 ºC	30 240
	Electricity	11 760
	IPS, 201 ºC	1 740 720
	LPS, 131 ºC	1 673 840
	Aqueous effluent disposal	679 488
	SUB TOTAL =	**4 136 048**
Area 6	Cooling water, 18 ºC	181 428
	LPS, 131 ºC	322 072
	Electricity	3 412
	Nitrogen	2 793
	Towns water, 20 ºC	260
	Compressed air	5
	SUB TOTAL =	**509 970**
	TOTAL =	**138 987 729**

6.2 DCF and NPV analyses for scenarios 1 & 2 at 2 different discount rates

Table 6: Cash flows, discounted cash flows and Net Present Value for scenario 1 where, f_d^n represents the discount factor and i represents the discount rate

Scenario 1		***i* = 5%**		***i* = 10%**	
Year n	**Cash flow / million £**	**f^n_d**	**DCF / million £**	**f^n_d**	**DCF / million £**
0	-215	1.000	-215	1.000	-215

1	-310	0.952	-295	0.909	-282
2	-268	0.907	-243	0.866	-232
3	-279	0.864	-241	0.825	-230
4	-290	0.823	-239	0.785	-228
5	-302	0.784	-237	0.748	-226
6	-314	0.746	-235	0.712	-224
7	-327	0.711	-233	0.678	-222
8	-341	0,677	-231	0.646	-220
9	-355	0.645	-229	0.615	-218
10	-369	0.614	-227	0.586	-216
11	-384	0.585	-225	0.558	-214
12	-400	0.557	-223	0,532	-213
13	-416	0.530	-221	0.506	-211
14	-433	0.505	-219	0.482	-209
15	-429	0.481	-206	0.459	-197
16	56	0.458	26	0.437	24

Total CF	-5 376	**$NPV_{t=0}$**	-3 690	**$NPV_{t=0}$**	-3 532

Table 7: Cash flows, discounted cash flows and Net Present Value for scenario 2 where, f_d^n represents the discount factor and i represents the discount rate

Scenario 2		***i* = 5%**		***i* = 10%**	
Year n	**Cash flow / million £**	**f^n_d**	**DCF / million £**	**f^n_d**	**DCF / million £**
0	-180	1.000	-180	1.000	-180
1	-259	0.952	-246	0.909	-235
2	-232	0.907	-211	0.866	-201
3	-242	0.864	-209	0.825	-199
4	-252	0.823	-207	0.785	-198
5	-262	0.784	-205	0.748	-196
6	-272	0.746	-203	0.712	-194
7	-283	0.711	-201	0.678	-192
8	-295	0.677	-199	0.646	-190
9	-307	0.645	-198	0.615	-189
10	-319	0.614	-196	0.586	-187
11	-332	0.585	-194	0.558	-185
12	-345	0.557	-192	0.532	-183
13	-359	0.530	-190	0.506	-182
14	-373	0.505	-188	0.482	-180
15	-379	0.481	-182	0.459	-174
16	38	0.458	18	0.437	17

Total CF	-4 650	**$NPV_{t=0}$**	-3 184	**$NPV_{t=0}$**	-3 048

6.3 Utilities and raw materials cost/area analysis for scenarios 1 & 2

Table 8: Utilities cost/area analysis for scenario 1

Ref. no	UTILITIES - COST/AREA ANALYSIS	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6	UTILITY TOTAL (£)	% OF PLANT TOTAL
1	Towns water, 20 ^{o}C	91 679	2 550 000	10 362 816	0	0	260	13 004 754	9%
2	Air	0	0	0	0	0	0	0	0%
3	Electricity	13 581 228	29 100 000	28 458 900	9 450 127	11 760	3 412	80 605 427	58%
4	LPS, 131 ^{o}C	0	1 830 000	7 970 000	1 728 000	1 673 840	322 072	13 523 912	10%
5	Cooling water, 18 ^{o}C	0	0	886 000	0	30 240	181 428	1 097 668	1%
6	IPS, 201 ^{o}C	0	0	0	0	1 740 720	0	1 740 720	1%
7	Compressed air	0	0	0	0	0	5	5	0%
8	Nitrogen	0	0	0	10 408.000	0	2 793	10 410 793	7%
9	Aqueous effluent disposal	0	0	0	17 924 961	679 488	0	18 604 449	13%
AREA AND PLANT TOTALS		**13 672 907**	**33 480 000**	**47 677 716**	**39 511 088**	**4 136 048**	**509 970**	**138 987 729**	**100%**

Table 9: Raw materials cost/area analysis for scenario 1

Ref. no	RAW MATERIAL- PLANT COSTS	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6	RAW MATERIAL TOTAL (£)	% OF PLANT TOTAL
1	Wheat	158 041 600	0	0	0	0	0	158 041 600	96%
2	α-amylase	0	0	60 960	0	0	0	60 960	0%
3	Glucoamylase	0	0	2 910 800	0	0	0	2 910 800	2%
4	Sulfuric acid	0	0	5 245	0	0	0	5 245	0%
5	Caustic soda	0	0		3 415 854	0	0	3 415 854	2%
AREA AND PLANT TOTALS		**158 041 600**	**0**	**2 977 005**	**3 415 854**	**0**	**0**	**164 434 458**	**100%**

Table 10: Utilities cost/area analysis for scenario 2

Ref. no	UTILITIES - COST/AREA ANALYSIS	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6	UTILITY TOTAL (£)	% OF PLANT TOTAL
1	Towns water, 20 ^{o}C	91 679	2 550 000	10 362 816	0	0	260	13 004 754	11%
2	Air	0	0	0	0	0	0	0	0%
3	Electricity	13 581 228	20 370 000	18 498 285	9.450.127	11 760	3 412	61 914 812	52%
4	LPS, 131 ^{o}C	0	1 830 000	5 770 000	1 728 000	1 673 840	322 072	11 323 912	10%
5	Cooling water, 18 ^{o}C	0	0	886 000	0	30 240	181 428	1 097 668	1%
6	IPS, 201 ^{o}C	0	0	0	0	1 740 720	0	1 740 720	1%
7	Compressed air	0	0	0	0	0	5	5	0%
8	Nitrogen	0	0	0	10 408 000	0	2 793	10 410 793	9%
9	Aqueous effluent disposal	0	0	0	17 924 961	679 488	0	18 604 449	16%
AREA AND PLANT TOTALS		**13 672 907**	**24 750 000**	**35 517 101**	**39 511 088**	**4 136 048**	**509 970**	**118 097 114**	**100%**

Table 11: Raw materials cost/area analysis for scenario 2

Ref. no	RAW MATERIAL COSTS	AREA 1	AREA 2	AREA 3	AREA 4	AREA 5	AREA 6	RAW MATERIAL TOTAL (£)	% OF TOTAL
1	Wheat	158 041 600	0	0	0	0	0	158 041 600	96%
2	α-amylase	0	0	60 960	0	0	0	60 960	0%
3	Glucoamylase	0	0	2 910 800	0	0	0	2 910 800	2%
4	Sulfuric acid	0	0	5 245	0	0	0	5 245	0%
5	Caustic soda	0	0	0	3 415 854	0	0	3 415 854	2%
AREA AND PLANT TOTALS		**158 041 600**	**0**	**2 977 005**	**3 415 854**	**0**	**0**	**164 434 458**	**100%**

6.4 Assumptions employed in completing the cost summaries for scenarios 1 & 2

FIXED CAPITAL INVESTMENT - Estimate	Lang factor (Fluids-Solids type processing plant) (Sinnott et al., 2005 p252)	S1	S2
		Relevant Cost	Relevant Cost
A. DIRECT COSTS		**£**	**£**
Equipment erection	0.45	32 502 619	27 103 813
Piping	0.45	32 502 619	27 103 813
Instrumentation	0.15	10 834 206	9 034 604
Electrical	0.10	7 222 804	6 023 070
Buildings	0.10	7 222 804	6 023 070
Land		2 876 500	2 876 500
Equipment		72 228 042	60 230 697
SUB TOTAL		**165 389 593**	**138 395 567**
B. INDIRECT COSTS			
Design and engineering	0.25	41 347 398	34 598 892
Contractor's fees	0.05	8 269 480	6 919 778
Contingency allowance (Incl. in working capital)	0.10	16 538 959	13 839 557
SUB TOTAL		**66 155 837**	**55 358 227**
TOTAL FIXED CAPITAL INVESTMENT (A+B)	1.40	**231 545 431**	**193 753 794**

Notes:
1. Estimates made from total equipment cost
2. S1: Scenario 1 - Original estimates
3. S2: Scenario 2 – Revised estimates following feasible cost reduction

Figure 5: Fixed capital investment estimate using Lang factors (Sinnott et al., 2005 p.261-267)

CAPEX	SCENARIO 1		SCENARIO 2	S2/S1
FIXED CAPITAL	**£**	**Factor used %**	**£**	**%**
Equipment cost	72 228 042		60 230 697	83.4%
Equipment erection and structural work	32 502 619		27 103 813	83.4%
Piping insulation and painting	32 502 619		27 103 813	83.4%
Instrumentation and control equipment	10 834 206		9.034 604	83.4%
Electrical power and lighting	7 222 804		6 023 070	83.4%
Process buildings and structures	7 222 804		6 023 070	83.4%
Land	2 876 500		2 876 500	100.0%
SUB-TOTAL	**165 389 593**		**138 395 567**	**83.7%**
Design & engineering costs	41 347 398		34 598 892	83.7%
Contractor's fees	8 269 480		6 919 778	83.7%
SUB-TOTAL	**49 616 878**		**41 518 670**	**83.7%**
TOTAL FIXED CAPITAL	**215 006 471**		**179 914 237**	**83.7%**
WORKING CAPITAL	**£**		**£**	**%**
Start-up	3 000 000		2 300 000	76.7%
Initial catalyst charges	1 485 880		1 485 880	100.0%
Raw materials and intermediates in the process	21 500 647	5%	8 995 712	41.8%
Finished product inventories	10 750 324	5%	8 995 712	83.7%
Contingency allowance	16 538 959		13 839 557	83.7%
Funds to cover outstanding accounts from customers	0	0%	0	
TOTAL WORKING CAPITAL	**53 275 810**	20%	**35 616 860**	**66.9%**
TOTAL CAPITAL INVESTMENT	**268 282 282**		**215 531 098**	**80.3%**
OPEX	**£**	**%**	**£**	**%**

VARIABLE COSTS				
Raw materials	164 434 458		164 434 458	100.0%
Miscellaneous materials [10% (2)]	1 505 045	10%	899 571	59.8%
Utilities	138 987 729		118 097 114	85.0%
TOTAL VARIABLE COSTS	**304 927 232**		**283 431 143**	**93.0%**
FIXED COSTS	**£**	**%**	**£**	**%**
Maintenance [5-10% (1)] used 7%	15 050 453	5%	8 995 712	59.8%
Operating labour [max 15% (3)] used 5%	15 171 109	5%	14 126 579	93.1%
Laboratory costs [20-30% (4)] used 20%	3 034 222	20%	2 825 316	93.1%
Supervision (estimated assuming personnel for 6 Areas)	2 063 100		2 063 100	100.0%
Plant overheads [50-100% (3)] used 50%	7 585 555	50%	7 063 289	93.1%
Capital charges - Buildings	722 280	10%	602 307	83.4%
Capital charges - Equipment	7 222 804	10%	6 023 070	83.4%
Tax - Gaseous emissions	232 480	10%	232 480	100.0%
Tax – Corporation tax (19%)	0		0	
TOTAL FIXED COSTS	**51 082 003**		**41 931 852**	**82.1%**
TOTAL VARIABLE & FIXED COSTS	**356 009 236**		**325 362 995**	**91.4%**
INDIRECT [20-30 % (5)]	**£**	**%**	**£**	**%**
Sales expense (5 % of indirect costs)	15 246 362	3%	8 502 934	55.8%
Insurance (2% of indirect costs)	4 300 129	2%	3 598 285	83.7%
Royalties and licence fees (2% of indirect costs)	2 499 316	1%	1 249 658	50.0%
General overheads (3% of indirect costs)	9 147 817	3%	8 502 934	93.0%
R&D *	0	0%	0	
TOTAL INDIRECT COSTS	**31 193 624**		**21 853 811**	**70.1%**
TOTAL OPEX	**387 202 860**		**347 216 807**	**89.7%**

Notes (Sinnott et al., 2005 p 261-267):

(1) – of total fixed capital
(2) – of maintenance costs
(3) – of total operating costs
(4) – of total operating labour
(5) – of total direct production costs
(6) – of total sales
* Assumed no R&D as royalties and fees are paid

Figure 6: Cost summary breakdown for scenarios 1 & 2 including key assumptions employed (Sinnott et al., 2005 p.261-267)

6.5 Cash flow statements for both scenarios 1 & 2 including discounted cash flow calculations at two different discount rates

	CASH-FLOW STATEMENT - PERIOD: 15 YEARS (SCENARIO 1)		YR0	YR1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10	YR11	YR12	YR13	YR14	YR15	YR16
	CURRENCY: £ Millions		**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**
1	*ANNUAL INCREASE - estimate FOR VARIABLE COSTS*			*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*
1	*ANNUAL INCREASE - estimate FOR FIXED COSTS*			*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*
1	*ANNUAL INCREASE - estimate FOR SALES*			*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*
CASH OUTFLOW																			
	FIXED CAPITAL																		
	EQUIPMENT COST		**72**																
	EQUIPMENT ERECTION, FOUNDATIONS AND STRUCTURAL WORK		**33**																
	PIPING INSULATION AND PAINTING		**33**																
	INSTRUMENTATION AND CONTROL EQUIPMENT		**11**																
	ELECTRICAL POWER AND LIGHTING		**7**																
	PROCESS BUILDINGS AND STRUCTURES		**7**																
	LAND		**3**																
	DESIGN AND ENGINEERING COSTS		**41**																
	CONTRACTOR'S FEES		**8**																
	TOTAL CASH OUTFLOW FROM FIXED CAPITAL		**215**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
2	**WORKING CAPITAL**																		
	START-UP			**3**															
	INITIAL CATALYST CHARGES			**1**															
	RAW MATERIALS FOR INTERMEDIATES IN THE PROCESS			**22**															
	FINISHED PRODUCT INVENTORIES			**11**															
	CONTIGENCY ALLOWANCE			**17**															
	FUNDS TO COVER OUTSTANDING ACCOUNTS FROM CUSTOMERS		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	TOTAL CASH OUTFLOW FROM WORKING CAPITAL		**0**	**53**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

	OPEX																		
	VARIABLE COSTS																		
	RAW MATERIALS			**171**	**178**	**185**	**192**	**200**	**208**	**216**	**225**	**234**	**243**	**253**	**263**	**274**	**285**	**274**	**0**
	MISCELLANEOUS MATERIALS			**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**3**	**3**	**3**	**0**
	UTILITIES		**0**	**145**	**150**	**156**	**163**	**169**	**176**	**183**	**190**	**198**	**206**	**214**	**223**	**231**	**241**	**250**	**0**
	TOTAL CASH OUTFLOW VARIABLE COSTS		**0**	**317**	**330**	**343**	**357**	**371**	**386**	**401**	**417**	**434**	**451**	**469**	**488**	**508**	**528**	**527**	**0**
	FIXED COSTS																		
	MAINTENANCE			**16**	**17**	**18**	**19**	**20**	**21**	**23**	**24**	**25**	**27**	**29**	**30**	**32**	**34**	**36**	
	OPERATING LABOUR			**16**	**17**	**18**	**19**	**20**	**22**	**23**	**24**	**26**	**27**	**29**	**31**	**32**	**34**	**36**	
	LABORATORY COSTS			**3**	**3**	**4**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**6**	**6**	**6**	**7**	**7**	
	SUPERVISION			**2**	**2**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**4**	**5**	**5**	
	PLANT OVERHEADS (65% OF LABOUR COSTS)			**8**	**9**	**9**	**10**	**10**	**11**	**11**	**12**	**13**	**14**	**14**	**15**	**16**	**17**	**18**	
	CAPITAL CHARGES - BUILDINGS			**0**															
	CAPITAL CHARGES - EQUIPMENT			**0**															
3	TAX - GASEOUS EMISSIONS			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
4	TAX - CORPORATION TAX			**0**															
	TOTAL FIXED COSTS		**0**	**45**	**48**	**51**	**54**	**58**	**61**	**65**	**69**	**73**	**77**	**82**	**87**	**92**	**97**	**103**	**0**
	TOTAL VARIABLE & FIXED COSTS		**0**	**363**	**378**	**394**	**411**	**429**	**447**	**466**	**486**	**507**	**528**	**551**	**575**	**599**	**625**	**630**	**0**
	INDIRECT																		
	SALES EXPENSE 0,25 OF DIRECT PRODUCTION COST			**16**	**16**	**17**	**18**	**19**	**19**	**20**	**21**	**22**	**23**	**23**	**24**	**25**	**26**	**27**	
	GENERAL OVERHEADS			**10**	**10**	**10**	**11**	**11**	**12**	**12**	**13**	**13**	**14**	**14**	**15**	**15**	**16**	**16**	
	R&D			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
	TOTAL INDIRECT COSTS		**0**	**25**	**26**	**27**	**29**	**30**	**31**	**32**	**33**	**35**	**36**	**38**	**39**	**41**	**42**	**44**	**0**
	TOTAL CASH OUTFLOW FROM OPEX		**0**	**388**	**405**	**422**	**440**	**458**	**478**	**498**	**519**	**541**	**565**	**589**	**614**	**640**	**668**	**674**	**0**
	TOTAL CASH OUTFLOW		**215**	**441**	**405**	**422**	**440**	**458**	**478**	**498**	**519**	**541**	**565**	**589**	**614**	**640**	**668**	**674**	**0**
CASH INFLOW																			
	BUTANOL			**107**	**112**	**118**	**124**	**130**	**137**	**144**	**151**	**158**	**166**	**174**	**183**	**192**	**202**	**212**	
	ETHANOL			**8**	**9**	**9**	**10**	**10**	**11**	**11**	**12**	**12**	**13**	**14**	**14**	**15**	**16**	**17**	
	ACETONE			**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	**15**	

	HYDROGEN			1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	
	TOTAL CASH INFLOW FROM SALES		0	131	137	143	150	156	163	171	179	187	195	204	214	224	234	245	0
	WORKING CAPITAL RELEASE		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	53
	LAND REALEASE		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
	TOTAL CASH INFLOW		0	131	137	143	150	156	163	171	179	187	195	204	214	224	234	245	56
	NET CASH INFLOW / -OUTFLOW		-215	-310	-268	-279	-290	-302	-314	-327	-341	-355	-369	-384	-400	-416	-433	-429	56
	NET CASH INFLOW / -OUTFLOW CUMULATIVE		-215	-525	-793	-1 071	-1 361	-1 663	-1 978	-2 305	-2 646	-3 001	-3 370	-3 754	-4 154	-4 570	-5 003	-5 432	-5 376
7	**DISCOUNT RATE (*i*)**	5%		105%	110%	116%	122%	128%	134%	141%	148%	155%	163%	171%	180%	189%	198%	208%	218%
	DISCOUNT FACTOR			*0,952*	*0,907*	*0,864*	*0,823*	*0,784*	*0,746*	*0,711*	*0,677*	*0,645*	*0,614*	*0,585*	*0,557*	*0,530*	*0,505*	*0,481*	*0,458*
	DCF		-215	-295	-243	-241	-239	-237	-235	-233	-231	-229	-227	-225	-223	-221	-219	-206	26
	CUMULATIVE DCF		-215	-510	-753	-994	-1 232	-1 469	-1 704	-1 936	-2 167	-2 395	-2 622	-2 847	-3 070	-3 290	-3 509	-3 715	-3 690
8	**DISCOUNT RATE (*i*)**	10%		110%	116%	121%	127%	134%	140%	147%	155%	163%	171%	179%	188%	198%	207%	218%	229%
	DISCOUNT FACTOR			*0,909*	*0,866*	*0,825*	*0,785*	*0,748*	*0,712*	*0,678*	*0,646*	*0,615*	*0,586*	*0,558*	*0,532*	*0,506*	*0,482*	*0,459*	*0,437*
	DCF		-215	-282	-232	-230	-228	-226	-224	-222	-220	-218	-216	-214	-213	-211	-209	-197	24
	CUMULATIVE DCF		-215	-497	-729	-958	-1 186	-1 412	-1 636	-1 858	-2 078	-2 296	-2 513	-2 727	-2 940	-3 150	-3 359	-3 556	-3 532

NOTES:

1 Estimated Inflation rate per year used as follows:

ANNUAL INCREASE - estimate FOR VARIABLE COSTS	4%
ANNUAL INCREASE - estimate FOR FIXED COSTS	6%
ANNUAL INCREASE - estimate FOR SALES	5%

2 Working capital included in year 1 and not in year 0 as it is assumed that it will be incurred at the end of year 0 (Dec 2020) and after completion of construction of plant

3 Emissions tax (Gaseous emissions) is paid 1 year in arrears

4 There is no corporation tax liability

5 VAT is ignored for simplicity

	It is assumed that equipment/buildings have no scrap value at the end of the	
6	**project**	
7	**DISCOUNT RATE (*i*) %**	**5**
	1. INTEREST RATE	3%
	2. INFLATION	2%
8	**DISCOUNT RATE (*i*) %**	**10**
	1. INTEREST RATE	8%
	2. INFLATION	2%

Figure 7: Cash flow statement assuming 15-year operating life for plant, including DCF analysis for scenario 1

CASH-FLOW STATEMENT - PERIOD: 15 YEARS (SCENARIO 2)	**YR0**	**YR1**	**YR2**	**YR3**	**YR4**	**YR5**	**YR6**	**YR7**	**YR8**	**YR9**	**YR10**	**YR11**	**YR12**	**YR13**	**YR14**	**YR15**	**YR16**
CURRENCY: £ Millions	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**
ANNUAL INCREASE - estimate FOR VARIABLE COSTS		*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*
ANNUAL INCREASE - estimate FOR FIXED COSTS		*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*
ANNUAL INCREASE - estimate FOR SALES		*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*
CASH OUTFLOW																	
FIXED CAPITAL																	
EQUIPMENT COST	**60**																
EQUIPMENT ERECTION, FOUNDATIONS AND STRUCTURAL WORK	**27**																
PIPING INSULATION AND PAINTING	**27**																
INSTRUMENTATION AND CONTROL EQUIPMENT	**9**																
ELECTRICAL POWER AND LIGHTING	**6**																
PROCESS BUILDINGS AND STRUCTURES	**6**																
LAND	**3**																
DESIGN AND ENGINEERING COSTS	**35**																
CONTRACTOR'S FEES	**7**																
TOTAL CASH OUTFLOW FROM FIXED CAPITAL	**180**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
WORKING CAPITAL																	
START-UP		**2**															
INITIAL CATALYST CHARGES		**1**															

	RAW MATERIALS FOR INTERMEDIATES IN THE PROCESS			**9**														
	FINISHED PRODUCT INVENTORIES			**9**														
	CONTIGENCY ALLOWANCE			**14**														
	FUNDS TO COVER OUTSTANDING ACCOUNTS FROM CUSTOMERS		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	TOTAL CASH OUTFLOW FROM WORKING CAPITAL		**0**	**36**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	OPEX																	
	VARIABLE COSTS																	
	RAW MATERIALS			**171**	**178**	**185**	**192**	**200**	**208**	**216**	**225**	**234**	**243**	**253**	**263**	**274**	**285**	**287**	**0**
	MISCELLANEOUS MATERIALS			**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**0**
	UTILITIES		**0**	**123**	**128**	**133**	**138**	**144**	**149**	**155**	**162**	**168**	**175**	**182**	**189**	**197**	**205**	**213**	**0**
	TOTAL CASH OUTFLOW VARIABLE COSTS		**0**	**295**	**307**	**319**	**332**	**345**	**359**	**373**	**388**	**403**	**420**	**436**	**454**	**472**	**491**	**501**	**0**
	FIXED COSTS																	
	MAINTENANCE			**10**	**10**	**11**	**11**	**12**	**13**	**14**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**22**	
	OPERATING LABOUR			**15**	**16**	**17**	**18**	**19**	**20**	**21**	**23**	**24**	**25**	**27**	**28**	**30**	**32**	**34**	
	LABORATORY COSTS			**3**	**3**	**3**	**4**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**6**	**6**	**6**	**7**	
	SUPERVISION			**2**	**2**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**4**	**5**	**5**	
	PLANT OVERHEADS (65% OF LABOUR COSTS)			**7**	**7**	**8**	**8**	**9**	**9**	**10**	**11**	**11**	**12**	**13**	**13**	**14**	**15**	**16**	
	CAPITAL CHARGES - BUILDINGS			**0**															
	CAPITAL CHARGES - EQUIPMENT			**0**															
	TAX - GASEOUS EMISSIONS			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	TAX - CORPORATION TAX			**0**															
	TOTAL FIXED COSTS		**0**	**37**	**39**	**42**	**44**	**47**	**49**	**52**	**55**	**59**	**62**	**66**	**70**	**74**	**79**	**83**	**0**
	TOTAL VARIABLE & FIXED COSTS		**0**	**332**	**346**	**360**	**376**	**391**	**408**	**425**	**443**	**462**	**482**	**502**	**524**	**546**	**569**	**584**	**0**
	INDIRECT																	
	SALES EXPENSE 0,25 OF DIRECT PRODUCTION COST			**9**	**9**	**10**	**10**	**10**	**11**	**11**	**12**	**12**	**13**	**13**	**14**	**14**	**15**	**15**	
	INSURANCE			**4**	**4**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**6**	**6**	**6**	**6**	**6**	
	ROYALTIES & LICENSE FEES			**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	
	GENERAL OVERHEADS			**9**	**9**	**10**	**10**	**10**	**11**	**11**	**12**	**12**	**13**	**13**	**14**	**14**	**15**	**15**	

	R&D			0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	TOTAL INDIRECT COSTS		0	23	24	25	26	27	28	29	30	31	32	34	35	36	38	39	0
	TOTAL CASH OUTFLOW FROM OPEX		0	354	369	385	401	418	436	454	473	493	514	536	559	583	607	624	0
	TOTAL CASH OUTFLOW		180	390	369	385	401	418	436	454	473	493	514	536	559	583	607	624	0
CASH INFLOW																			
	BUTANOL			107	112	118	124	130	137	144	151	158	166	174	183	192	202	212	
	ETHANOL			8	9	9	10	10	11	11	12	12	13	14	14	15	16	17	
	ACETONE			15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	
	HYDROGEN			1	1	1	1	1	1	1	1	1	1	1	1	2	2	2	
	TOTAL CASH INFLOW FROM SALES		0	131	137	143	150	156	163	171	179	187	195	204	214	224	234	245	0
	WORKING CAPITAL RELEASE		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	36
	LAND REALEASE		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
	TOTAL CASH INFLOW		0	131	137	143	150	156	163	171	179	187	195	204	214	224	234	245	38
	NET CASH INFLOW / -OUTFLOW		-180	-259	-232	-242	-252	-262	-272	-283	-295	-307	-319	-332	-345	-359	-373	-379	38
	NET CASH INFLOW / -OUTFLOW CUMULATIVE		-180	-439	-671	-913	-1164	-1426	-1698	-1982	-2276	-2583	-2902	-3233	-3578	-3937	-4310	-4689	-4650
	DISCOUNT RATE (*i*)	5%		105%	110%	116%	122%	128%	134%	141%	148%	155%	163%	171%	180%	189%	198%	208%	218%
	DISCOUNT FACTOR			*0,952*	*0,907*	*0,864*	*0,823*	*0,784*	*0,746*	*0,711*	*0,677*	*0,645*	*0,614*	*0,585*	*0,557*	*0,530*	*0,505*	*0,481*	*0,458*
	DCF		-180	-246	-211	-209	-207	-205	-203	-201	-199	-198	-196	-194	-192	-190	-188	-182	18
	CUMULATIVE DCF		-180	-426	-637	-846	-1053	-1258	-1461	-1663	-1862	-2060	-2255	-2449	-2641	-2832	-3020	-3202	-3184
	DISCOUNT RATE (*i*)	10%		110%	116%	121%	127%	134%	140%	147%	155%	163%	171%	179%	188%	198%	207%	218%	229%
	DISCOUNT FACTOR			*0,909*	*0,866*	*0,825*	*0,785*	*0,748*	*0,712*	*0,678*	*0,646*	*0,615*	*0,586*	*0,558*	*0,532*	*0,506*	*0,482*	*0,459*	*0,437*
	DCF		-180	-235	-201	-199	-198	-196	-194	-192	-190	-189	-187	-185	-183	-182	-180	-174	17
	CUMULATIVE DCF		-180	-415	-616	-816	-1013	-1209	-1403	-1595	-1786	-1974	-2161	-2346	-2529	-2711	-2891	-3065	-3048
	NOTES: **Same as for Scenario 1 Cash Flow Statement**																		

Figure 8: Cash flow statement assuming 15-year operating life for plant, including DCF analysis for scenario 2

6.6 Cash flow statement for breakeven scenario including discounted cash flow calculations at two different discount rates

CASH-FLOW STATEMENT - PERIOD: 15 YEARS (BREAKEVEN SCENARIO)		YR0	YR1	YR2	YR3	YR4	YR5	YR6	YR7	YR8	YR9	YR10	YR11	YR12	YR13	YR14	YR15	YR16
CURRENCY: £ Millions		**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**
ANNUALY INCREASE - estimate FOR VARIABLE COSTS			*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*	*104%*
ANNUALY INCREASE - estimate FOR FIXED COSTS			*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*	*106%*
ANNUALY INCREASE - estimate FOR SALES			*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*	*105%*
CASH OUTFLOW																		
FIXED CAPITAL																		
EQUIPMENT COST		**60**																
EQUIPMENT ERECTION, FOUNDATIONS AND STRUCTURAL WORK		**27**																
PIPING INSULATION AND PAINTING		**27**																
INSTRUMENTATION AND CONTROL EQUIPMENT		**9**																
ELECTRICAL POWER AND LIGHTING		**6**																
PROCESS BUILDINGS AND STRUCTURES		**6**																
LAND		**3**																
DESIGN AND ENGINEERING COSTS		**35**																
CONTRACTOR'S FEES		**7**																
TOTAL CASH OUTFLOW FROM FIXED CAPITAL		**180**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
WORKING CAPITAL																		
START-UP			**2**															
INITIAL CATALYST CHARGES			**1**															
RAW MATERIALS FOR INTERMEDIATES IN THE PROCESS			**9**															
FINISHED PRODUCT INVENTORIES			**9**															
CONTIGENCY ALLOWANCE			**14**															
FUNDS TO COVER OUTSTANDING ACCOUNTS FROM CUSTOMERS		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**

	TOTAL CASH OUTFLOW FROM WORKING CAPITAL		**0**	**36**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	OPEX																	
	VARIABLE COSTS																	
	RAW MATERIALS			**171**	**178**	**185**	**192**	**200**	**208**	**216**	**225**	**234**	**243**	**253**	**263**	**274**	**285**	**287**	**0**
	MISCELLANEOUS MATERIALS			**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**2**	**2**	**0**
	UTILITIES		**0**	**88**	**92**	**96**	**99**	**103**	**107**	**112**	**116**	**121**	**126**	**131**	**136**	**141**	**147**	**153**	**0**
	TOTAL CASH OUTFLOW VARIABLE COSTS		**0**	**260**	**271**	**282**	**293**	**304**	**317**	**329**	**342**	**356**	**370**	**385**	**401**	**417**	**433**	**441**	**0**
	FIXED COSTS																	
	MAINTENANCE			**10**	**10**	**11**	**11**	**12**	**13**	**14**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**22**	
	OPERATING LABOUR			**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**24**	**25**	**27**	**28**	**30**	
	LABORATORY COSTS			**3**	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**4**	**4**	**5**	**5**	**5**	**6**	**6**	
	SUPERVISION			**2**	**2**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**4**	**5**	**5**	
	PLANT OVERHEADS (65% OF LABOUR COSTS)			**6**	**7**	**7**	**7**	**8**	**8**	**9**	**9**	**10**	**11**	**11**	**12**	**13**	**13**	**14**	
	CAPITAL CHARGES - BUILDINGS			**0**															
	CAPITAL CHARGES - EQUIPMENT			**0**															
	TAX - GASEOUS EMISSIONS			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
	TAX - CORPORATION TAX			**0**															
	TOTAL FIXED COSTS		**0**	**34**	**36**	**38**	**41**	**43**	**45**	**48**	**51**	**54**	**57**	**61**	**64**	**68**	**72**	**77**	**0**
	TOTAL VARIABLE & FIXED COSTS		**0**	**294**	**307**	**320**	**333**	**347**	**362**	**378**	**394**	**410**	**428**	**446**	**465**	**485**	**506**	**518**	**0**
	INDIRECT																	
	SALES EXPENSE 0,25 OF DIRECT PRODUCTION COST			**8**	**8**	**8**	**9**	**9**	**9**	**10**	**10**	**11**	**11**	**12**	**12**	**13**	**13**	**14**	
	INSURANCE			**4**	**4**	**4**	**4**	**4**	**5**	**5**	**5**	**5**	**5**	**6**	**6**	**6**	**6**	**6**	
	ROYALTIES & LICENSE FEES			**1**	**1**	**1**	**1**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	
	GENERAL OVERHEADS			**8**	**8**	**8**	**9**	**9**	**9**	**10**	**10**	**11**	**11**	**12**	**12**	**13**	**13**	**14**	
	R&D			**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	
	TOTAL INDIRECT COSTS		**0**	**21**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**31**	**32**	**33**	**34**	**36**	**0**
	TOTAL CASH OUTFLOW FROM OPEX		**0**	**315**	**328**	**342**	**357**	**372**	**387**	**404**	**421**	**439**	**457**	**477**	**497**	**518**	**540**	**554**	**0**

TOTAL CASH OUTFLOW		**180**	**350**	**328**	**342**	**357**	**372**	**387**	**404**	**421**	**439**	**457**	**477**	**497**	**518**	**540**	**554**	**0**
CASH INFLOW																		
BUTANOL			**268**	**281**	**295**	**310**	**325**	**342**	**359**	**377**	**396**	**415**	**436**	**458**	**481**	**505**	**530**	
ETHANOL			**21**	**22**	**23**	**24**	**26**	**27**	**28**	**30**	**31**	**33**	**34**	**36**	**38**	**40**	**42**	
ACETONE			**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	**37**	
HYDROGEN			**2**	**2**	**2**	**2**	**3**	**3**	**3**	**3**	**3**	**3**	**3**	**4**	**4**	**4**	**4**	
TOTAL CASH INFLOW FROM SALES		**0**	**328**	**343**	**358**	**374**	**391**	**408**	**427**	**446**	**467**	**488**	**511**	**535**	**560**	**586**	**613**	**0**
WORKING CAPITAL RELEASE		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**36**
LAND REALEASE		**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**3**
TOTAL CASH INFLOW		**0**	**328**	**343**	**358**	**374**	**391**	**408**	**427**	**446**	**467**	**488**	**511**	**535**	**560**	**586**	**613**	**38**
NET CASH INFLOW / -OUTFLOW		**-180**	**-22**	**14**	**16**	**17**	**19**	**21**	**23**	**26**	**28**	**31**	**34**	**38**	**42**	**46**	**59**	**38**
NET CASH INFLOW / -OUTFLOW CUMULATIVE		**-180**	**-202**	**-188**	**-172**	**-155**	**-136**	**-114**	**-91**	**-65**	**-37**	**-6**	**28**	**66**	**108**	**153**	**213**	**251**
DISCOUNT RATE (*i*)	**5%**		**105%**	**110%**	**116%**	**122%**	**128%**	**134%**	**141%**	**148%**	**155%**	**163%**	**171%**	**180%**	**189%**	**198%**	**208%**	**218%**
DISCOUNT FACTOR			***0,952***	***0,907***	***0,864***	***0,823***	***0,784***	***0,746***	***0,711***	***0,677***	***0,645***	***0,614***	***0,585***	***0,557***	***0,530***	***0,505***	***0,481***	***0,458***
DCF		**-180**	**-21**	**13**	**14**	**14**	**15**	**16**	**17**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**29**	**18**
CUMULATIVE DCF		**-180**	**-201**	**-188**	**-175**	**-160**	**-145**	**-129**	**-113**	**-96**	**-77**	**-58**	**-38**	**-17**	**5**	**28**	**57**	**74**
DISCOUNT RATE (*i*)	**10%**		**110%**	**116%**	**121%**	**127%**	**134%**	**140%**	**147%**	**155%**	**163%**	**171%**	**179%**	**188%**	**198%**	**207%**	**218%**	**229%**
DISCOUNT FACTOR			***0,909***	***0,866***	***0,825***	***0,785***	***0,748***	***0,712***	***0,678***	***0,646***	***0,615***	***0,586***	***0,558***	***0,532***	***0,506***	***0,482***	***0,459***	***0,437***
DCF		**-180**	**-20**	**12**	**13**	**14**	**14**	**15**	**16**	**17**	**17**	**18**	**19**	**20**	**21**	**22**	**27**	**17**
CUMULATIVE DCF		**-180**	**-200**	**-188**	**-175**	**-161**	**-147**	**-132**	**-116**	**-99**	**-82**	**-64**	**-44**	**-24**	**-3**	**19**	**46**	**63**

Figure 9: Cash flow statement assuming 15-year operating life for plant, including DCF analysis for breakeven scenario

7 References

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