CO_2 Price 138.152

Process Assumptions	future steady-state
Design capacity	2,739,726
Average production rate	2,465,753
Capacity factor	90%
Oceanwater target pH	**4**
Membrane contactor efficiency	**90%**
Electrodialysis acidified stream target pH	0.4
[H+] in acid stream needed to achieve target pH above	0.401
[H+]/s added to OW stream to achieve target pH (*nonEq)	2.55E-03
[CO_2]/s at oceanwater target pH (*nonEq)	2.17E-03
[CO_2]/[DIC] at oceanwater target pH	0.99
x electrodialyzed oceanwater for acidified stream	0.01
Multiplier	4.00
	Steady-state
CO_2 partial pressure (Torr)	**10.00**
Liquid flow rate	60.00
Gas flow rate	60.00
Extraction efficiency	80%
Ratio of flow rates	1.00
Extraction efficiency (= cell below when varying ctf)	**80%**
Calculated extraction efficiency (for varying ctf)	89%
Catalytic turnover factor (*nonEq unless CTF=1)	**1.0**
Calculated ctf (for varying extraction efficiency)	0.9
Catalytic turnover number (Eq)	0.85
Calculated ctn (for varying extraction efficiency or ctf)	0.77
Current density	**500**
Voltage	**2.5**
Baseline capacity	30,976
Labor baseline capacity	21,120
Scaling factor exponent	0.60
Scale ratio	88.45
Labor scale ratio	129.72
Industrial electricity	0.02

CEPCI inflator (basis year to startup year)	1.00
Consumer price inflator (basis year to startup year)	1.00
Labor inflator (2018 to startup year)	1.12
Chemical price inflator (basis year to startup year)	1.00

System cost

Intake	
Screening	
Micro/ultrafiltration	
Nanofiltration	
Electrodialysis	
CO_2 stripping	
PV system	
Total	
Scale Factor	14.72

Financial

Length of Construction Period (years)		1
Startup year (= reference year = current year)		**2019**
Basis year		2019
Year of analysis		2020
% of Capital Spent in 1st Year of Construction		100%
% of Capital Spent in 2nd Year of Construction		0%
% of Capital Spent in 3rd Year of Construction		0%
% of Capital Spent in 4th Year of Construction		0%
Start-up Time (years)		1
Plant life (years)		**40**
Analysis period (years)		40
Depreciation Schedule Length (years)		20
Depreciation Type	**MACRS**	
% Debt Financing		60%
% Equity Financing		40%
Interest rate on debt, if applicable (%)		3.70%
Debt period (years)		Constant debt
% of Fixed Operating Costs During Start-up (%)		75%
% of Revenues During Start-up (%)		50%
% of Variable Operating Costs During Start-up (%)		75%
Decommissioning costs (% of depreciable capital investment)		10%
Salvage value (% of total capital investment)		10%
Inflation rate (%)		1.9%
State Taxes (%)		6.0%
Federal Taxes (%)		21.0%
Total Tax Rate (%)		25.74%
WORKING CAPITAL (% of yearly change in operating costs)		15%
After-tax real IRR		6%
After-tax nominal IRR		8.01%
Inflation factor (basis year to startup year)		1.00

Capital costs

Depreciable capital costs	
Direct capital cost	
Indirect capital cost	
Site preparation	2%
Engineering and design	10%
Project contingency	15%
Upfront permitting cost (legal and contractors fees)	7.5%
Total depreciable capital cost	
Non depreciable capital costs	
Cost of land (5 acre, $50,000/acre)	0
Total capital costs	

Fixed operating costs

Labor cost ($50/FTE/hour) ($/year)	10.50
G&A ($/year)	20%
Property taxes and insurance ($/year)	2%
Production maintenance and repairs ($/year)	3%
Total fixed operating costs ($/year)	

Variable operating costs

Energy utilities costs	
Intake energy	0.561
Screening energy	-
Micro/ultrafiltration energy	0.023
Nanofiltration energy	0.020
Electrodialysis energy	2.224
CO_2 stripping energy	0.371
Non energy utilities costs	
Total variable operating costs ($/year)	**3.199**

Replacements

Unplanned replacement capital cost (0.5% of total direct capital cos	0.5%
Replacement costs (15% of *remaining* depreciable capital cost/5 ye	15%
Specified replacement cost (electrodialyzer/5year)	100%
Specified replacement cost (60% pre-treatment/5year)	60%
Specified replacement cost (gas stripping/10year)	100%

Year	Plant cost index
1992	358.2
1993	359.2
1994	368.1
1995	381.1
1996	381.7
1997	386.5
1998	389.5
1999	390.6
2000	394.1
2001	394.3
2002	395.6
2003	402
2004	444.2
2005	468.2
2006	499.6
2007	525.4
2008	575.4
2009	521.9
2010	550.8
2011	585.7
2012	584.6
2013	567.3
2014	576.1
2015	556.8
2016	541.7
2017	567.5
2018	603.1
2019	607.5

$/ton CO_2

current or future?
equilibrium or steady-state (0D model)?

kg CO_2/day	**1,000,000**	t CO_2/year
kg CO_2/day	900,000	t CO_2/year

1/x = 156
Number of channels in electrodialyzer (3, but flow 2x in diluate)

Torr
1/min
1/min

89% 80%

mA/cm^2
V

kg CO_2/day	30,976	
kg CO_2/day	20 kmol/hr, from Eisaman, used only for labor scaling	
	7,709	t CO2/year in Eisaman analysis

$/kWh

Baseline installed cost in basis year dollars	Baseline installed cost in startup year dollars	Scaled installed cost in startup year dollars
$3,249,551	$3,249,551	$47,844,550
$4,220,778	$4,220,778	$62,144,335
$2,236,588	$2,236,588	$32,930,254
$467,876	$467,876	$6,888,745
$964,465	$964,465	$14,200,230
$8,778,621	$8,778,621	$129,251,443
		$0
$19,917,879	**$19,917,879**	**$293,259,556**

Ratio of total scaled installed capital capital cost to total baseline installed capital costs. Used fo

Values in startup year dollars (except land in basis year)	Combined plant scaling and inflation factor	Values in startup year dollars
$293,259,556	1	$293,259,556
		$0
$5,865,191	1	$5,865,191
$29,325,956	1	$29,325,956
$43,988,933	1	$43,988,933
$21,994,467	1	$21,994,467
		$394,434,102
$0	14.72	$0.00
		$394,434,102

Values in basis year dollars	Combined plant scaling and inflation factor	Values in startup year dollars
$415,000	3.78	$1,569,861
$83,000	3.78	$313,972
		$7,888,682
	1.00	$8,797,787
		$18,570,302

Values in startup year dollars	Combined plant scaling and inflation factor	Values in startup year dollars
$10,100,967	1	$10,100,967
$0	1	$0
$408,542	1	$408,542
$356,576	1	$356,576
$40,031,829	1	$40,031,829
$6,685,540	1	$6,685,540
$0	1	$0
$57,583,453		**$57,583,453**

Frequency	Cost reference	Values in startup year
1	$293,259,556	$1,466,298
5	$211,163,431	$31,674,515
5	$14,200,230	$14,200,230
5	$39,818,998	$23,891,399
10	$129,251,443	$129,251,443

Deflator price index	Labor cost index	Chemical price index
67.932	13.70	109.7583333
69.505	13.97	108.8416667
70.960	14.33	110.425
72.387	14.86	117.1833333
73.668	15.37	119.3333333
74.824	15.78	116.825
75.641	16.23	117.8666667
76.873	16.40	108.9166667
78.723	17.09	108.9083333
80.268	17.57	118.4833333
81.654	17.97	115.8916667
83.201	18.50	121.1416667
85.712	19.17	125.475
88.489	19.67	141.4333333
90.815	19.60	173.8
93.145	19.55	185.9916667
94.986	19.50	261.3916667
95.259	20.30	271.8583333
96.763	21.07	253.175
98.703	21.45	300.9083333
100.737	21.45	298.1916667
102.517	21.40	281.0916667
104.123	21.49	270.3083333
104.937	21.76	270.0083333
106.469	22.72	252.125
108.598	24.28	256.7916667
111.14	25.46	276.9
112.95	25.46	279.5916667

r exponential scaling.

CO_2 Price 138.152 $/ton CO_2

Cash Flow

	PV of cash flows	Discounted values	Categorization
Revenue	$1,615,732,386	$1,745,217,180	revenue
Initial depreciable cap	-$215,016,344	-$232,247,754	X (included in principal + interest)
Initial equity depriciab	-$143,344,230	-$154,831,836	capex
Replacement costs	-$289,532,893	-$312,736,059	replacements
Cash from working ca	-$11,329,364	-$12,237,299	taxes & working capital
Non-depreciable capi	$0	$0	capex
Salvage value	$3,484,060	$3,763,272	fixed opex (cancels)
Decommisioning cost	-$3,484,060	-$3,763,272	fixed opex (cancels)
Fixed operating costs	-$249,880,824	-$269,906,273	fixed opex
Variable operating co	-$774,839,333	-$836,934,957	variable opex
Debt interest	-$102,681,018	-$110,909,875	capex
Pre-depreciation inco	$488,331,211	$527,466,074	X (sum)
Depreciation charge	-$355,159,083	-$383,621,532	X (sum)
Taxable income	$133,172,128	$143,844,542	X (sum)
Total tax	-$34,278,506	-$37,025,585	taxes & working capital
Principal payment	-$9,846,219	-$10,635,295	capex
After-tax, post-deprec	$0	$0	X (sum)
Total	0	$0	

Breakdown by Process Step

	Capital cost $/ton	Electricity cost $/tor	Replacements $/ton	Capital cost %
Intake	$3.57	$11.62	$0.00	16%
Screening	$4.64	$0.00	$0.00	21%
Microfiltration	$2.46	$0.47	$4.50	11%
Nanofiltration	$0.51	$0.41	$0.00	2%
Electrodialysis	$1.06	$46.06	$2.68	5%
CO_2 stripping	$9.64	$7.69	$9.89	44%
Other	$0.00	$0.00	$7.68	0%
Total	$21.88	$66.25	$24.76	100%
		Total	$138.15	

Parameter Sweep

Param to vary current_density
Also calculate extraction_efficiency

CTF = 2

Values to sweep	Price	Secondary result
25.0	$238	80%
50.0	$186	80%
75.0	$168	80%
100.0	$159	80%
200.0	$146	80%
300.0	$142	80%
400.0	$140	80%
500.0	$138	80%
600.0	$137	80%
700.0	$137	80%
800.0	$136	80%
900.0	$136	80%
1,000.0	$136	80%

Equlibirum Line
x
89%
0.887745553

$100/ton Line
x
0%
100%

Detailed Breakdown

Param to vary voltage

Values to sweep	1	2	3	4
Label	1	2	3	4
Intake/screening Cap	$48.64	$48.64	$48.64	$48.64
Electrodialysis CapEx	$22.15	$22.15	$22.15	$22.15
CO_2 stripping CapEx	$79.17	$79.17	$79.17	$79.17
Intake electricity	$20.95	$20.95	$20.95	$20.95
Electrodialysis electric	$33.20	$66.41	$99.61	$132.82
Fixed OpEx & Other	$282.29	$282.78	$283.28	$283.77
Total	$486.40	$520.10	$553.80	$587.49

*Includes replacements

2D Parameter Sweep

Param to vary 1 elec_cost
Param to vary 2 cap_factor
Secondary result ctn_calc

primary result (price)

0.00	**0.00**	**0.05**	**0.10**	**0.15**
0.000	51680.20	1033.60	516.80	344.50
0.005	51695.10	1048.50	531.70	359.40
0.010	51710.00	1063.40	546.60	374.30
0.015	51724.80	1078.20	561.40	389.20
0.020	51739.70	1093.10	576.30	404.00
0.025	51754.60	1108.00	591.20	418.90
0.030	51769.50	1122.90	606.10	433.80
0.035	51784.30	1137.70	620.90	448.70
0.040	51799.20	1152.60	635.80	463.50
0.045	51814.10	1167.50	650.70	478.40
0.050	51829.00	1182.40	665.60	493.30
0.055	51843.80	1197.20	680.40	508.20
0.060	51858.70	1212.10	695.30	523.00

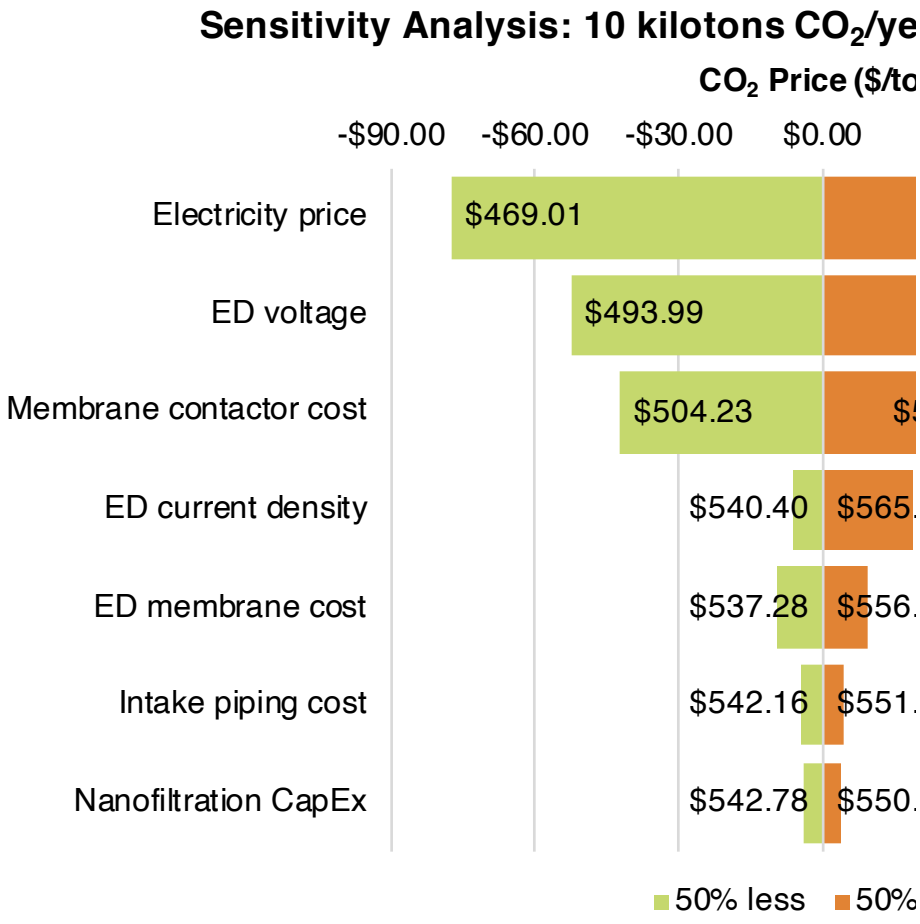
secondary result

0.00	**0.00**	**0.05**	**0.10**	**0.15**
0.00	0.85	0.85	0.85	0.85
0.01	0.85	0.85	0.85	0.85
0.01	0.85	0.85	0.85	0.85
0.02	0.85	0.85	0.85	0.85
0.02	0.85	0.85	0.85	0.85
0.03	0.85	0.85	0.85	0.85
0.03	0.85	0.85	0.85	0.85
0.04	0.85	0.85	0.85	0.85
0.04	0.85	0.85	0.85	0.85
0.05	0.85	0.85	0.85	0.85
0.05	0.85	0.85	0.85	0.85

0.06	0.85	0.85	0.85	0.85
0.06	0.85	0.85	0.85	0.85
0.00	0.00	0.20	0.40	0.60
0.00	0.00	0.25	0.49	0.74
0.00	0.01	0.30	0.60	0.90

Sensitivity Analysis: 10 kiloton scale, $0.05/kWh

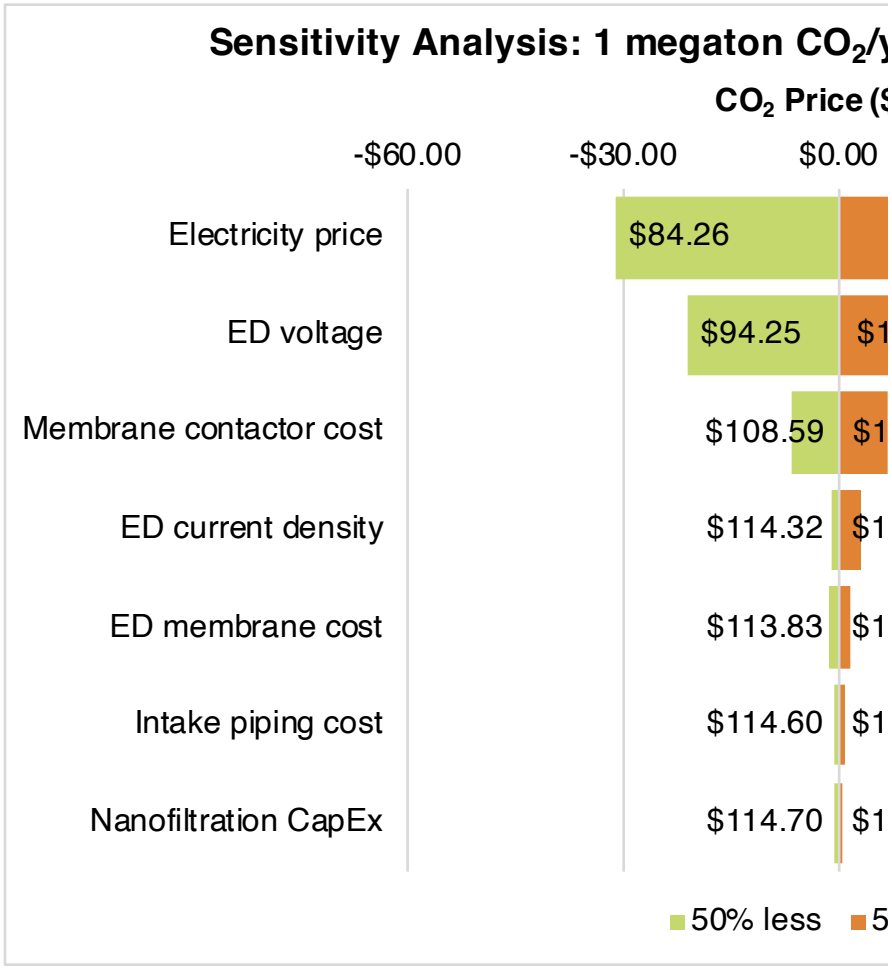
	50% less	**50% more**	0.5x	1x	
Electricity price	-$77.63	$77.64	$469.01	$546.64
ED voltage	-$52.65	$52.66	$493.99	$546.64
Membrane contactor	-$42.41	$42.42	$504.23	$546.64
ED current density	-$6.24	$18.73	$540.40	$546.64
ED membrane cost	-$9.36	$9.37	$537.28	$546.64
Intake piping cost	-$4.48	$4.49	$542.16	$546.64
Nanofiltration CapEx	-$3.86	$3.87	$542.78	$546.64



Sensitivity Analysis: megaton scale, $0.02/kWh

	50% less	**50% more**	0.5x	1x	
Electricity price	-$31.05	$31.06	$84.26	$115.31
ED voltage	-$21.06	$21.06	$94.25	$115.31

Membrane contactor	-$6.72	$6.73	$108.59	$115.31
ED current density	-$0.99	$2.97	$114.32	$115.31
ED membrane cost	-$1.48	$1.49	$113.83	$115.31
Intake piping cost	-$0.71	$0.71	$114.60	$115.31
Nanofiltration CapEx	-$0.61	$0.62	$114.70	$115.31



Category	Cost breakdown	Contribution to CO_2 pri	%
CapEx	$276,377,006	21.88	16%
Replacements	$312,736,059	24.76	18%
Fixed OpEx	$269,906,273	21.37	15%
Variable OpEx	$836,934,957	66.25	48%
Taxes & Working Cap	$49,262,884	3.90	3%
Revenue	$1,745,217,180		
Total CO2 Sales (kg)	13,117,138,882		
Total	$0	$138.15	

Electricity cost %	Replacements %
18%	0%
0%	0%
1%	18%
1%	0%
70%	11%
12%	40%
0%	31%
100%	100%

Direct Capital Co

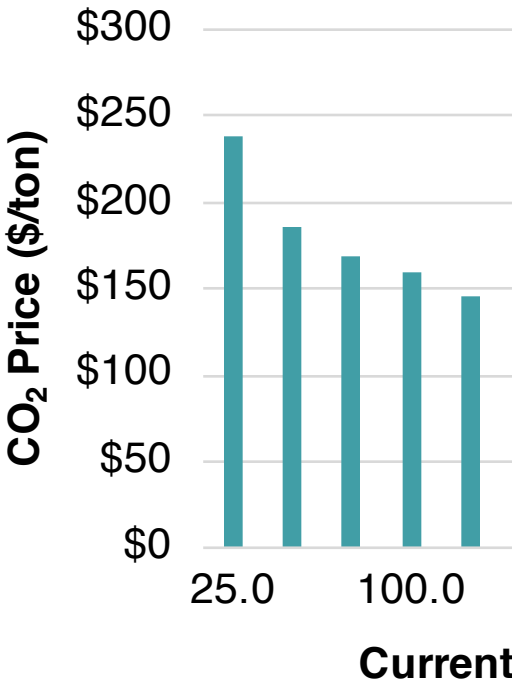
Current D

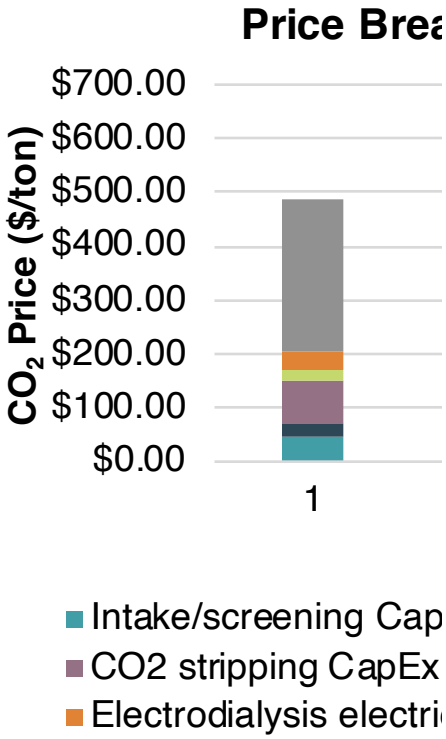
y

0
7

y

$100
$100


$300
$250
$200
$150
$100
$50
$0
CO_2 Price ($/ton)
25.0
100.0
Current


Price Brea
$700.00
$600.00
$500.00
$400.00
$300.00
$200.00
$100.00
$0.00
CO_2 Price ($/ton)
1
Intake/screening Cap
CO2 stripping CapEx
Electrodialysis electri

0.20	0.25	0.30	0.35
258.40	206.70	172.30	147.70
273.30	221.60	187.10	162.50
288.20	236.50	202.00	177.40
303.00	251.30	216.90	192.30
317.90	266.20	231.80	207.20
332.80	281.10	246.60	222.00
347.70	296.00	261.50	236.90
362.50	310.80	276.40	251.80
377.40	325.70	291.30	266.70
392.30	340.60	306.10	281.50
407.20	355.50	321.00	296.40
422.00	370.30	335.90	311.30
436.90	385.20	350.80	326.20

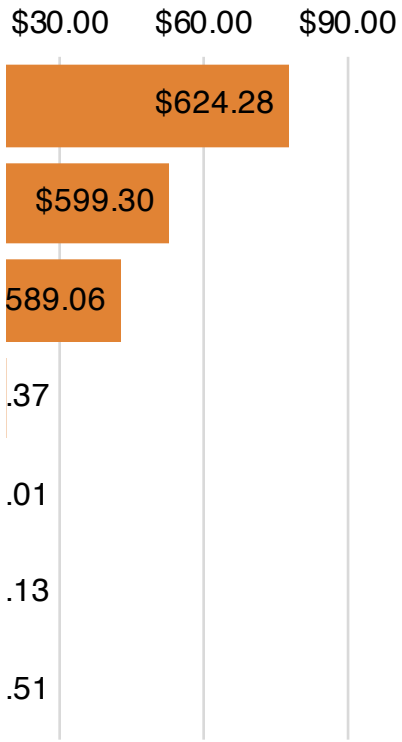
0.20	0.25	0.30	0.35
0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85

0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85
0.80	1.00	1.20	1.40
0.99	1.24	1.48	1.73
1.20	1.50	1.80	2.10

1.5x	
	$624.28
	$599.30
	$589.06
	$565.37
	$556.01
	$551.13
	$550.51

ear, $0.05/kWh

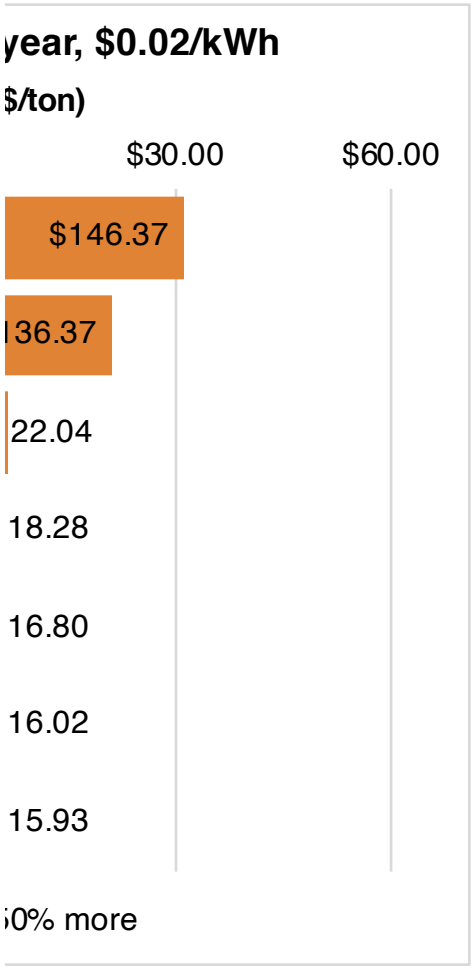
on)



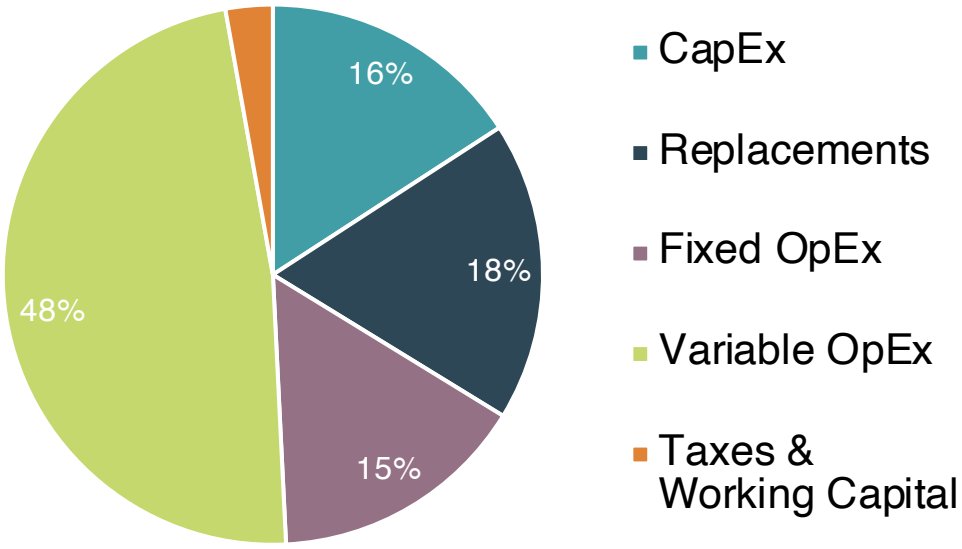
› more

1.5x	
	$146.37
	$136.37

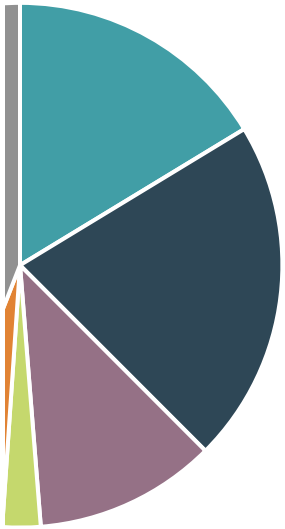
$122.04
$118.28
$116.80
$116.02
$115.93



Cost Breakdown

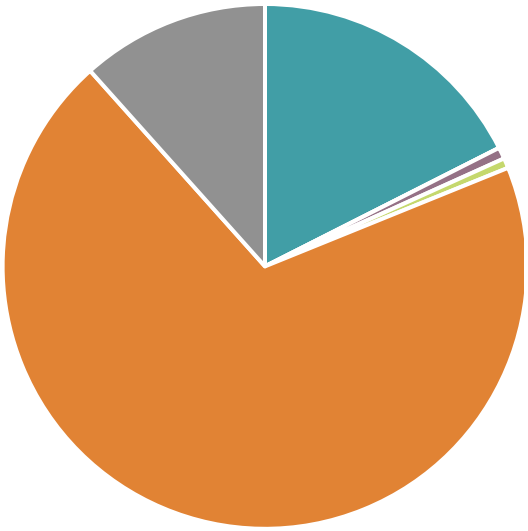


st by Process Step



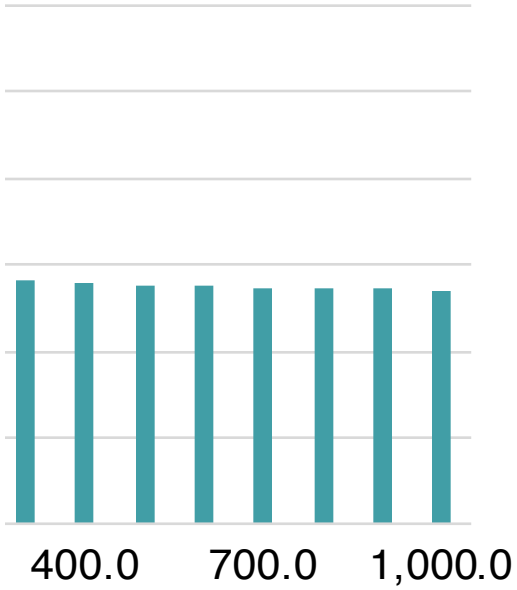
ening
Microfiltration
rodialysis
CO2 stripping

Electricity Cost by Process S



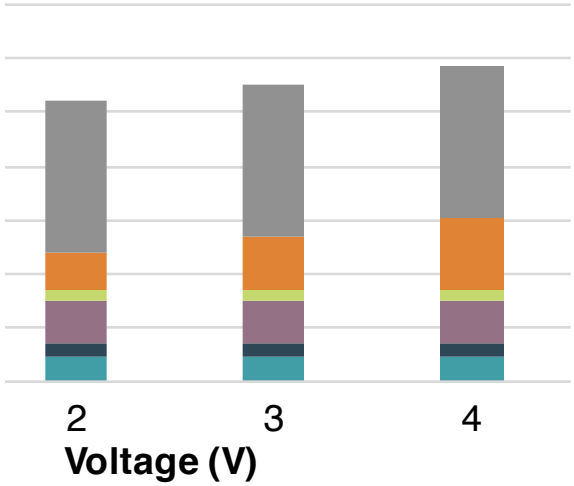
Intake
Screening
Micro
Nanofiltration
Electrodialysis
CO2

ensity Sweep



: Density (mA/cm²)

ıkdown: Current



ɔEx
city
Electrodialysis CapEx
Intake electricity
Fixed OpEx & Other

0.40	0.45	0.50	0.55	0.60
129.20	114.80	103.40	94.00	86.10
144.10	129.70	118.20	108.80	101.00
159.00	144.60	133.10	123.70	115.90
173.80	159.50	148.00	138.60	130.80
188.70	174.30	162.90	153.50	145.60
203.60	189.20	177.70	168.30	160.50
218.50	204.10	192.60	183.20	175.40
233.30	219.00	207.50	198.10	190.30
248.20	233.80	222.40	213.00	205.10
263.10	248.70	237.20	227.80	220.00
278.00	263.60	252.10	242.70	234.90
292.80	278.50	267.00	257.60	249.80
307.70	293.30	281.90	272.50	264.60

0.40	0.45	0.50	0.55	0.60
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85

0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
1.60	1.79	1.99	2.19	2.39
1.98	2.23	2.47	2.72	2.97
2.41	2.71	3.01	3.31	3.61

tep

filtration
stripping

6.5512

0.65	**0.70**	**0.75**	**0.80**	**0.85**
79.50	73.80	68.90	64.60	60.80
94.40	88.70	83.80	79.50	75.70
109.30	103.60	98.70	94.40	90.60
124.10	118.50	113.50	109.20	105.40
139.00	133.30	128.40	124.10	120.30
153.90	148.20	143.30	139.00	135.20
168.80	163.10	158.20	153.90	150.10
183.60	178.00	173.00	168.70	164.90
198.50	192.80	187.90	183.60	179.80
213.40	207.70	202.80	198.50	194.70
228.30	222.60	217.70	213.40	209.60
243.10	237.50	232.50	228.20	224.40
258.00	252.30	247.40	243.10	239.30

0.65	**0.70**	**0.75**	**0.80**	**0.85**
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85

0.85	0.85	0.85	0.85	0.85
0.85	0.85	0.85	0.85	0.85
2.59	2.79	2.99	3.19	3.39
3.21	3.46	3.71	3.96	4.20
3.91	4.21	4.51	4.81	5.11

0.90	0.95	1.00
57.40	54.4	51.7
72.30	69.3	66.6
87.20	84.2	81.4
102.00	99.0	96.3
116.90	113.9	111.2
131.80	128.8	126.1
146.70	143.7	140.9
161.50	158.5	155.8
176.40	173.4	170.7
191.30	188.3	185.6
206.20	203.2	200.4
221.00	218.0	215.3
235.90	232.9	230.2

0.90	0.95	1.00
0.85	0.8	0.8
0.85	0.8	0.8
0.85	0.8	0.8
0.85	0.8	0.8
0.85	0.8	0.8
0.85	0.8	0.8
0.85	0.8	0.8
0.85	0.8	0.8
0.85	0.8	0.8
0.85	0.8	0.8
0.85	0.8	0.8

0.85	0.8	0.8
0.85	0.8	0.8
3.59	3.8	4.0
4.45	4.7	4.9
5.41	5.7	6.0

CO_2 Price 138.152 $/ton CO_2

Results

CO_2 production cost ($/kg	$0.14
NPV	$0
CO_2 cost ($/kg) in year of	$0.14

Calculation

	Depreciable capital	Depreciation charge	Principal	
Discounted values	479,805,194	(383,621,532)	10,635,295	
Tax coefficient	100.00%	25.74%	100.00%	
Present values	479,805,194	(98,744,182)	10,635,295	

Cash flow

Year	Analysis year	Operation year	Inflation rate increase factor
2018	1	-1	0.98
2019	2	1	1.00
2020	3	2	1.02
2021	4	3	1.04
2022	5	4	1.06
2023	6	5	1.08
2024	7	6	1.10
2025	8	7	1.12
2026	9	8	1.14
2027	10	9	1.16
2028	11	10	1.18
2029	12	11	1.21
2030	13	12	1.23
2031	14	13	1.25
2032	15	14	1.28
2033	16	15	1.30
2034	17	16	1.33
2035	18	17	1.35
2036	19	18	1.38
2037	20	19	1.40
2038	21	20	1.43
2039	22	21	1.46
2040	23	22	1.48
2041	24	23	1.51
2042	25	24	1.54
2043	26	25	1.57
2044	27	26	1.60
2045	28	27	1.63
2046	29	28	1.66
2047	30	29	1.69

2048	31	30	1.73
2049	32	31	1.76
2050	33	32	1.79
2051	34	33	1.83
2052	35	34	1.86
2053	36	35	1.90
2054	37	36	1.93
2055	38	37	1.97
2056	39	38	2.01
2057	40	39	2.04
2058	41	40	2.08

PV of cash flows
Discounted values

Depreciation type

Depreciation type	MACRS	
Depreciation period		20
Total initial depreciable cap		387,079,590

Depreciation calculation table

Operation year	Annual depreciable capit	1	2
-1	$0	$0	$0
1	$388,545,888	$14,570,471	$28,049,128
2	$1,494,157	$56,031	$107,863
3	$1,522,546	$57,095	$109,913
4	$1,551,475	$58,180	$112,001
5	$1,580,953	$59,286	$114,129
6	$78,261,605	$2,934,810	$5,649,705
7	$1,641,600	$61,560	$118,507
8	$1,672,790	$62,730	$120,759
9	$1,704,573	$63,921	$123,053
10	$1,736,960	$65,136	$125,391
11	$242,003,311	$9,075,124	$17,470,219
12	$1,803,592	$67,635	$130,201
13	$1,837,860	$68,920	$132,675
14	$1,872,779	$70,229	$135,196
15	$1,908,362	$71,564	$137,765
16	$94,469,277	$3,542,598	$6,819,737
17	$1,981,569	$74,309	$143,049
18	$2,019,218	$75,721	$145,767
19	$2,057,584	$77,159	$148,537
20	$2,096,678	$78,625	$151,359
21	$292,121,248	$10,954,547	$21,088,233
22	$2,177,108	$81,642	$157,165
23	$2,218,473	$83,193	$160,152
24	$2,260,624	$84,773	$163,194
25	$2,303,576	$86,384	$166,295
26	$114,033,494	$4,276,256	$8,232,078
27	$2,391,944	$89,698	$172,674

28	$2,437,391	$91,402	$175,955
29	$2,483,701	$93,139	$179,298
30	$2,530,891	$94,908	$182,705
31	$352,618,414	$13,223,191	$25,455,523
32	$2,627,979	$98,549	$189,714
33	$2,677,911	$100,422	$193,318
34	$2,728,791	$102,330	$196,991
35	$2,780,638	$104,274	$200,734
36	$137,649,383	$5,161,852	$9,936,909
37	$2,887,306	$108,274	$208,435
38	$2,942,165	$110,331	$212,395
39	$2,998,066	$112,427	$216,430
40	$3,055,029	$114,564	$220,543

MACRS Depreciation Table (Half-Year Convention)

	Recovery Period		
Recovery Year	3	5	7
1	33.33%	20.00%	14.29%
2	44.45%	32.00%	24.49%
3	14.81%	19.20%	17.49%
4	7.41%	11.52%	12.49%
5		11.52%	8.93%
6		5.76%	8.92%
7			8.93%
8			4.46%
9			
10			
11			
12			
13			

	14			
	15			
	16			
	17			
	18			
	19			
	20			
	21			
NPV - Real IRR		**89.31%**	**85.26%**	**81.55%**
NPV - Nominal IRR		**86.15%**	**81.10%**	**76.58%**

Replacements

Year	Analysis year	Operation year	Inflation rate increase factor
2018	1	-1	0.98
2019	2	1	1.00
2020	3	2	1.02
2021	4	3	1.04
2022	5	4	1.06
2023	6	5	1.08
2024	7	6	1.10
2025	8	7	1.12
2026	9	8	1.14
2027	10	9	1.16
2028	11	10	1.18
2029	12	11	1.21
2030	13	12	1.23
2031	14	13	1.25
2032	15	14	1.28
2033	16	15	1.30
2034	17	16	1.33
2035	18	17	1.35
2036	19	18	1.38
2037	20	19	1.40
2038	21	20	1.43
2039	22	21	1.46
2040	23	22	1.48
2041	24	23	1.51
2042	25	24	1.54
2043	26	25	1.57
2044	27	26	1.60
2045	28	27	1.63
2046	29	28	1.66
2047	30	29	1.69
2048	31	30	1.73
2049	32	31	1.76
2050	33	32	1.79
2051	34	33	1.83

2052	35	34	1.86
2053	36	35	1.90
2054	37	36	1.93
2055	38	37	1.97
2056	39	38	2.01
2057	40	39	2.04
2058	41	40	2.08
Total			

Operating costs	Tax incentives	CO_2 sales (kg/year)
1,217,751,105	0	13,117,138,882
74.26%	100.00%	74.26%
904,301,971	0	9,740,787,334

Revenues	Initial depreciable capital financed with debt	Initial equity depreciable capital	Replacement costs
0	(232,247,754)	(154,831,836)	0
61,009,443		0	(1,466,298)
124,337,245		0	(1,494,157)
126,699,653		0	(1,522,546)
129,106,946		0	(1,551,475)
131,559,978		0	(1,580,953)
134,059,618		0	(78,261,605)
136,606,750		0	(1,641,600)
139,202,279		0	(1,672,790)
141,847,122		0	(1,704,573)
144,542,217		0	(1,736,960)
147,288,519		0	(242,003,311)
150,087,001		0	(1,803,592)
152,938,654		0	(1,837,860)
155,844,489		0	(1,872,779)
158,805,534		0	(1,908,362)
161,822,839		0	(94,469,277)
164,897,473		0	(1,981,569)
168,030,525		0	(2,019,218)
171,223,105		0	(2,057,584)
174,476,344		0	(2,096,678)
177,791,394		0	(292,121,248)
181,169,431		0	(2,177,108)
184,611,650		0	(2,218,473)
188,119,272		0	(2,260,624)
191,693,538		0	(2,303,576)
195,335,715		0	(114,033,494)
199,047,093		0	(2,391,944)
202,828,988		0	(2,437,391)
206,682,739		0	(2,483,701)

210,609,711		0	(2,530,891)
214,611,296		0	(352,618,414)
218,688,910		0	(2,627,979)
222,843,999		0	(2,677,911)
227,078,035		0	(2,728,791)
231,392,518		0	(2,780,638)
235,788,976		0	(137,649,383)
240,268,967		0	(2,887,306)
244,834,077		0	(2,942,165)
249,485,924		0	(2,998,066)
254,226,157		0	(3,055,029)
1,615,732,386	**(215,016,344)**	**(143,344,230)**	**(289,532,893)**
1,745,217,180	**(232,247,754)**	**(154,831,836)**	**(312,736,059)**

3	**4**	**5**	**6**
$0	$0	$0	$0
$25,943,209	$24,000,480	$22,197,627	$20,534,650
$99,765	$92,294	$85,361	$78,966
$101,660	$94,048	$86,983	$80,467
$103,592	$95,835	$88,636	$81,995
$105,560	$97,655	$90,320	$83,553
$5,225,527	$4,834,219	$4,471,085	$4,136,126
$109,610	$101,402	$93,785	$86,759
$111,692	$103,328	$95,567	$88,407
$113,814	$105,291	$97,382	$90,087
$115,977	$107,292	$99,233	$91,798
$16,158,561	$14,948,545	$13,825,649	$12,789,875
$120,426	$111,408	$103,039	$95,320
$122,714	$113,525	$104,997	$97,131
$125,045	$115,682	$106,992	$98,976
$127,421	$117,880	$109,025	$100,857
$6,307,714	$5,835,367	$5,397,030	$4,992,701
$132,309	$122,401	$113,207	$104,726
$134,823	$124,727	$115,358	$106,716
$137,385	$127,097	$117,550	$108,743
$139,995	$129,512	$119,783	$110,809
$19,504,936	$18,044,330	$16,688,887	$15,438,608
$145,366	$134,480	$124,378	$115,060
$148,127	$137,035	$126,741	$117,246
$150,942	$139,639	$129,149	$119,474
$153,810	$142,292	$131,603	$121,744
$7,614,016	$7,043,849	$6,514,733	$6,026,670
$159,710	$147,750	$136,652	$126,414

$162,745	$150,558	$139,248	$128,816
$165,837	$153,418	$141,894	$131,264
$168,988	$156,333	$144,590	$133,758
$23,544,332	$21,781,239	$20,145,090	$18,635,883
$175,470	$162,330	$150,136	$138,889
$178,804	$165,415	$152,989	$141,528
$182,201	$168,557	$155,896	$144,217
$185,663	$171,760	$158,858	$146,957
$9,190,849	$8,502,602	$7,863,909	$7,274,770
$192,785	$178,349	$164,952	$152,594
$196,448	$181,738	$168,086	$155,493
$200,181	$185,191	$171,280	$158,448
$203,984	$188,709	$174,534	$161,458

10	15	20
10.00%	5.00%	3.75%
18.00%	9.50%	7.22%
14.40%	8.55%	6.68%
11.52%	7.70%	6.18%
9.22%	6.93%	5.71%
7.37%	6.23%	5.29%
6.55%	5.90%	4.89%
6.55%	5.90%	4.52%
6.56%	5.91%	4.46%
6.55%	5.90%	4.46%
3.28%	5.91%	4.46%
	5.90%	4.46%
	5.91%	4.46%

	5.90%	4.46%
	5.91%	4.46%
	2.95%	4.46%
		4.46%
		4.46%
		4.46%
		4.46%
		2.23%
76.49%	**65.49%**	**58.67%**
70.55%	**57.92%**	**50.57%**

Unplanned yearly	**Unspecified/regular basi**	**Specified: electrodialysis**	**Specified: pre-treatment**
$0	$0	$0	$0
-$1,466,298	$0	$0	$0
-$1,494,157	$0	$0	$0
-$1,522,546	$0	$0	$0
-$1,551,475	$0	$0	$0
-$1,580,953	$0	$0	$0
-$1,610,991	-$34,800,132	-$15,601,498	-$26,248,984
-$1,641,600	$0	$0	$0
-$1,672,790	$0	$0	$0
-$1,704,573	$0	$0	$0
-$1,736,960	$0	$0	$0
-$1,769,962	-$38,234,183	-$17,141,042	-$28,839,214
-$1,803,592	$0	$0	$0
-$1,837,860	$0	$0	$0
-$1,872,779	$0	$0	$0
-$1,908,362	$0	$0	$0
-$1,944,621	-$42,007,103	-$18,832,507	-$31,685,046
-$1,981,569	$0	$0	$0
-$2,019,218	$0	$0	$0
-$2,057,584	$0	$0	$0
-$2,096,678	$0	$0	$0
-$2,136,515	-$46,152,332	-$20,690,884	-$34,811,702
-$2,177,108	$0	$0	$0
-$2,218,473	$0	$0	$0
-$2,260,624	$0	$0	$0
-$2,303,576	$0	$0	$0
-$2,347,344	-$50,706,609	-$22,732,645	-$38,246,895
-$2,391,944	$0	$0	$0
-$2,437,391	$0	$0	$0
-$2,483,701	$0	$0	$0
-$2,530,891	$0	$0	$0
-$2,578,978	-$55,710,299	-$24,975,886	-$42,021,070
-$2,627,979	$0	$0	$0
-$2,677,911	$0	$0	$0

-$2,728,791	$0	$0	$0
-$2,780,638	$0	$0	$0
-$2,833,470	-$61,207,749	-$27,440,487	-$46,167,677
-$2,887,306	$0	$0	$0
-$2,942,165	$0	$0	$0
-$2,998,066	$0	$0	$0
-$3,055,029	$0	$0	$0
-$21,650,983	-$75,420,637	-$33,812,369	-$56,888,150

Taxes		
-$37,025,585		
$0.14	Calculated without tax coefficient	

Cash from working capital reserve	Non-depreciable capital cost	Salvage value	Decommisioning cost
0	0	0	0
(8,567,297)	0	0	0
(3,072,804)	0	0	0
(221,162)	0	0	0
(225,364)	0	0	0
(229,646)	0	0	0
(234,009)	0	0	0
(238,455)	0	0	0
(242,986)	0	0	0
(247,603)	0	0	0
(252,307)	0	0	0
(257,101)	0	0	0
(261,986)	0	0	0
(266,964)	0	0	0
(272,036)	0	0	0
(277,205)	0	0	0
(282,472)	0	0	0
(287,839)	0	0	0
(293,307)	0	0	0
(298,880)	0	0	0
(304,559)	0	0	0
(310,346)	0	0	0
(316,242)	0	0	0
(322,251)	0	0	0
(328,374)	0	0	0
(334,613)	0	0	0
(340,970)	0	0	0
(347,449)	0	0	0
(354,050)	0	0	0
(360,777)	0	0	0

(367,632)	0	0	0
(374,617)	0	0	0
(381,735)	0	0	0
(388,988)	0	0	0
(396,378)	0	0	0
(403,910)	0	0	0
(411,584)	0	0	0
(419,404)	0	0	0
(427,373)	0	0	0
(435,493)	0	0	0
23,356,167	0	82,180,283	(82,180,283)
(11,329,364)	**0**	**3,484,060**	**(3,484,060)**
(12,237,299)	**0**	**3,763,272**	**(3,763,272)**

7	**8**	**9**	**10**
$0	$0	$0	$0
$18,992,123	$17,570,045	$17,336,918	$17,333,032
$73,034	$67,566	$66,669	$66,654
$74,422	$68,850	$67,936	$67,921
$75,836	$70,158	$69,227	$69,211
$77,277	$71,491	$70,542	$70,526
$3,825,427	$3,538,990	$3,492,033	$3,491,250
$80,241	$74,233	$73,248	$73,232
$81,766	$75,644	$74,640	$74,623
$83,320	$77,081	$76,058	$76,041
$84,903	$78,545	$77,503	$77,486
$11,829,122	$10,943,390	$10,798,188	$10,795,768
$88,160	$81,558	$80,476	$80,458
$89,835	$83,108	$82,005	$81,987
$91,541	$84,687	$83,563	$83,545
$93,281	$86,296	$85,151	$85,132
$4,617,658	$4,271,901	$4,215,219	$4,214,274
$96,859	$89,607	$88,418	$88,398
$98,699	$91,309	$90,098	$90,077
$100,575	$93,044	$91,809	$91,789
$102,486	$94,812	$93,554	$93,533
$14,278,887	$13,209,723	$13,034,450	$13,031,529
$106,417	$98,449	$97,143	$97,121
$108,439	$100,319	$98,988	$98,966
$110,499	$102,225	$100,869	$100,846
$112,599	$104,168	$102,786	$102,763
$5,573,957	$5,156,595	$5,088,174	$5,087,034
$116,918	$108,164	$106,729	$106,705

$119,140	$110,219	$108,756	$108,732
$121,403	$112,313	$110,823	$110,798
$123,710	$114,447	$112,928	$112,903
$17,235,988	$15,945,405	$15,733,834	$15,730,307
$128,456	$118,837	$117,260	$117,234
$130,896	$121,095	$119,488	$119,462
$133,383	$123,396	$121,759	$121,731
$135,918	$125,740	$124,072	$124,044
$6,728,302	$6,224,505	$6,141,915	$6,140,539
$141,132	$130,564	$128,832	$128,803
$143,813	$133,045	$131,279	$131,250
$146,545	$135,573	$133,774	$133,744
$149,330	$138,148	$136,315	$136,285

Specified: gas stripping	Total
$0	$0
$0	-$1,466,298
$0	-$1,494,157
$0	-$1,522,546
$0	-$1,551,475
$0	-$1,580,953
$0	-$78,261,605
$0	-$1,641,600
$0	-$1,672,790
$0	-$1,704,573
$0	-$1,736,960
-$156,018,910	-$242,003,311
$0	-$1,803,592
$0	-$1,837,860
$0	-$1,872,779
$0	-$1,908,362
$0	-$94,469,277
$0	-$1,981,569
$0	-$2,019,218
$0	-$2,057,584
$0	-$2,096,678
-$188,329,815	-$292,121,248
$0	-$2,177,108
$0	-$2,218,473
$0	-$2,260,624
$0	-$2,303,576
$0	-$114,033,494
$0	-$2,391,944
$0	-$2,437,391
$0	-$2,483,701
$0	-$2,530,891
-$227,332,182	-$352,618,414
$0	-$2,627,979
$0	-$2,677,911

$0	-$2,728,791
$0	-$2,780,638
$0	-$137,649,383
$0	-$2,887,306
$0	-$2,942,165
$0	-$2,998,066
$0	-$3,055,029
-$124,963,919	-$312,736,059

Fixed operating costs	Variable operating costs	Debt interest	Pre-depreciation income
0	0	(8,593,167)	(8,593,167)
(13,927,727)	(43,187,590)	(8,593,167)	(4,699,040)
(18,923,138)	(58,677,538)	(8,593,167)	38,143,402
(19,282,678)	(59,792,412)	(8,593,167)	39,031,397
(19,649,048)	(60,928,467)	(8,593,167)	39,936,263
(20,022,380)	(62,086,108)	(8,593,167)	40,858,322
(20,402,806)	(63,265,744)	(8,593,167)	41,797,901
(20,790,459)	(64,467,793)	(8,593,167)	42,755,331
(21,185,478)	(65,692,682)	(8,593,167)	43,730,952
(21,588,002)	(66,940,842)	(8,593,167)	44,725,111
(21,998,174)	(68,212,718)	(8,593,167)	45,738,158
(22,416,139)	(69,508,760)	(8,593,167)	46,770,453
(22,842,046)	(70,829,427)	(8,593,167)	47,822,362
(23,276,045)	(72,175,186)	(8,593,167)	48,894,257
(23,718,289)	(73,546,514)	(8,593,167)	49,986,518
(24,168,937)	(74,943,898)	(8,593,167)	51,099,532
(24,628,147)	(76,367,832)	(8,593,167)	52,233,693
(25,096,082)	(77,818,821)	(8,593,167)	53,389,404
(25,572,907)	(79,297,378)	(8,593,167)	54,567,073
(26,058,792)	(80,804,029)	(8,593,167)	55,767,117
(26,553,909)	(82,339,305)	(8,593,167)	56,989,962
(27,058,434)	(83,903,752)	(8,593,167)	58,236,042
(27,572,544)	(85,497,923)	(8,593,167)	59,505,797
(28,096,422)	(87,122,384)	(8,593,167)	60,799,677
(28,630,254)	(88,777,709)	(8,593,167)	62,118,141
(29,174,229)	(90,464,486)	(8,593,167)	63,461,656
(29,728,539)	(92,183,311)	(8,593,167)	64,830,698
(30,293,382)	(93,934,794)	(8,593,167)	66,225,751
(30,868,956)	(95,719,555)	(8,593,167)	67,647,311
(31,455,466)	(97,538,226)	(8,593,167)	69,095,880

(32,053,120)	(99,391,453)	(8,593,167)	70,571,972
(32,662,129)	(101,279,890)	(8,593,167)	72,076,109
(33,282,710)	(103,204,208)	(8,593,167)	73,608,825
(33,915,081)	(105,165,088)	(8,593,167)	75,170,663
(34,559,468)	(107,163,225)	(8,593,167)	76,762,176
(35,216,098)	(109,199,326)	(8,593,167)	78,383,928
(35,885,203)	(111,274,113)	(8,593,167)	80,036,492
(36,567,022)	(113,388,321)	(8,593,167)	81,720,456
(37,261,796)	(115,542,700)	(8,593,167)	83,436,415
(37,969,770)	(117,738,011)	(8,593,167)	85,184,977
(38,691,195)	(119,975,033)	(8,593,167)	86,966,762
(249,880,824)	**(774,839,333)**	**(102,681,018)**	**488,331,211**
(269,906,273)	**(836,934,957)**	**(110,909,875)**	**527,466,074**

11	**12**	**13**	**14**
$0	$0	$0	$0
$17,336,918	$17,333,032	$17,336,918	$17,333,032
$66,669	$66,654	$66,669	$66,654
$67,936	$67,921	$67,936	$67,921
$69,227	$69,211	$69,227	$69,211
$70,542	$70,526	$70,542	$70,526
$3,492,033	$3,491,250	$3,492,033	$3,491,250
$73,248	$73,232	$73,248	$73,232
$74,640	$74,623	$74,640	$74,623
$76,058	$76,041	$76,058	$76,041
$77,503	$77,486	$77,503	$77,486
$10,798,188	$10,795,768	$10,798,188	$10,795,768
$80,476	$80,458	$80,476	$80,458
$82,005	$81,987	$82,005	$81,987
$83,563	$83,545	$83,563	$83,545
$85,151	$85,132	$85,151	$85,132
$4,215,219	$4,214,274	$4,215,219	$4,214,274
$88,418	$88,398	$88,418	$88,398
$90,098	$90,077	$90,098	$90,077
$91,809	$91,789	$91,809	$91,789
$93,554	$93,533	$93,554	$93,533
$13,034,450	$13,031,529	$13,034,450	$13,031,529
$97,143	$97,121	$97,143	$97,121
$98,988	$98,966	$98,988	$98,966
$100,869	$100,846	$100,869	$100,846
$102,786	$102,763	$102,786	$102,763
$5,088,174	$5,087,034	$5,088,174	$5,087,034
$106,729	$106,705	$106,729	$106,705

$108,756	$108,732	$108,756	$108,732
$110,823	$110,798	$110,823	$110,798
$112,928	$112,903	$112,928	$112,903
$15,733,834	$15,730,307	$15,733,834	$15,730,307
$117,260	$117,234	$117,260	$117,234
$119,488	$119,462	$119,488	$119,462
$121,759	$121,731	$121,759	$121,731
$124,072	$124,044	$124,072	$124,044
$6,141,915	$6,140,539	$6,141,915	$6,140,539
$128,832	$128,803	$128,832	$128,803
$131,279	$131,250	$131,279	$131,250
$133,774	$133,744	$133,774	$133,744
$136,315	$136,285	$136,315	$136,285

Depreciation charge	Taxable income	Total tax	Principal payment
0	(8,593,167)	2,211,881	0
(14,570,471)	(19,269,511)	4,959,972	0
(28,105,159)	10,038,243	(2,583,844)	0
(26,108,168)	12,923,229	(3,326,439)	0
(24,268,337)	15,667,926	(4,032,924)	0
(22,562,868)	18,295,455	(4,709,250)	0
(23,866,590)	17,931,310	(4,615,519)	0
(25,070,732)	17,684,599	(4,552,016)	0
(23,316,601)	20,414,351	(5,254,654)	0
(22,779,730)	21,945,381	(5,648,741)	0
(22,500,309)	23,237,849	(5,981,422)	0
(31,266,511)	15,503,942	(3,990,715)	0
(39,375,214)	8,447,148	(2,174,296)	0
(37,881,256)	11,013,001	(2,834,747)	0
(36,716,601)	13,269,917	(3,415,677)	0
(35,693,052)	15,406,481	(3,965,628)	0
(38,221,110)	14,012,583	(3,606,839)	0
(40,571,574)	12,817,830	(3,299,309)	0
(39,280,859)	15,286,213	(3,934,671)	0
(38,772,112)	16,995,005	(4,374,514)	0
(38,433,991)	18,555,971	(4,776,307)	0
(40,348,013)	17,888,029	(4,604,379)	0
(41,437,256)	18,068,541	(4,650,842)	0
(39,563,565)	21,236,112	(5,466,175)	0
(38,092,186)	24,025,955	(6,184,281)	0
(36,783,742)	26,677,914	(6,866,895)	0
(38,057,117)	26,773,581	(6,891,520)	0
(39,109,441)	27,116,310	(6,979,738)	0
(37,479,768)	30,167,543	(7,765,125)	0
(36,788,042)	32,307,838	(8,316,038)	0

(41,437,256)	29,134,715	(7,499,276)	0
(39,563,565)	32,512,544	(8,368,729)	0
(38,092,186)	35,516,639	(9,141,983)	0
(36,783,742)	38,386,922	(9,880,794)	0
(38,057,117)	38,705,059	(9,962,682)	0
(39,109,441)	39,274,486	(10,109,253)	0
(37,479,768)	42,556,724	(10,954,101)	0
(36,788,042)	44,932,414	(11,565,603)	0
(36,305,404)	47,131,010	(12,131,522)	0
(43,639,360)	41,545,617	(10,693,842)	0
(714,458,224)	(627,491,462)	161,516,302	(232,247,754)
(355,159,083)	**133,172,128**	**(34,278,506)**	**(9,846,219)**
(383,621,532)	**143,844,542**	**(37,025,585)**	**(10,635,295)**

15	**16**	**17**	**18**
$0	$0	$0	$0
$17,336,918	$17,333,032	$17,336,918	$17,333,032
$66,669	$66,654	$66,669	$66,654
$67,936	$67,921	$67,936	$67,921
$69,227	$69,211	$69,227	$69,211
$70,542	$70,526	$70,542	$70,526
$3,492,033	$3,491,250	$3,492,033	$3,491,250
$73,248	$73,232	$73,248	$73,232
$74,640	$74,623	$74,640	$74,623
$76,058	$76,041	$76,058	$76,041
$77,503	$77,486	$77,503	$77,486
$10,798,188	$10,795,768	$10,798,188	$10,795,768
$80,476	$80,458	$80,476	$80,458
$82,005	$81,987	$82,005	$81,987
$83,563	$83,545	$83,563	$83,545
$85,151	$85,132	$85,151	$85,132
$4,215,219	$4,214,274	$4,215,219	$4,214,274
$88,418	$88,398	$88,418	$88,398
$90,098	$90,077	$90,098	$90,077
$91,809	$91,789	$91,809	$91,789
$93,554	$93,533	$93,554	$93,533
$13,034,450	$13,031,529	$13,034,450	$13,031,529
$97,143	$97,121	$97,143	$97,121
$98,988	$98,966	$98,988	$98,966
$100,869	$100,846	$100,869	$100,846
$102,786	$102,763	$102,786	$102,763
$5,088,174	$5,087,034	$5,088,174	$5,087,034
$106,729	$106,705	$106,729	$106,705

$108,756	$108,732	$108,756	$108,732
$110,823	$110,798	$110,823	$110,798
$112,928	$112,903	$112,928	$112,903
$15,733,834	$15,730,307	$15,733,834	$15,730,307
$117,260	$117,234	$117,260	$117,234
$119,488	$119,462	$119,488	$119,462
$121,759	$121,731	$121,759	$121,731
$124,072	$124,044	$124,072	$124,044
$6,141,915	$6,140,539	$6,141,915	$6,140,539
$128,832	$128,803	$128,832	$128,803
$131,279	$131,250	$131,279	$131,250
$133,774	$133,744	$133,774	$133,744
$136,315	$136,285	$136,315	$136,285

After-tax, post-depreciation cash flow	Cumulative cash flow	Pre-tax cash flow
(161,213,122)	(161,213,122)	(163,425,003)
(9,772,663)	(170,985,785)	(14,732,635)
30,992,596	(139,993,189)	33,576,440
33,961,249	(106,031,939)	37,287,688
34,126,500	(71,905,439)	38,159,424
34,338,474	(37,566,965)	39,047,724
(41,313,233)	(78,880,198)	(36,697,713)
36,323,260	(42,556,938)	40,875,276
36,560,522	(5,996,416)	41,815,176
37,124,194	31,127,778	42,772,935
37,767,468	68,895,246	43,748,891
(199,480,674)	(130,585,427)	(195,489,959)
43,582,489	(87,002,939)	45,756,784
43,954,687	(43,048,252)	46,789,433
44,426,026	1,377,775	47,841,703
44,948,337	46,326,112	48,913,965
(46,124,894)	201,218	(42,518,055)
47,820,687	48,021,905	51,119,997
48,319,875	96,341,780	52,254,547
49,036,139	145,377,919	53,410,653
49,812,419	195,190,338	54,588,726
(238,799,931)	(43,609,593)	(234,195,552)
52,361,604	8,752,011	57,012,446
52,792,778	61,544,789	58,258,953
53,344,862	114,889,651	59,529,143
53,956,572	168,846,223	60,823,467
(56,435,286)	112,410,938	(49,543,766)
56,506,620	168,917,558	63,486,359
57,090,744	226,008,302	64,855,870
57,935,364	283,943,666	66,251,401

60,174,172	344,117,838	67,673,448
(289,285,651)	54,832,187	(280,916,922)
61,457,129	116,289,316	70,599,112
62,222,971	178,512,288	72,103,765
63,674,325	242,186,612	73,637,007
65,090,127	307,276,740	75,199,380
(68,978,576)	238,298,164	(58,024,475)
66,848,143	305,146,306	78,413,746
67,935,355	373,081,662	80,066,877
71,057,576	444,139,238	81,751,418
36,536,448	480,675,686	(124,979,855)
0	**(254,285,032)**	**34,278,506**
0	**(274,663,434)**	**37,025,585**

19	**20**	**21**	**Depreciation charges**
$0	$0	$0	$0
$17,336,918	$17,333,032	$8,668,459	$14,570,471
$66,669	$66,654	$33,335	$28,105,159
$67,936	$67,921	$33,968	$26,108,168
$69,227	$69,211	$34,613	$24,268,337
$70,542	$70,526	$35,271	$22,562,868
$3,492,033	$3,491,250	$1,746,016	$23,866,590
$73,248	$73,232	$36,624	$25,070,732
$74,640	$74,623	$37,320	$23,316,601
$76,058	$76,041	$38,029	$22,779,730
$77,503	$77,486	$38,752	$22,500,309
$10,798,188	$10,795,768	$5,399,094	$31,266,511
$80,476	$80,458	$40,238	$39,375,214
$82,005	$81,987	$41,003	$37,881,256
$83,563	$83,545	$41,782	$36,716,601
$85,151	$85,132	$42,576	$35,693,052
$4,215,219	$4,214,274	$2,107,610	$38,221,110
$88,418	$88,398	$44,209	$40,571,574
$90,098	$90,077	$45,049	$39,280,859
$91,809	$91,789	$45,905	$38,772,112
$93,554	$93,533	$46,777	$38,433,991
$13,034,450	$13,031,529	$6,517,225	$40,348,013
$97,143	$97,121	$48,571	$41,437,256
$98,988	$98,966	$49,494	$39,563,565
$100,869	$100,846	$50,435	$38,092,186
$102,786	$102,763	$51,393	$36,783,742
$5,088,174	$5,087,034	$2,544,087	$38,057,117
$106,729	$106,705	$53,364	$39,109,441

$108,756	$108,732	$54,378	$37,479,768
$110,823	$110,798	$55,411	$36,788,042
$112,928	$112,903	$56,464	$41,437,256
$15,733,834	$15,730,307	$7,866,917	$39,563,565
$117,260	$117,234	$58,630	$38,092,186
$119,488	$119,462	$59,744	$36,783,742
$121,759	$121,731	$60,879	$38,057,117
$124,072	$124,044	$62,036	$39,109,441
$6,141,915	$6,140,539	$3,070,958	$37,479,768
$128,832	$128,803	$64,416	$36,788,042
$131,279	$131,250	$65,640	$36,305,404
$133,774	$133,744	$66,887	$43,639,360
$136,315	$136,285	$68,158	$50,018,750
			$47,757,024
			$45,980,929
			$44,401,510
			$45,938,597
			$47,208,853
			$45,241,681
			$44,406,701
			$43,824,111
			$36,715,239
			$29,531,216
			$28,876,825
			$28,642,665
			$28,504,392
			$25,883,007
			$23,274,724
			$23,162,994
			$23,055,353
			$22,941,353
			$15,020,122
			$7,095,951
			$6,976,227

CO_2 sales (kg/year)
0
450,000,000
900,000,000
900,000,000
900,000,000
900,000,000
900,000,000
900,000,000
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900,000,000
13,117,138,882

CO_2 Price 138.152 $/ton CO_2

	6/10 rule	Extrapolation
	6,178,607	885,573

Intake

Fraction Oceanwater	100%	
Flow Rate	400,000	m^3/day
Pressure	1.25	bar
Head	42	ft

Capital Cost

Equipment	**Unit capacity (m^3/day)**	**Cost per unit, CE 607.5**
Centrifugal pump #1	27,255	$41,942
Centrifugal motor #1	27,255	$6,779
Intake piping	400,000	$419,644
TOTAL		

Centrifugal Pump Calculations

Pump Index	**Valid?**	**Pump capacity (gal/min)**
4	Yes	5000

Motor Type	**Valid?**	**Pump efficiency**
2	Yes	86%

Screening

Fraction Oceanwater	100%	
Flow Rate	400,000	m^3/day
Pressure	0.25	bar
Head	8	ft

Capital Cost

Equipment	**Unit capacity (m^3/day)**	**Cost per unit, CE 607.5**
Centrifugal Pump #1		
Centrifugal Motor #1		
Microscreening	400,000	$3,246,752
TOTAL		

Micro/ultrafiltration

Fraction oceanwater	2.6%	
Flow rate	10,476	m^3/day
Pressure	2.0	bar
Head	67	ft
Recovery rate	98%	

Capital Cost

Equipment	Unit capacity (m^3/day)	Cost per unit, CE 607.5
Centrifugal pump #2	27,255	$47,040
Centrifugal motor #2	27,255	$10,935
Filter	400,000	$1,555,446
TOTAL		

Centrifugal Pump Calculations

Pump Index	Valid?	Pump capacity (gal/min)
4	Yes	5000

Motor Type	Valid?	Pump efficiency
2	Yes	86%

Nanofiltration

Fraction oceanwater	0.6%	
Flow rate	2,852	m^3/day
Pressure	6.5	bar
Head	217	ft
Recovery rate	90%	

Capital Cost

Equipment	Unit capacity (m^3/day)	Cost per unit, CE 607.5
Centrifugal pump #3	8,176	$29,981
Centrifugal motor #3	8,176	$12,364
Filter	4	$180
TOTAL		

Centrifugal Pump Calculations

Pump Index	Valid?	Pump capacity (gal/min)
3	Yes	1500

Motor Type	Valid?	Pump efficiency
5	Yes	80%

Electrodialysis

Fraction oceanwater	0.6%	
Flow rate	2,852	m^3/day
Pressure	1.0	bar
Head	33	ft
Recovery rate	90%	

Capital Cost

Equipment	Unit capacity (m^3/day)	Cost per unit, CE 607.5
ED Stack	2,852	$688,903
TOTAL		

ED Stack Calculations

Membrane Cost ($/cm^2)	BPM cost	CEM/AEM cost
0.05	$229,634	$114,817

CO_2 Stripping

Fraction Oceanwater	100%	
Flow Rate	400,000	m^3/day
Pressure	0.5	bar
Head	17	ft
MC type	1	

Capital Cost

Equipment	Unit capacity (m^3/day)	Cost per unit, CE 607.5
Centrifugal pump #1		
Centrifugal motor #1		
Membrane contactor	1,920	$6,600
Water condenser	272,727	$21,000
Vacuum pump #1	80,095	$251,785
TOTAL		

0D Model Calculations

Lfr	Max MC Lfr	Max unit capacity
60.0	38	1920

Assume vols are equal at min number of each. If lfr multiplier > 1, need lower gfr and more VPs. I

Vacuum Pump Calculations

Pump Index	Valid?	Pump capacity (m^3/h)
2	Yes	10,000

Partial presure in (Torr)	Partial pressure out (Torr)	Pump efficiency
10	760	35%
10	(copy-paste this when varying pressure)	

Partial pressure in	10 kilotons/year	1 megaton/year
150 Torr	$519	$112
70 Torr	$537	$117
20 Torr	$621	$132
2 Torr	$1,625	$297

Proportionality		**Total Capital Cost**
37,116,184		**Total Energy Usage**

		Capital Cost
		Energy Usage

5 m (intake) + 0.5 bar (membrane contactor) + 0.25 bar (screening)

Number of units	**Uninstalled cost**	**Cost factor**
15	$629,134	3.7
15	$101,680	3.7
1.0	$419,644	1.3

Size factor	**Bare cost**	**Material type factor**
32,324	$8,630	2

Pump brake horsepower	**Motor efficiency**	**Motor power consumption**
64	93%	69

		Capital Cost
		Energy Usage

Included in intake pumping, desal pg 248

Number of units	**Uninstalled cost**	**Cost factor**
1.0	$3,246,752	1.3

		Capital Cost
		Energy Usage

Desal pg 315

Number of units	Uninstalled cost	Cost factor
1	$47,040	3.7
1	$10,935	3.7
1.0	$1,555,446	1.3

Size factor	Bare cost	Material type factor
40,887	$9,679	2

Pump brake horsepower	Motor efficiency	Motor power consumption
102	94%	108

	Capital Cost
	Energy Usage

Desal Table 14.1

Number of units	Uninstalled cost	Cost factor
1	$29,981	3.7
1	$12,364	3.7
753	$135,303	2.3

Size factor	Bare cost	Material type factor
22,113	$7,258	2

Pump brake horsepower	Motor efficiency	Motor power consumption
107	95%	114

	Total Fixed Cost
	Energy Usage

1 bar included in microfiltration pumping

Number of units	Uninstalled cost	Cost factor
1	$688,903	1.4

Stack cost
$688,903

	Total Fixed Cost
	Energy Usage

Included in intake pumping, from Liquicell spec sheet

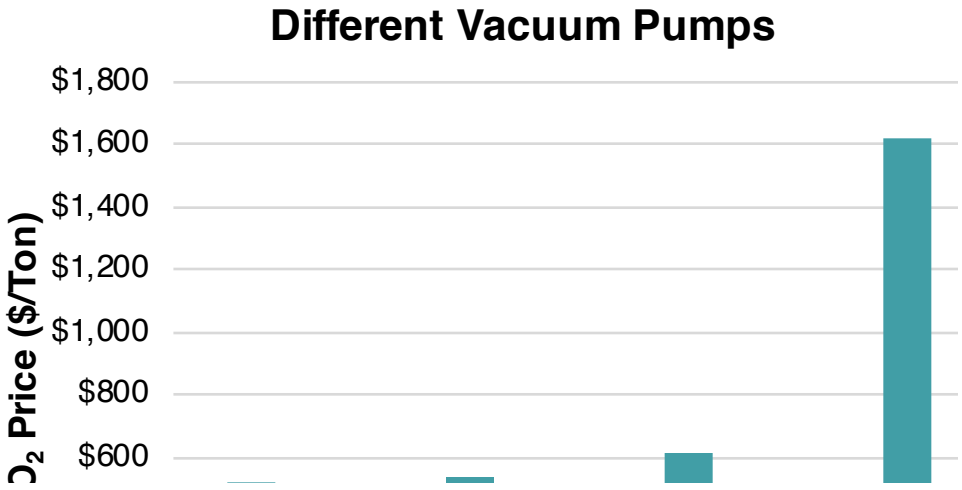
Number of units	Uninstalled cost	Cost factor
208	$1,375,000	2.9
2	$42,000	3.3
5.0	$1,257,438	3.7

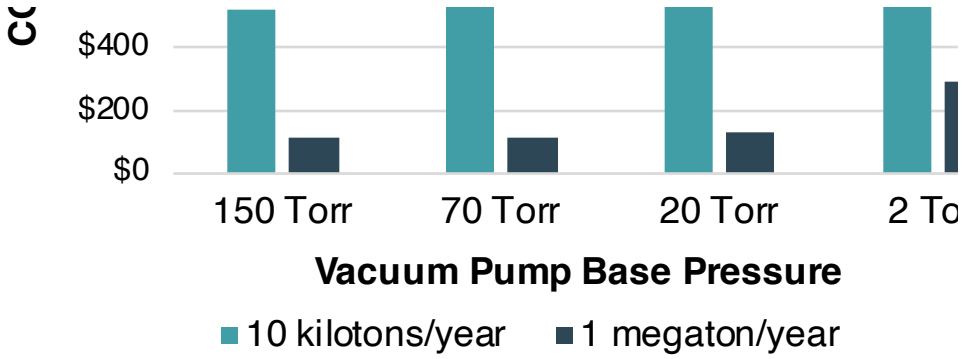
Unit capacity
1,920

f multiplier < 1, need lower lfr and more MCs.

Size factor	Purchase cost, CE 500	CO_2 pumping speed (mol/s)
10,000	$207,231	1.63

Pump power consumption (W)	Energy of vacuum pump (J/kg	Pump power (W/(m^3/hr))
393,090	1,096,428	10




$400
$200
$0
150 Torr
70 Torr
20 Torr
Vacuum Pump Base Pressure
10 kilotons/year
1 megaton/year

$19,917,879	
3.199	kWh/kg CO_2

$3,249,551	
0.561	kWh/kg CO_2

Installed cost	**Notes**
$2,327,796	Seider
$376,217	Seider
$545,538	Desal Fig 6.8. HDPE, offshore intake, 10 m of piping
$3,249,551	

Pump type factor	**Purchase cost, CE 500**	**Notes**
2	$34,520	4 or 2 are best

Bare cost motor	**Motor type factor**	**Purchase cost, CE 500**
$4,292	1.3	$5,579

$4,220,778	
0.00	kWh/kg CO_2

Installed cost	**Notes**
$0	Included in intake
$0	Included in intake
$4,220,778	Desal Fig 8.14, microscreen to go with MF/UF
$4,220,778	

$2,236,588	
0.023	kWh/kg CO_2

Installed cost	Notes
$174,049	Seider
$40,460	Seider
$2,022,079	Desal fig 12.11, redid fit as polynomial
$2,236,588	

Pump type factor	Purchase cost, CE 500	Notes
2	$38,716	

Bare cost motor	Motor type factor	Purchase cost, CE 500
$6,923	1.3	$9,000

$467,876	
0.020	kWh/kg CO_2

Installed cost	Notes
$110,931	Seider
$45,747	Seider
$311,198	Desal table 14.23 and following pages
$467,876	

Pump type factor	Purchase cost, CE 500	Notes
1.7	$24,676	

Bare cost motor	Motor type factor	Purchase cost, CE 500
$7,269	1.4	$10,176

$964,465	
2.224	kWh/kg CO_2

Installed cost	Notes
$964,465	
$0	
$964,465	

$8,778,621	
0.371	kWh/kg CO_2

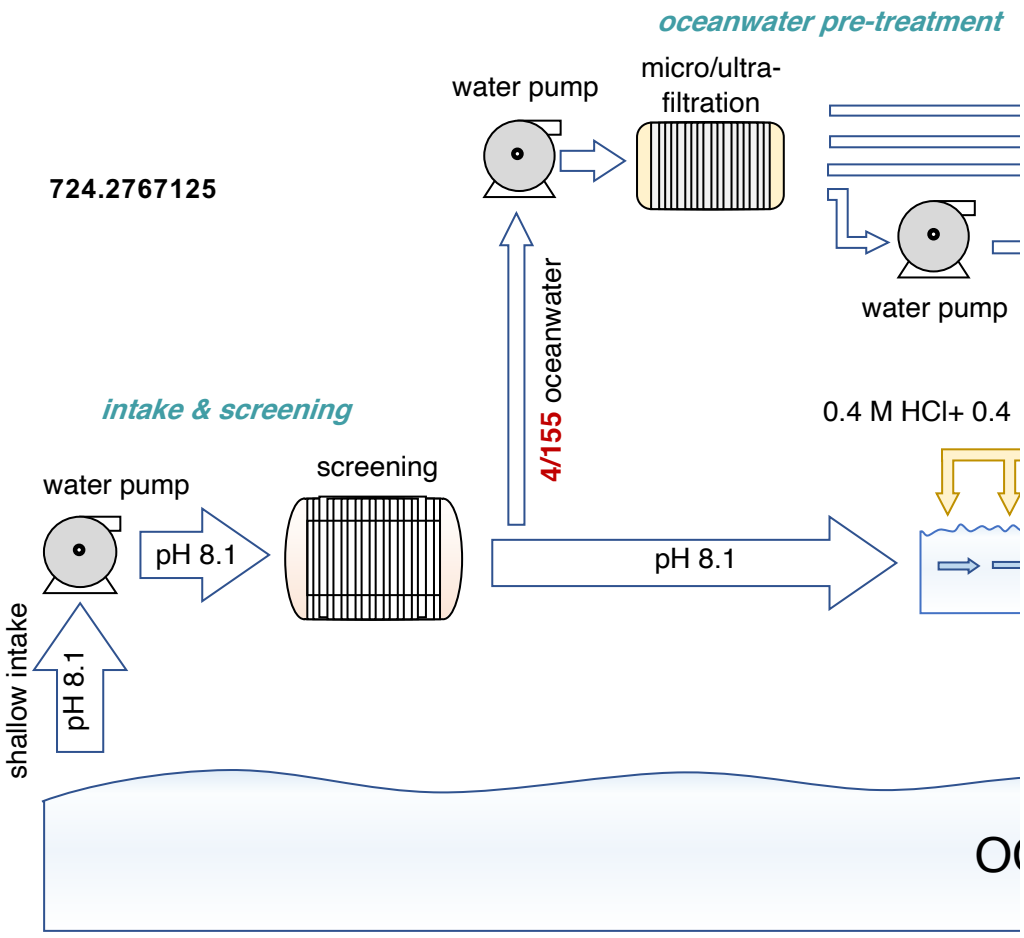
Installed cost	**Notes**
$0	Included in intake
$0	Included in intake
$3,987,500	Liquicell/Eisaman
$138,600	Eisaman
$4,652,521	Seider. Not rounding for ease of lfr/gfr calculation
$8,778,621	

CO_2 pumping speed (kg/s)	**CO2 pumping speed (m^3/day)**	**Unit capacity, OW (m^3/day)**
0.07	240,000	80,095

Electrical efficiency	**Pump energy usage (kWh/kg CO_2)**	
82%	0.371	Power consumption is the work
		Since the pressure is the partial

20.72306306	vacuum
82.5	membrane contactor

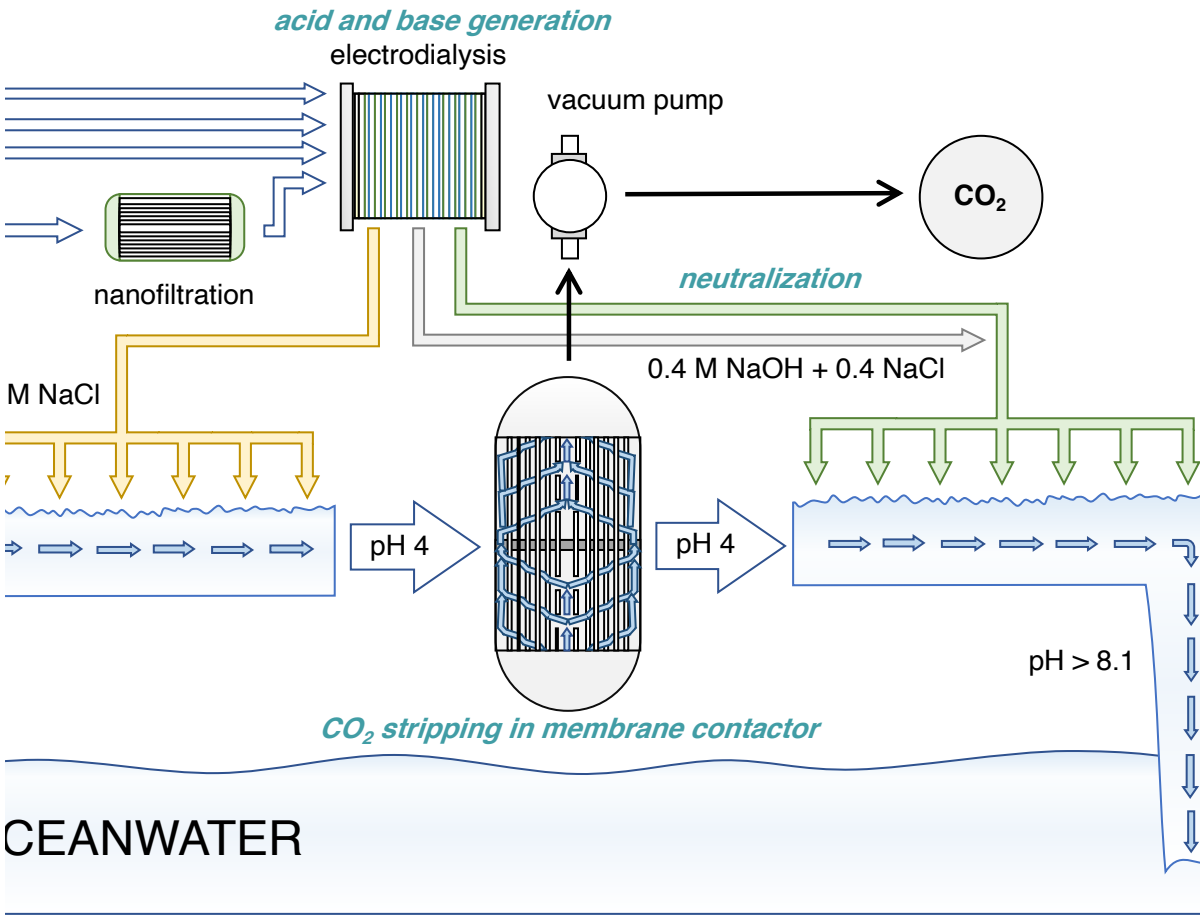
ɔrr


oceanwater pre-treatment
water pump
micro/ultra-
filtration
724.2767125
water pump
4/155 oceanwater
intake & screening
0.4 M HCl+ 0.4
water pump
screening
pH 8.1
pH 8.1
shallow intake
pH 8.1

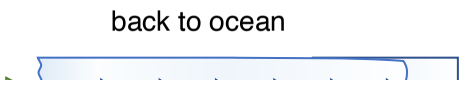
Assuming CTN=1

1.578282828

of adiabatic compression. Note that this is for ALL pumps, not just for one pump – multiplied by # pressure of CO_2, we don't need to multiply by the fraction of the gas that is CO_2 (Dalton's Law).


acid and base generation
electrodialysis
vacuum pump
CO_2
nanofiltration
neutralization
0.4 M NaOH + 0.4 NaCl
M NaCl
pH 4
pH 4
pH > 8.1
CO_2 stripping in membrane contactor
CEANWATER

of pumps.


back to ocean

CO_2 Price 138.152 $/ton CO_2

CO2 Concentration		
DIC concentration	2.20E-03	mol/L
CO_2 molar mass	4.40E-02	kg/mol
Density seawater	8.68	lb/gallon

Oceanwater Flow Rate (At a given extraction efficiency)		
m^3/day	400,000	m^3/day
m^3/h	16,667	m^3/h
gal/min	73,381	gal/min
MGD	106	MGD
L/s	4,630	L/s

CO2 Production Rate (At a given extraction efficiency)		
tons/yr	11,306	tons/year
kg/day	30,976	kg CO_2/day
ft/min	657	m^3 CO_2/h
mol/s	8.15	mol/s
kmol/hr	29.33	kmol/hr
kg/s	0.36	kg/s

CO_2 to H+ and Oceanwater Inverconversions		
Oceanwater volume to extract	7.74E-05	kg/L (ss)
Oceanwater volume to extracte	25.37	L_{OW}/L_{CO2}
Oceanwater volume to extracte	7.74E-02	kg/m^3 (ss)
Moles H+ produced by ED to m	9.94E-01	mol/mol
Moles H+ added to moles CO_2	8.50E-01	mol/mol
Moles H+ added to moles CO_2 e	7.65E-01	mol/mol
Moles H+ added to kg CO_2	3.03E-02	kg/mol

Constants		
R (gas constant)	8.314	J/(K*mol)
T (temperature)	273	K
κCO_2 (adibatic constant of CO_2)	1.3	
κN_2 (adibatic constant of N_2)	1.4	
Faraday's constant	96485.3	As/mol (charge per mol e-s)

Conversions (non-SI to SI, SI/non-SI)		
Liters to cubic meters	1.00E-03	m^3/L

Hours to seconds	3.60E+03	s/hr
Days to minutes	1.44E+03	days/min
Energy in kWh to energy in Joul	3.60E+06	Ws/kWh
Tons to kg	1.00E+03	kg/ton
Bar to pascal	1.00E+05	Pa/bar
Torr to pascal	1.33E+02	Pa/torr
Bar to ft head	3.34E+01	ft head/bar
Gas volume of 1 mol	2.24E+01	L/mol
Gallons to cubic meters	3.79E-03	m^3/gal
Cubic feet to cubic meters	2.83E-02	m^3/ft^3

Radial Centrifugal Pump Types

Seider Table 22.20 Page 561

Type	No. Stages	Shaft rpm
1	1	3600
2	1	1800
3	1	3600
4	1	1800
5	2	3600
6	2	3600

Centrifugal Pump Materials of Construction

Seider Table 22.21 Page 562

Material	Material Factor
Cast iron	1
Ductile iron	1.15
Cast steel	1.35
Bronze	1.9
Stainless steel	2
Hastelloy C	2.95
Monel	3.3
Nickel	3.5
Titanium	9.7

Motor Types

Seider Table 22.22 Page 563

Type	Name	Shaft rpm
1	Open, drip-proof	1800
2	Totally enclosed, fan-cooled	1800
3	Explosion-proof	1800
4	Open, drip-proof	3600
5	Totally enclosed, fan-cooled	3600
6	Explosion-proof	3600

Vacuum Pumps

Seider Table 22.32 Page 595 CP=(purchase cost factor)*S^(purchase cost exponent)

Type		Name	Flow rate min (m^3/hr)
	1	One-stage jet ejector	657
	2	Liquid ring pumps	85
	3	Three-stage lobe (roots)	102
	4	Three-stage claw	102
	5	Screw compressors	85

Cost Factors

Item	Factor	Notes
Pumps	3.7	Eisaman Table S1
ED	1.4	Eisaman Table S1
Membrane contactor	2.9	Eisaman Table S1
Water condenser	3.3	Eisaman Table S1
Filters	2.3	Eisaman Table S1
Other	1.3	Desal Table 17.4 (~buildings + e

Membrane Contactors

Permselect & liquicell websites Assuming liquid flow on shell side (more efficient)

Type		Name	Price
	1	Liquicell (PP)	$6,600
	2	Permselect (PDMS)	$1,045

Area	0.25	m^2
Thickness	0.00005	m
Henry's constant	34	mM/atm
CO2 dissolved	2	mM
Head gas	0.06	Atm
Gas permeability	1.10E-12	mol*m/(m^2 s Pa)
Rate	4.36	L/min
	3.24E-05	mol/s

1.025 kg/m3

CO_2 volumetric flow rate	
10	torr
49,941	m^3/h (air, pumping)
0.33	equilibrium lfr/gfr

For STP

Case-split orientation	Flow rate min (gpm)	Flow rate max (gpm)
VSC	50	900
VSC	50	3500
HSC	100	1500
HSC	250	5000
HSC	50	1100
HSC	100	1500

Hp min	Hp Max	Type factor
1	700	0.9
1	250	1.3
1	250	1.7
1	700	1
1	250	1.4
1	250	1.8

Max flow rates updated from:
https://vacaero.com/information-resources/vacuum-pump-technology-education-and-training/103

Flow rate max (m^3/hr)	Purchase cost exponent	Purchase cost factor
657	0.41	1690
10,000	0.35	8250
100,000	0.41	7120
800	0.36	8630
750	0.38	9590

T&S Table 7.5, Fluids	
Equipment erection	0.3
Piping	0.8
Instrumentation & control	0.3
Electrical	0.2
Civil	0.3
Structures & buildings	0.2
Lagging & Paint	0.1
Total ISBL	3.2
Offsites	0.3
D&E	0.3
Contingency	0.3
Total OSBL	1.9
Total	6.1

ɜlectrical)

Area (m^2)	Price per area ($/m^2)	Max liquid flow rate (m^3/hr)
220	$30	80
2.1	$498	0.48

50% CO2
50% H2O
40-50 Torr
Partial pressure of CO2 is 25 Torr

Coincidence that this is the same as the OW flow rate at 35 Torr? Yes

Pump head min (ft)	Pump head max (ft)	Maximum motor Hp
50	400	75
50	200	200
100	450	150
50	500	250
300	1100	250
650	3200	1450

9-an-introduction-to-vacuum-pumps.html

Base pressure (Torr)	Notes	Flow rate min (ft^3/min)	
75	Not possible to separate workin		429
35	Some amount of liquid in output		50
1.00E-03	Low pumping efficiency from atr		60
1.00E-03	""		60
1.00E-02	""		50

Use to compare to ID
1.00
1.25
1.00
1.00
1.00
1.00

Max flow rate (m^3/hr/m^2)	Volume (m^3)	Max lfr (1/min)	
0.36	0.035		38
0.23	8.83E-04		9

Type Factor
1
1.5
1.7
2
2.7
8.9

Flow rate max (ft^3/min)
429
350
240
270
350

Packing fraction (m^2/m^3)	Thickness (m)
6,286	3.00E-05
2,377	5.50E-05

DIC	0.0022		K1	1.38038E-06		K2	1.20226E-09
new titration data							
equilibrium concentrations							change in H+ io
CO_2	HCO_3^-	CO_3^{2-}	H^+	OH^-	pH	CO_2	HCO_3^-
2.20E-03	3.04E-09	3.65E-18	1.00	6.03E-14	0		-1.90E-03
2.20E-03	3.82E-09	5.79E-18	0.79	7.59E-14	0.1		-1.90E-03
2.20E-03	4.81E-09	9.17E-18	0.63	9.55E-14	0.2		-1.90E-03
2.20E-03	6.06E-09	1.45E-17	0.50	1.20E-13	0.3		-1.90E-03
2.20E-03	7.63E-09	2.30E-17	3.98E-01	1.51E-13	0.4		-1.90E-03
2.20E-03	9.60E-09	3.65E-17	3.16E-01	1.91E-13	0.5		-1.90E-03
2.20E-03	1.21E-08	5.79E-17	2.51E-01	2.40E-13	0.6		-1.90E-03
2.20E-03	1.52E-08	9.17E-17	2.00E-01	3.02E-13	0.7		-1.90E-03
2.20E-03	1.92E-08	1.45E-16	1.58E-01	3.80E-13	0.8		-1.90E-03
2.20E-03	2.41E-08	2.30E-16	1.26E-01	4.79E-13	0.9		-1.90E-03
2.20E-03	3.04E-08	3.65E-16	1.00E-01	6.03E-13	1		-1.90E-03
2.20E-03	3.82E-08	5.79E-16	7.94E-02	7.59E-13	1.1		-1.90E-03
2.20E-03	4.81E-08	9.17E-16	6.31E-02	9.55E-13	1.2		-1.90E-03
2.20E-03	6.06E-08	1.45E-15	5.01E-02	1.20E-12	1.3		-1.90E-03
2.20E-03	7.63E-08	2.30E-15	3.98E-02	1.51E-12	1.4		-1.90E-03
2.20E-03	9.60E-08	3.65E-15	3.16E-02	1.91E-12	1.5		-1.90E-03
2.20E-03	1.21E-07	5.79E-15	2.51E-02	2.40E-12	1.6		-1.90E-03
2.20E-03	1.52E-07	9.17E-15	2.00E-02	3.02E-12	1.7		-1.90E-03
2.20E-03	1.92E-07	1.45E-14	1.58E-02	3.80E-12	1.8		-1.90E-03
2.20E-03	2.41E-07	2.30E-14	1.26E-02	4.79E-12	1.9		-1.90E-03
2.20E-03	3.04E-07	3.65E-14	1.00E-02	6.03E-12	2		-1.90E-03
2.20E-03	3.82E-07	5.79E-14	7.94E-03	7.59E-12	2.1		-1.90E-03
2.20E-03	4.81E-07	9.17E-14	6.31E-03	9.55E-12	2.2		-1.90E-03
2.20E-03	6.06E-07	1.45E-13	5.01E-03	1.20E-11	2.3		-1.90E-03
2.20E-03	7.63E-07	2.30E-13	3.98E-03	1.51E-11	2.4		-1.90E-03
2.20E-03	9.60E-07	3.65E-13	3.16E-03	1.91E-11	2.5		-1.90E-03
2.20E-03	1.21E-06	5.78E-13	2.51E-03	2.40E-11	2.6		-1.90E-03
2.20E-03	1.52E-06	9.16E-13	2.00E-03	3.02E-11	2.7		-1.90E-03
2.20E-03	1.91E-06	1.45E-12	1.58E-03	3.80E-11	2.8		-1.90E-03
2.20E-03	2.41E-06	2.30E-12	1.26E-03	4.79E-11	2.9		-1.90E-03
2.20E-03	3.03E-06	3.65E-12	1.00E-03	6.03E-11	3		-1.90E-03
2.20E-03	3.82E-06	5.78E-12	7.94E-04	7.59E-11	3.1		-1.90E-03
2.20E-03	4.80E-06	9.15E-12	6.31E-04	9.55E-11	3.2		-1.90E-03
2.19E-03	6.04E-06	1.45E-11	5.01E-04	1.20E-10	3.3		-1.90E-03
2.19E-03	7.60E-06	2.30E-11	3.98E-04	1.51E-10	3.4		-1.89E-03
2.19E-03	9.56E-06	3.64E-11	3.16E-04	1.91E-10	3.5		-1.89E-03
2.19E-03	1.20E-05	5.75E-11	2.51E-04	2.40E-10	3.6		-1.89E-03
2.18E-03	1.51E-05	9.11E-11	2.00E-04	3.02E-10	3.7		-1.89E-03
2.18E-03	1.90E-05	1.44E-10	1.58E-04	3.80E-10	3.8		-1.88E-03
2.18E-03	2.39E-05	2.28E-10	1.26E-04	4.79E-10	3.9		-1.88E-03
2.17E-03	3.00E-05	3.60E-10	1.00E-04	6.03E-10	4		-1.87E-03
2.16E-03	3.76E-05	5.69E-10	7.94328E-05	7.59E-10	4.1		-1.86E-03
2.15E-03	4.71E-05	8.97E-10	6.30957E-05	9.55E-10	4.2		-1.85E-03
2.14E-03	5.90E-05	1.41E-09	5.01187E-05	1.20E-09	4.3		-1.84E-03
2.13E-03	7.37E-05	2.23E-09	3.98107E-05	1.51E-09	4.4		-1.83E-03
2.11E-03	9.20E-05	3.50E-09	3.16228E-05	1.91E-09	4.5		-1.81E-03
2.09E-03	1.15E-04	5.49E-09	2.51189E-05	2.40E-09	4.6		-1.79E-03

2.06E-03	1.42E-04	8.58E-09	1.99526E-05	3.02E-09	4.7		-1.76E-03
2.02E-03	1.76E-04	1.34E-08	1.58489E-05	3.80E-09	4.8		-1.73E-03
1.98E-03	2.17E-04	2.08E-08	1.25893E-05	4.79E-09	4.9		-1.68E-03
1.93E-03	2.67E-04	3.21E-08	0.00001	6.03E-09	5		-1.63E-03
1.87E-03	3.26E-04	4.93E-08	7.94328E-06	7.59E-09	5.1		-1.58E-03
1.81E-03	3.95E-04	7.52E-08	6.30957E-06	9.55E-09	5.2		-1.51E-03
1.72E-03	4.75E-04	1.14E-07	5.01187E-06	1.20E-08	5.3		-1.43E-03
1.63E-03	5.66E-04	1.71E-07	3.98107E-06	1.51E-08	5.4		-1.33E-03
1.53E-03	6.68E-04	2.54E-07	3.16228E-06	1.91E-08	5.5		-1.23E-03
1.42E-03	7.80E-04	3.73E-07	2.51189E-06	2.40E-08	5.6		-1.12E-03
1.30E-03	8.99E-04	5.42E-07	1.99526E-06	3.02E-08	5.7		-1.00E-03
1.18E-03	1.02E-03	7.77E-07	1.58489E-06	3.80E-08	5.8		-8.78E-04
1.05E-03	1.15E-03	1.10E-06	1.25893E-06	4.79E-08	5.9		-7.51E-04
9.24E-04	1.27E-03	1.53E-06	0.000001	6.03E-08	6		-6.26E-04
8.03E-04	1.40E-03	2.11E-06	7.94328E-07	7.59E-08	6.1		-5.06E-04
6.89E-04	1.51E-03	2.87E-06	6.30957E-07	9.55E-08	6.2		-3.93E-04
5.85E-04	1.61E-03	3.86E-06	5.01187E-07	1.20E-07	6.3		-2.90E-04
4.91E-04	1.70E-03	5.14E-06	3.98107E-07	1.51E-07	6.4		-1.98E-04
4.09E-04	1.78E-03	6.78E-06	3.16228E-07	1.91E-07	6.5		-1.17E-04
3.37E-04	1.85E-03	8.87E-06	2.51189E-07	2.40E-07	6.6		-4.75E-05
2.76E-04	1.91E-03	1.15E-05	1.99526E-07	3.02E-07	6.7		1.08E-05
2.25E-04	1.96E-03	1.49E-05	1.58489E-07	3.80E-07	6.8		5.88E-05
1.82E-04	2.00E-03	1.91E-05	1.25893E-07	4.79E-07	6.9		9.73E-05
1.47E-04	2.03E-03	2.44E-05	0.0000001	6.03E-07	7		1.27E-04
1.18E-04	2.05E-03	3.10E-05	7.94328E-08	7.59E-07	7.1		1.50E-04
9.44E-05	2.07E-03	3.94E-05	6.30957E-08	9.55E-07	7.2		1.65E-04
7.53E-05	2.07E-03	4.98E-05	5.01187E-08	1.20E-06	7.3		1.74E-04
5.99E-05	2.08E-03	6.27E-05	3.98107E-08	1.51E-06	7.4		1.76E-04
4.75E-05	2.07E-03	7.88E-05	3.16228E-08	1.91E-06	7.5		1.72E-04
3.76E-05	2.06E-03	9.88E-05	2.51189E-08	2.40E-06	7.6		1.62E-04
2.96E-05	2.05E-03	1.23E-04	1.99526E-08	3.02E-06	7.7		1.46E-04
2.32E-05	2.02E-03	1.53E-04	1.58489E-08	3.80E-06	7.8		1.22E-04
1.82E-05	1.99E-03	1.90E-04	1.25893E-08	4.79E-06	7.9		9.03E-05
1.41E-05	1.95E-03	2.35E-04	0.00000001	6.03E-06	8		5.00E-05
1.09E-05	1.90E-03	2.88E-04	7.94328E-09	7.59E-06	8.1	0.00E+00	0.00E+00
8.41E-06	1.84E-03	3.51E-04	6.30957E-09	9.55E-06	8.2	5.05E-06	-6.05E-05
6.42E-06	1.77E-03	4.24E-04	5.01187E-09	1.20E-05	8.3	9.03E-06	-1.32E-04
4.86E-06	1.69E-03	5.09E-04	3.98107E-09	1.51E-05	8.4	1.22E-05	-2.15E-04
3.65E-06	1.59E-03	6.05E-04	3.16228E-09	1.91E-05	8.5	1.46E-05	-3.10E-04
2.70E-06	1.49E-03	7.11E-04	2.51189E-09	2.40E-05	8.6	1.65E-05	-4.15E-04
1.98E-06	1.37E-03	8.26E-04	1.99526E-09	3.02E-05	8.7	1.79E-05	-5.30E-04
1.44E-06	1.25E-03	9.48E-04	1.58489E-09	3.80E-05	8.8	1.90E-05	-6.51E-04
1.03E-06	1.12E-03	1.07E-03	1.25893E-09	4.79E-05	8.9	1.98E-05	-7.76E-04
7.23E-07	9.99E-04	1.20E-03	0.000000001	6.03E-05	9	2.04E-05	-9.03E-04
5.04E-07	8.75E-04	1.32E-03	7.94328E-10	7.59E-05	9.1	2.09E-05	-1.03E-03
3.46E-07	7.57E-04	1.44E-03	6.30957E-10	9.55E-05	9.2	2.12E-05	-1.14E-03
2.35E-07	6.47E-04	1.55E-03	5.01187E-10	1.20E-04	9.3	2.14E-05	-1.25E-03
1.58E-07	5.47E-04	1.65E-03	3.98107E-10	1.51E-04	9.4	2.16E-05	-1.35E-03
1.05E-07	4.58E-04	1.74E-03	3.16228E-10	1.91E-04	9.5	2.17E-05	-1.44E-03
6.92E-08	3.80E-04	1.82E-03	2.51189E-10	2.40E-04	9.6	2.17E-05	-1.52E-03
4.53E-08	3.13E-04	1.89E-03	1.99526E-10	3.02E-04	9.7	2.18E-05	-1.59E-03
2.94E-08	2.56E-04	1.94E-03	1.58489E-10	3.80E-04	9.8	2.18E-05	-1.65E-03

1.90E-08	2.09E-04	1.99E-03	1.25893E-10	4.79E-04	9.9	2.18E-05	-1.69E-03
1.22E-08	1.69E-04	2.03E-03	1E-10	6.03E-04	10	2.19E-05	-1.73E-03
7.85E-09	1.36E-04	2.06E-03	7.94328E-11	7.59E-04	10.1	2.19E-05	-1.76E-03
5.01E-09	1.10E-04	2.09E-03	6.30957E-11	9.55E-04	10.2	2.19E-05	-1.79E-03
3.20E-09	8.80E-05	2.11E-03	5.01187E-11	1.20E-03	10.3	2.19E-05	-1.81E-03
2.03E-09	7.05E-05	2.13E-03	3.98107E-11	1.51E-03	10.4	2.19E-05	-1.83E-03
1.29E-09	5.64E-05	2.14E-03	3.16228E-11	1.91E-03	10.5	2.19E-05	-1.84E-03
8.19E-10	4.50E-05	2.15E-03	2.51189E-11	2.40E-03	10.6	2.19E-05	-1.86E-03
5.19E-10	3.59E-05	2.16E-03	1.99526E-11	3.02E-03	10.7	2.19E-05	-1.87E-03
3.29E-10	2.86E-05	2.17E-03	1.58489E-11	3.80E-03	10.8	2.19E-05	-1.87E-03
2.08E-10	2.28E-05	2.18E-03	1.25893E-11	4.79E-03	10.9	2.19E-05	-1.88E-03
1.31E-10	1.81E-05	2.18E-03	1E-11	6.03E-03	11	2.19E-05	-1.88E-03
8.31E-11	1.44E-05	2.19E-03	7.94328E-12	7.59E-03	11.1	2.19E-05	-1.89E-03
5.25E-11	1.15E-05	2.19E-03	6.30957E-12	9.55E-03	11.2	2.19E-05	-1.89E-03
3.32E-11	9.13E-06	2.19E-03	5.01187E-12	1.20E-02	11.3	2.19E-05	-1.89E-03
2.09E-11	7.26E-06	2.19E-03	3.98107E-12	1.51E-02	11.4	2.19E-05	-1.89E-03
1.32E-11	5.77E-06	2.19E-03	3.16228E-12	1.91E-02	11.5	2.19E-05	-1.90E-03
8.35E-12	4.59E-06	2.20E-03	2.51189E-12	2.40E-02	11.6	2.19E-05	-1.90E-03
5.27E-12	3.65E-06	2.20E-03	1.99526E-12	3.02E-02	11.7	2.19E-05	-1.90E-03
3.33E-12	2.90E-06	2.20E-03	1.58489E-12	3.80E-02	11.8	2.19E-05	-1.90E-03
2.10E-12	2.30E-06	2.20E-03	1.25893E-12	4.79E-02	11.9	2.19E-05	-1.90E-03
1.32E-12	1.83E-06	2.20E-03	1E-12	6.03E-02	12	2.19E-05	-1.90E-03
8.36E-13	1.45E-06	2.20E-03	7.94328E-13	7.59E-02	12.1	2.19E-05	-1.90E-03
5.27E-13	1.15E-06	2.20E-03	6.30957E-13	9.55E-02	12.2	2.19E-05	-1.90E-03
3.33E-13	9.17E-07	2.20E-03	5.01187E-13	1.20E-01	12.3	2.19E-05	-1.90E-03
2.10E-13	7.28E-07	2.20E-03	3.98107E-13	1.51E-01	12.4	2.19E-05	-1.90E-03
1.33E-13	5.79E-07	2.20E-03	3.16228E-13	1.91E-01	12.5	2.19E-05	-1.90E-03
8.36E-14	4.60E-07	2.20E-03	2.51189E-13	2.40E-01	12.6	2.19E-05	-1.90E-03
5.28E-14	3.65E-07	2.20E-03	1.99526E-13	3.02E-01	12.7	2.19E-05	-1.90E-03
3.33E-14	2.90E-07	2.20E-03	1.58489E-13	3.80E-01	12.8	2.19E-05	-1.90E-03
2.10E-14	2.30E-07	2.20E-03	1.25893E-13	4.79E-01	12.9	2.19E-05	-1.90E-03
1.33E-14	1.83E-07	2.20E-03	1E-13	6.03E-01	13	2.19E-05	-1.90E-03
8.36E-15	1.45E-07	2.20E-03	7.94328E-14	7.59E-01	13.1	2.19E-05	-1.90E-03
5.28E-15	1.15E-07	2.20E-03	6.30957E-14	9.55E-01	13.2	2.19E-05	-1.90E-03
3.33E-15	9.17E-08	2.20E-03	5.01187E-14	1.20E+00	13.3	2.19E-05	-1.90E-03
2.10E-15	7.28E-08	2.20E-03	3.98107E-14	1.51E+00	13.4	2.19E-05	-1.90E-03
1.33E-15	5.79E-08	2.20E-03	3.16228E-14	1.91E+00	13.5	2.19E-05	-1.90E-03
8.36E-16	4.60E-08	2.20E-03	2.51189E-14	2.40E+00	13.6	2.19E-05	-1.90E-03
5.28E-16	3.65E-08	2.20E-03	1.99526E-14	3.02E+00	13.7	2.19E-05	-1.90E-03
3.33E-16	2.90E-08	2.20E-03	1.58489E-14	3.80E+00	13.8	2.19E-05	-1.90E-03
2.10E-16	2.30E-08	2.20E-03	1.25893E-14	4.79E+00	13.9	2.19E-05	-1.90E-03
1.33E-16	1.83E-08	2.20E-03	1E-14	6.03E+00	14	2.19E-05	-1.90E-03

ons due to this species from pH 8.1

CO_3^{2-}	H^+	OH^-	H^+ / OH− added	1/*x* process	x processe	Extractable	Extraction E
-5.76E-04	1.00E+00	-7.59E-06	1.00E+00			0.00	100%
-5.76E-04	7.94E-01	-7.59E-06	7.97E-01			0.00	100%
-5.76E-04	6.31E-01	-7.59E-06	6.33E-01			0.00	100%
-5.76E-04	5.01E-01	-7.59E-06	5.04E-01			0.00	100%
-5.76E-04	3.98E-01	-7.59E-06	4.01E-01	1.0	1.01E+00	0.01	100%
-5.76E-04	3.16E-01	-7.59E-06	3.19E-01	1.2	8.01E-01	0.01	100%
-5.76E-04	2.51E-01	-7.59E-06	2.54E-01	1.6	6.37E-01	0.01	100%
-5.76E-04	2.00E-01	-7.59E-06	2.02E-01	2.0	5.07E-01	0.01	100%
-5.76E-04	1.58E-01	-7.59E-06	1.61E-01	2.5	4.04E-01	0.01	100%
-5.76E-04	1.26E-01	-7.59E-06	1.28E-01	3.1	3.22E-01	0.02	100%
-5.76E-04	1.00E-01	-7.59E-06	1.02E-01	3.9	2.57E-01	0.02	100%
-5.76E-04	7.94E-02	-7.59E-06	8.19E-02	4.9	2.06E-01	0.03	100%
-5.76E-04	6.31E-02	-7.59E-06	6.56E-02	6.1	1.65E-01	0.03	100%
-5.76E-04	5.01E-02	-7.59E-06	5.26E-02	7.6	1.32E-01	0.04	100%
-5.76E-04	3.98E-02	-7.59E-06	4.23E-02	9.4	1.06E-01	0.05	100%
-5.76E-04	3.16E-02	-7.59E-06	3.41E-02	11.7	8.57E-02	0.06	100%
-5.76E-04	2.51E-02	-7.59E-06	2.76E-02	14.4	6.93E-02	0.08	100%
-5.76E-04	2.00E-02	-7.59E-06	2.24E-02	17.7	5.64E-02	0.10	100%
-5.76E-04	1.58E-02	-7.59E-06	1.83E-02	21.7	4.61E-02	0.12	100%
-5.76E-04	1.26E-02	-7.59E-06	1.51E-02	26.4	3.79E-02	0.15	100%
-5.76E-04	1.00E-02	-7.59E-06	1.25E-02	31.9	3.14E-02	0.18	100%
-5.76E-04	7.94E-03	-7.59E-06	1.04E-02	38.2	2.62E-02	0.21	100%
-5.76E-04	6.31E-03	-7.59E-06	8.79E-03	45.3	2.21E-02	0.25	100%
-5.76E-04	5.01E-03	-7.59E-06	7.50E-03	53.1	1.88E-02	0.29	100%
-5.76E-04	3.98E-03	-7.59E-06	6.46E-03	61.6	1.62E-02	0.34	100%
-5.76E-04	3.16E-03	-7.59E-06	5.65E-03	70.5	1.42E-02	0.39	100%
-5.76E-04	2.51E-03	-7.59E-06	5.00E-03	79.7	1.25E-02	0.44	100%
-5.76E-04	2.00E-03	-7.59E-06	4.48E-03	88.9	1.12E-02	0.49	100%
-5.76E-04	1.58E-03	-7.59E-06	4.07E-03	97.9	1.02E-02	0.54	100%
-5.76E-04	1.26E-03	-7.59E-06	3.74E-03	106.4	9.40E-03	0.59	100%
-5.76E-04	1.00E-03	-7.59E-06	3.48E-03	114.4	8.74E-03	0.63	100%
-5.76E-04	7.94E-04	-7.59E-06	3.27E-03	121.6	8.23E-03	0.67	100%
-5.76E-04	6.31E-04	-7.59E-06	3.11E-03	128.0	7.81E-03	0.71	100%
-5.76E-04	5.01E-04	-7.59E-06	2.98E-03	133.6	7.48E-03	0.74	100%
-5.76E-04	3.98E-04	-7.59E-06	2.87E-03	138.5	7.22E-03	0.76	100%
-5.76E-04	3.16E-04	-7.59E-06	2.79E-03	142.6	7.01E-03	0.78	100%
-5.76E-04	2.51E-04	-7.59E-06	2.72E-03	146.2	6.84E-03	0.80	99%
-5.76E-04	2.00E-04	-7.59E-06	2.67E-03	149.2	6.70E-03	0.82	99%
-5.76E-04	1.58E-04	-7.59E-06	2.62E-03	151.7	6.59E-03	0.83	99%
-5.76E-04	1.26E-04	-7.59E-06	2.59E-03	153.9	6.50E-03	0.84	99%
-5.76E-04	1.00E-04	-7.59E-06	2.55E-03	155.8	6.42E-03	0.85	99%
-5.76E-04	7.94E-05	-7.59E-06	2.53E-03	157.6	6.35E-03	0.86	98%
-5.76E-04	6.31E-05	-7.58E-06	2.50E-03	159.2	6.28E-03	0.86	98%
-5.76E-04	5.01E-05	-7.58E-06	2.48E-03	160.8	6.22E-03	0.86	97%
-5.76E-04	3.98E-05	-7.58E-06	2.45E-03	162.5	6.16E-03	0.87	97%
-5.76E-04	3.16E-05	-7.58E-06	2.42E-03	164.2	6.09E-03	0.87	96%
-5.76E-04	2.51E-05	-7.58E-06	2.39E-03	166.2	6.02E-03	0.87	95%

-5.76E-04	1.99E-05	-7.58E-06	2.36E-03	168.5	5.93E-03	0.87	94%
-5.76E-04	1.58E-05	-7.58E-06	2.32E-03	171.3	5.84E-03	0.87	92%
-5.76E-04	1.26E-05	-7.58E-06	2.28E-03	174.6	5.73E-03	0.87	90%
-5.75E-04	9.99E-06	-7.58E-06	2.23E-03	178.7	5.60E-03	0.87	88%
-5.75E-04	7.94E-06	-7.58E-06	2.17E-03	183.8	5.44E-03	0.87	85%
-5.75E-04	6.30E-06	-7.58E-06	2.10E-03	190.0	5.26E-03	0.86	82%
-5.75E-04	5.00E-06	-7.57E-06	2.01E-03	197.7	5.06E-03	0.86	78%
-5.75E-04	3.97E-06	-7.57E-06	1.92E-03	207.2	4.83E-03	0.85	74%
-5.75E-04	3.15E-06	-7.57E-06	1.82E-03	218.9	4.57E-03	0.84	70%
-5.75E-04	2.50E-06	-7.56E-06	1.71E-03	233.3	4.29E-03	0.83	65%
-5.74E-04	1.99E-06	-7.56E-06	1.59E-03	251.0	3.98E-03	0.82	59%
-5.74E-04	1.58E-06	-7.55E-06	1.46E-03	272.6	3.67E-03	0.80	53%
-5.73E-04	1.25E-06	-7.54E-06	1.33E-03	298.6	3.35E-03	0.79	48%
-5.72E-04	9.92E-07	-7.53E-06	1.21E-03	329.7	3.03E-03	0.76	42%
-5.71E-04	7.86E-07	-7.51E-06	1.09E-03	366.6	2.73E-03	0.74	36%
-5.70E-04	6.23E-07	-7.49E-06	9.71E-04	409.9	2.44E-03	0.71	31%
-5.68E-04	4.93E-07	-7.47E-06	8.66E-04	459.8	2.18E-03	0.68	27%
-5.65E-04	3.90E-07	-7.43E-06	7.71E-04	516.5	1.94E-03	0.64	22%
-5.62E-04	3.08E-07	-7.40E-06	6.87E-04	579.9	1.72E-03	0.60	19%
-5.58E-04	2.43E-07	-7.35E-06	6.13E-04	649.6	1.54E-03	0.55	15%
-5.53E-04	1.92E-07	-7.28E-06	5.49E-04	724.9	1.38E-03	0.50	13%
-5.46E-04	1.51E-07	-7.21E-06	4.94E-04	805.3	1.24E-03	0.46	10%
-5.37E-04	1.18E-07	-7.11E-06	4.47E-04	890.1	1.12E-03	0.41	8%
-5.27E-04	9.21E-08	-6.98E-06	4.06E-04	979.4	1.02E-03	0.36	7%
-5.13E-04	7.15E-08	-6.83E-06	3.71E-04	1073.9	9.31E-04	0.32	5%
-4.97E-04	5.52E-08	-6.63E-06	3.39E-04	1175.8	8.50E-04	0.28	4%
-4.76E-04	4.22E-08	-6.38E-06	3.09E-04	1289.1	7.76E-04	0.24	3%
-4.50E-04	3.19E-08	-6.07E-06	2.80E-04	1421.2	7.04E-04	0.21	3%
-4.18E-04	2.37E-08	-5.68E-06	2.51E-04	1584.8	6.31E-04	0.19	2%
-3.78E-04	1.72E-08	-5.19E-06	2.21E-04	1802.9	5.55E-04	0.17	2%
-3.29E-04	1.20E-08	-4.57E-06	1.88E-04	2121.5	4.71E-04	0.16	1%
-2.69E-04	7.91E-09	-3.78E-06	1.50E-04	2647.5	3.78E-04	0.15	1%
-1.95E-04	4.65E-09	-2.80E-06	1.08E-04	3699.9	2.70E-04	0.17	1%
-1.06E-04	2.06E-09	-1.56E-06	5.79E-05	6871.7	1.46E-04	0.24	1%
0.00E+00	0.00E+00	0.00E+00	0.00E+00	#DIV/0!	0.00E+00	#DIV/0!	0%
	-1.63E-09	1.96E-06	5.85E-05			0.14	0%
	-2.93E-09	4.44E-06	1.28E-04			0.05	0%
	-3.96E-09	7.55E-06	2.08E-04			0.02	0%
	-4.78E-09	1.15E-05	2.98E-04			0.01	0%
	-5.43E-09	1.64E-05	3.99E-04			0.01	0%
	-5.95E-09	2.26E-05	5.07E-04			0.00	0%
	-6.36E-09	3.04E-05	6.21E-04			0.00	0%
	-6.68E-09	4.03E-05	7.36E-04			0.00	0%
	-6.94E-09	5.27E-05	8.50E-04			0.00	0%
	-7.15E-09	6.83E-05	9.58E-04			0.00	0%
	-7.31E-09	8.79E-05	1.06E-03			0.00	0%
	-7.44E-09	1.13E-04	1.14E-03			0.00	0%
	-7.55E-09	1.44E-04	1.21E-03			0.00	0%
	-7.63E-09	1.83E-04	1.26E-03			0.00	0%
	-7.69E-09	2.32E-04	1.29E-03			0.00	0%
	-7.74E-09	2.94E-04	1.29E-03			0.00	0%
	-7.78E-09	3.73E-04	1.27E-03			0.00	0%

-7.82E-09	4.71E-04	1.22E-03	0.00	0%
-7.84E-09	5.95E-04	1.14E-03	0.00	0%
-7.86E-09	7.51E-04	1.01E-03	0.00	0%
-7.88E-09	9.47E-04	8.44E-04	0.00	0%
-7.89E-09	1.19E-03	6.19E-04	0.00	0%
-7.90E-09	1.51E-03	3.25E-04	0.00	0%
-7.91E-09	1.90E-03	-5.30E-05	(0.00)	0%
-7.92E-09	2.39E-03	-5.35E-04	(0.00)	0%
-7.92E-09	3.01E-03	-1.15E-03	(0.00)	0%
-7.93E-09	3.79E-03	-1.92E-03	(0.00)	0%
-7.93E-09	4.78E-03	-2.90E-03	(0.00)	0%
-7.93E-09	6.02E-03	-4.13E-03	(0.00)	0%
-7.94E-09	7.58E-03	-5.69E-03	(0.00)	0%
-7.94E-09	9.54E-03	-7.65E-03	(0.00)	0%
-7.94E-09	1.20E-02	-1.01E-02	(0.00)	0%
-7.94E-09	1.51E-02	-1.32E-02	(0.00)	0%
-7.94E-09	1.90E-02	-1.72E-02	(0.00)	0%
-7.94E-09	2.40E-02	-2.21E-02	(0.00)	0%
-7.94E-09	3.02E-02	-2.83E-02	(0.00)	0%
-7.94E-09	3.80E-02	-3.61E-02	(0.00)	0%
-7.94E-09	4.79E-02	-4.60E-02	(0.00)	0%
-7.94E-09	6.02E-02	-5.83E-02	(0.00)	0%
-7.94E-09	7.59E-02	-7.40E-02	(0.00)	0%
-7.94E-09	9.55E-02	-9.36E-02	(0.00)	0%
-7.94E-09	1.20E-01	-1.18E-01	(0.00)	0%
-7.94E-09	1.51E-01	-1.49E-01	(0.00)	0%
-7.94E-09	1.91E-01	-1.89E-01	(0.00)	0%
-7.94E-09	2.40E-01	-2.38E-01	(0.00)	0%
-7.94E-09	3.02E-01	-3.00E-01	(0.00)	0%
-7.94E-09	3.80E-01	-3.78E-01	(0.00)	0%
-7.94E-09	4.79E-01	-4.77E-01	(0.00)	0%
-7.94E-09	6.03E-01	-6.01E-01	(0.00)	0%
-7.94E-09	7.59E-01	-7.57E-01	(0.00)	0%
-7.94E-09	9.55E-01	-9.53E-01	(0.00)	0%
-7.94E-09	1.20E+00	-1.20E+00	(0.00)	0%
-7.94E-09	1.51E+00	-1.51E+00	(0.00)	0%
-7.94E-09	1.91E+00	-1.90E+00	(0.00)	0%
-7.94E-09	2.40E+00	-2.40E+00	(0.00)	0%
-7.94E-09	3.02E+00	-3.02E+00	(0.00)	0%
-7.94E-09	3.80E+00	-3.80E+00	(0.00)	0%
-7.94E-09	4.79E+00	-4.78E+00	(0.00)	0%
-7.94E-09	6.03E+00	-6.02E+00	(0.00)	0%

L OW/kg CO_2
1.15E+04
1.15E+04
1.15E+04
1.15E+04
1.15E+04
1.15E+04
1.15E+04
1.15E+04
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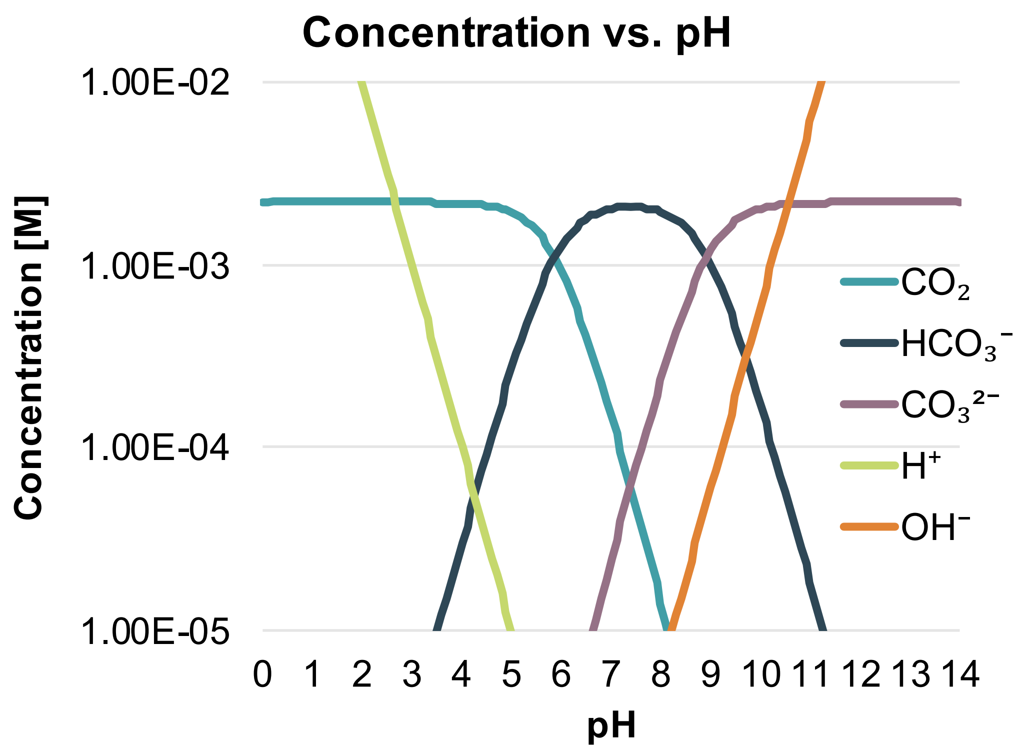
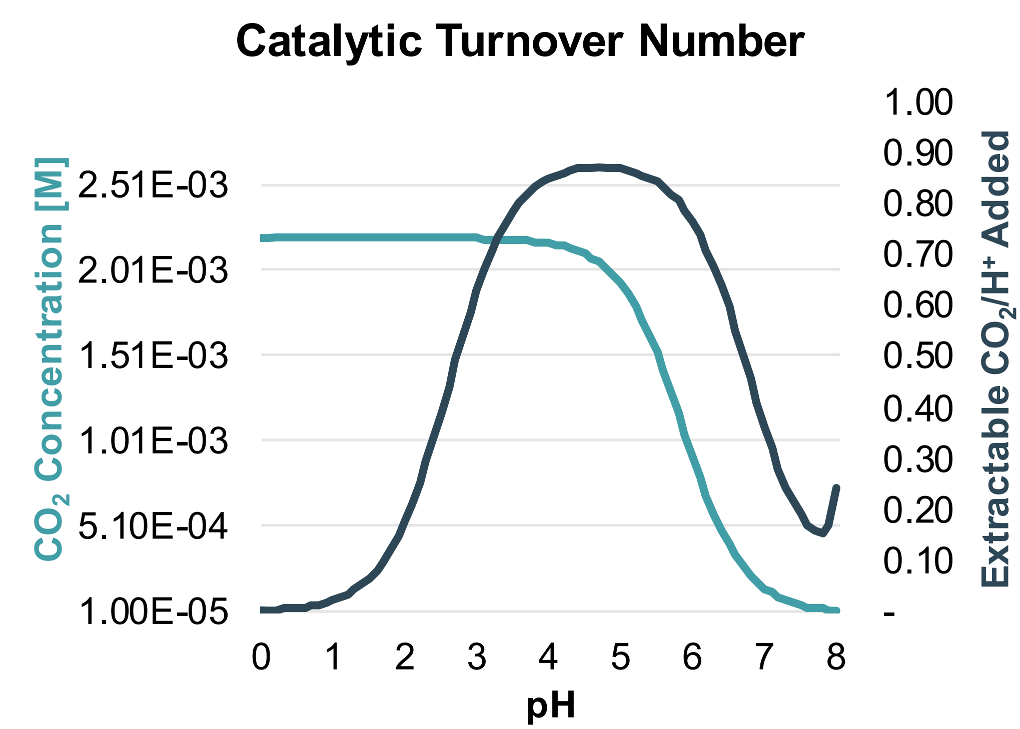
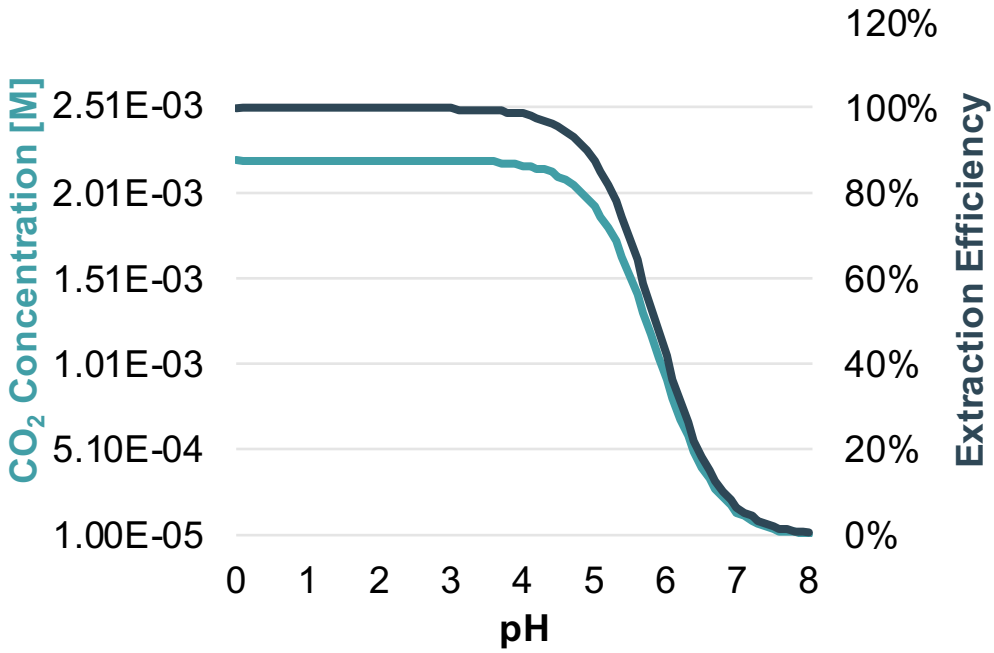
1.17E+04
1.18E+04
1.19E+04
1.20E+04
1.21E+04



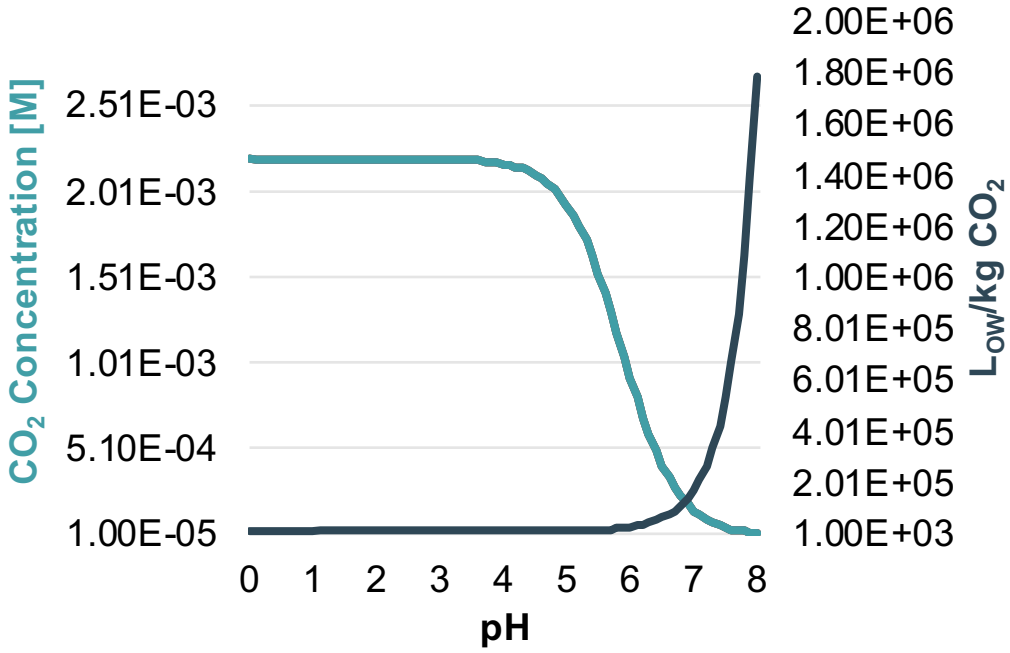


1.23E+04
1.25E+04
1.27E+04
1.31E+04
1.35E+04
1.40E+04
1.46E+04
1.55E+04
1.65E+04
1.78E+04
1.94E+04
2.15E+04
2.41E+04
2.73E+04
3.15E+04
3.66E+04
4.32E+04
5.14E+04
6.18E+04
7.49E+04
9.14E+04
1.12E+05
1.39E+05
1.72E+05
2.14E+05
2.67E+05
3.35E+05
4.21E+05
5.32E+05
6.72E+05
8.53E+05
1.09E+06
1.39E+06
1.79E+06
2.31E+06
3.00E+06
3.93E+06
5.19E+06
6.93E+06
9.34E+06
1.27E+07
1.76E+07
2.46E+07
3.49E+07
5.02E+07
7.30E+07
1.07E+08
1.60E+08
2.41E+08
3.65E+08
5.58E+08
8.58E+08

Extraction Efficiency

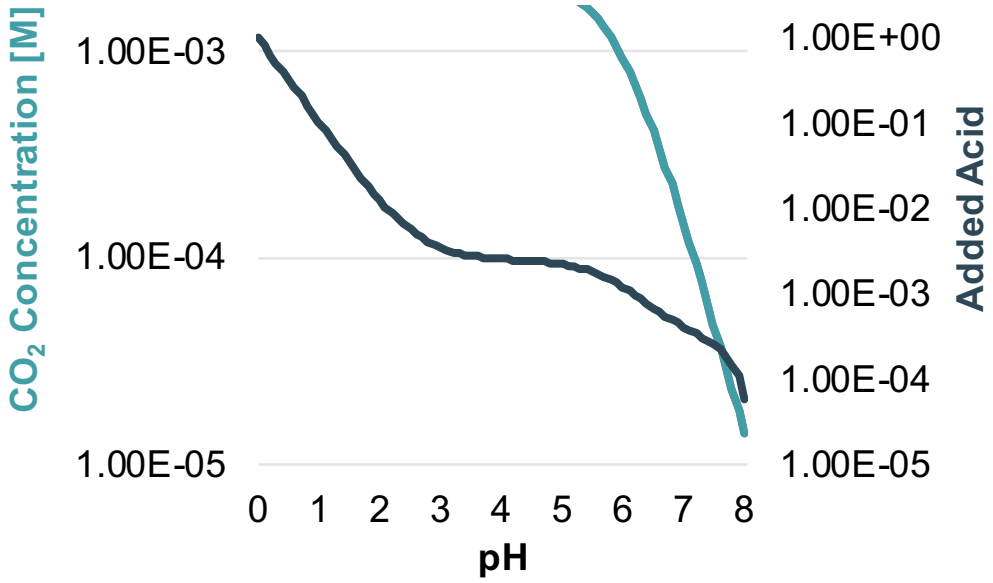


Oceanwater Volume



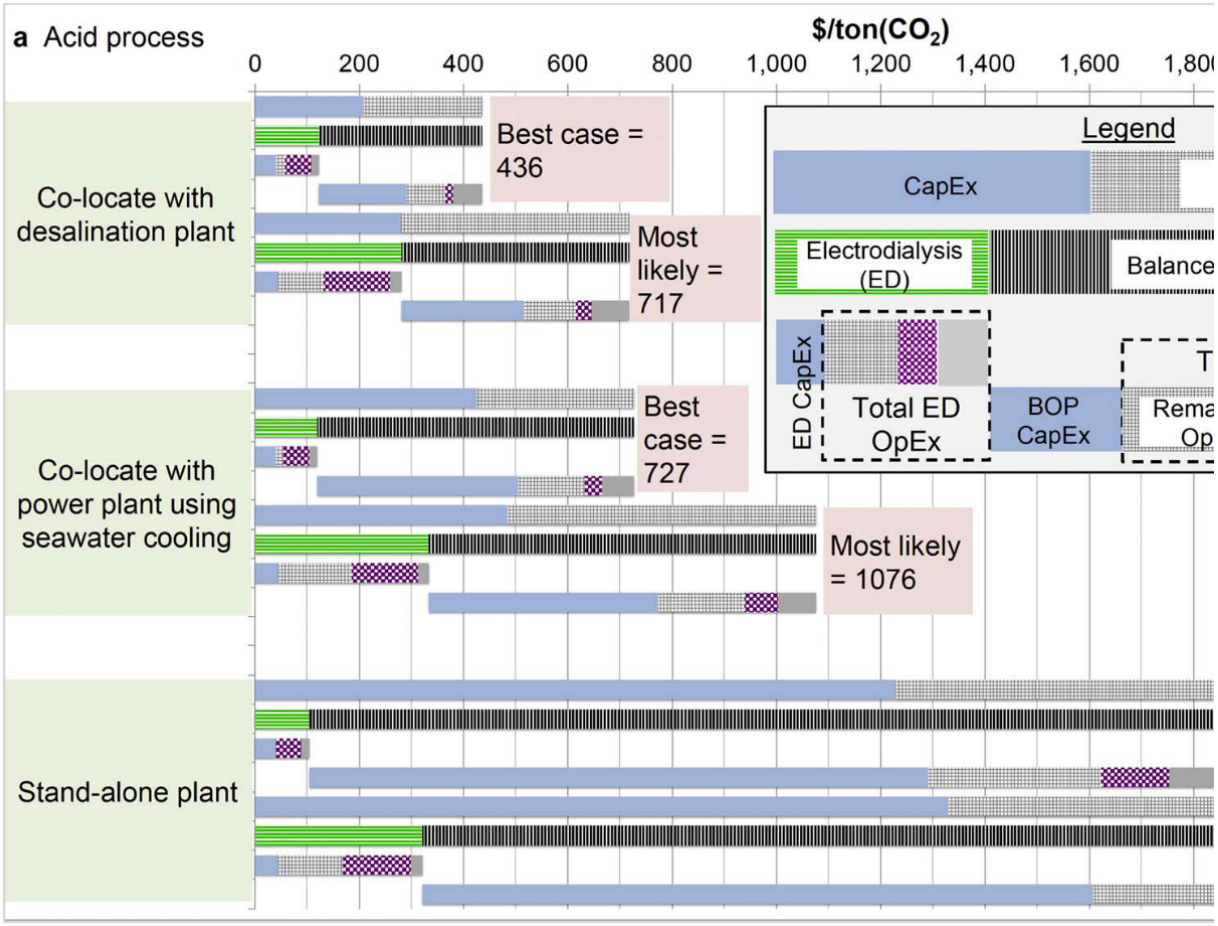
Added Acid vs. pH

1.33E+09
2.06E+09
3.22E+09
5.04E+09
7.90E+09
1.24E+10
1.96E+10
3.08E+10
4.86E+10
7.68E+10
1.21E+11
1.92E+11
3.04E+11
4.81E+11
7.62E+11
1.21E+12
1.91E+12
3.03E+12
4.79E+12
7.59E+12
1.20E+13
1.91E+13
3.02E+13
4.79E+13
7.59E+13
1.20E+14
1.91E+14
3.02E+14
4.79E+14
7.58E+14
1.20E+15
1.91E+15
3.02E+15
4.79E+15
7.58E+15
1.20E+16
1.90E+16
3.02E+16
4.79E+16
7.58E+16
1.20E+17
1.90E+17



CO_2 Price 138.152 $/ton CO_2

Eisaman's TEA shows much higher CO_2 cost than ours. Why?



1. Difference in scale

Eisaman:

CO2 Production Rate (At a given extraction efficiency)		
tons/yr	7,709	tons/year
kg/day	21,121	kg CO_2/day
ft/min	264	ft^3 CO_2/min
mol/s	5.56	mol/s
kmol/hr	20.00	kmol/hr
kg/s	0.24	kg/s

Oceanwater Flow Rate (At a given extraction efficiency)		
m^3/day	272,734	m^3/day
m^3/h	11,364	m^3/h
gal/min	50,034	gal/min

MGD	72	MGD
L/s	3,157	L/s

Our costs are relatively close if you compare their co-location, best c

Eisaman

	Capital cost $/ton	Electricity cost $/tor	Replacements $/ton
Electrodialysis	$40.00	$58	$15
BoP	$169.00	$15	$56
Total	$209.00	$73	$71

Us

	Capital cost $/ton	Electricity cost $/tor	Replacements $/ton
Electrodialysis	$34.86	$83.01	$88.07
BoP	$116.94	$34.24	$126.35
Total	$151.79	$117.26	$214.42

2. We assume a floating platform, much smaller intake costs

	Us	Them
Electricity price $/kWh	$0.020	$0.040
MC cost $/m^3/hr	$83	$110
ED membrane cost $/m^2	$400	$460
Intake $M/MGD	$0.45	$0.4
Outfall $M/MGD		$0.5
Pretreatment $M/MGD	$0.90	$0.5

3. We may be underestimating nanofiltration capital costs

Eisaman

Co-location, acid proc

Equipment	Qty	Purch. Cost ($/Unit)	Purch Cost ($)
Membrane contactor CO2	192	$6,930	$1,330,560
Nanofilter	1	$506,500	$506,500
RO Concentrator	1	$822,400	$822,400
Clarifier	1	$69,200	$69,200
Ion exchange	1	$120,700	$120,700
ED package	4	$422,700	$1,690,800
Water condenser	1	$21,000	$21,000
Vacuum pump	1	$316,300	$316,300
Vacuum pump chiller	1	$120,000	$120,000

Us

Equipment	Qty	Purch. Cost ($/Unit)	Purch Cost ($)
Membrane contactor CO2	209	$6,600	$1,379,400
Nanofilter	753	$180	$135,540
RO Concentrator			$0
Clarifier			$0
Ion exchange			$0
ED package	1	$3,444,516	$3,444,516
Water condenser			$0
Vacuum pump	2	$107,930	$251,785
Vacuum pump chiller			$0

We can achieve a pretty good match if we increase CapEx at multiple

Breakdown by Process Step

	Capital cost $/ton	Electricity cost $/tor	Replacements $/ton
Intake	$469.57	$10.47	$0.00
Screening	$304.96	$0.00	$0.00
Microfiltration	$161.60	$0.42	$29.62
Nanofiltration	$33.80	$0.37	$0.00
Electrodialysis	$34.84	$41.51	$88.03
CO2 stripping	$43.37	$5.86	$44.49
Other	$0.00	$0.00	$52.18
Total	$1,048.14	$58.63	$214.32
		Total	$669.23
Eisaman	$1,300	$150	$100

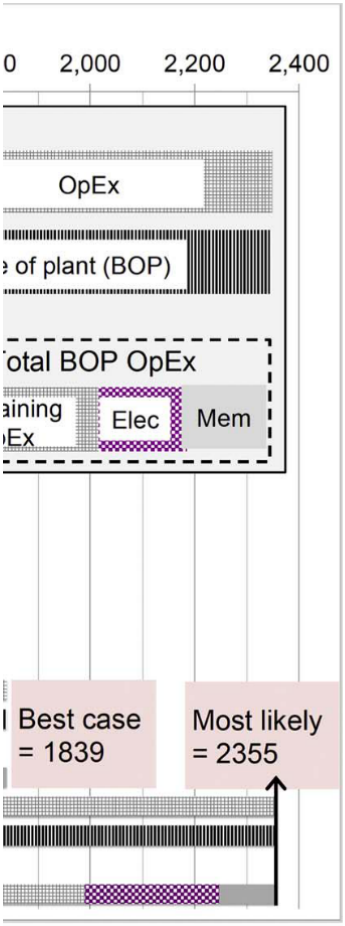
	ED CapEx & Replace	BoP CapEx	ED Electricity
Eisaman	$55	$1,225	$58
Our baseline	$4	$34	$42
Smaller scale	$25	$237	$42
Worse ED performance	$123	$243	$42
Higher electricity price	$123	$243	$102
Onshore intake & outfall	$123	$952	$102
	$4	$43	$46

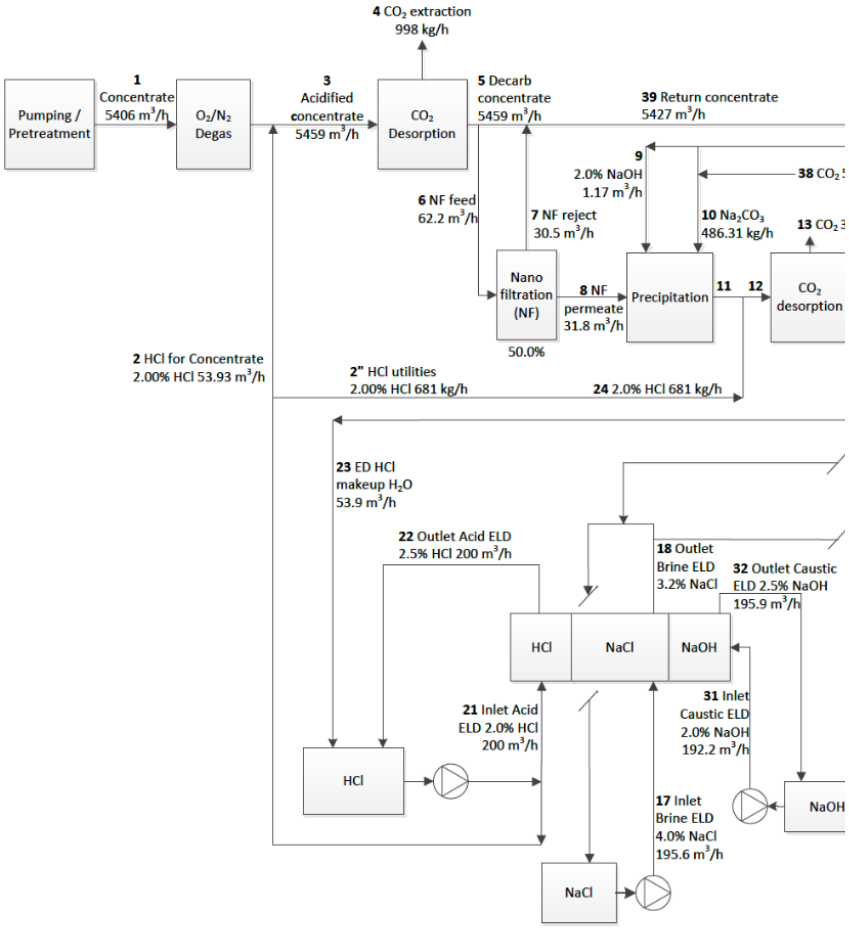
	Capital cost $/ton	Electricity cost $/tor	Replacements $/ton

Electrodialysis	$40.00	$58	$15
BoP	$169.00	$15	$56
Total	$209.00	$73	$71

Breakdown by Process Step	LINKED		
	Capital cost $/ton	Electricity cost $/ton	Replacements $/ton
Intake	$4	$12	$0
Screening	$5	$0	$0
Microfiltration	$2	$0	$5
Nanofiltration	$1	$0	$0
Electrodialysis	$1	$46	$3
CO2 stripping	$10	$8	$10
Other	$0	$0	$8
Total	$22	$66	$25
		Total	$138

Category	Cost breakdown	Contribution to CO2 p	LINKED
CapEx	276377006.3	$22	
Replacements	312736058.6	$25	
Fixed OpEx	269906273.1	$21	
Variable OpEx	836934957.4	$66	
Taxes & Working Capital	49262884.41	$4	





Us:

CO2 Production Rate (At a given extraction efficiency)

tons/yr	1,000,000	tons/year
kg/day	2,739,726	kg CO_2/day
ft/min	34,205	ft^3 CO_2/min
mol/s	720.68	mol/s
kmol/hr	2,594.44	kmol/hr
kg/s	31.71	kg/s

Scale (tons/yr)
7,709
100,000
1,000,000

Oceanwater Flow Rate (At a given extraction efficiency)

m^3/day	35,378,694	m^3/day
m^3/h	1,474,112	m^3/h
gal/min	6,490,320	gal/min

MGD	9,346	MGD
L/s	409,476	L/s

ase to ours (but theirs doesn't include costs of intake & micro/ultrafiltratio

Best case, co-location, acid process

Fixed OpEx $/ton	Waste $/ton
$9	
$54	
$63.00	$20
TOTAL	**$436**

100 mA/cm2, 2.5 V, same scale as theirs

Fixed OpEx $/ton	Waste $/ton
$217	
$216.59	$20
TOTAL	**$720**

Breakdown by Process Step

	Capital cost $/ton
Intake	$23.49
Screening	$30.51
Microfiltration	$16.17
Nanofiltration	$3.38
Electrodialysis	$34.86
CO2 stripping	$43.39
Other	$0.00
Total	$151.79

System cost

	Baseline installed cost in basis year dollars	Baseline installed cost in startup year dollars	Scaled installed cost in startup year dollars
Intake	$3,249,551	$3,249,551	$47,844,550
Screening	$4,220,778	$4,220,778	$62,144,335
Micro/ultrafiltration	$2,236,588	$2,236,588	$32,930,254

ess

Cost Factor	Installed Cost	
2.9	$3,858,624	
2.3	$1,164,950	
2.3	$1,891,520	
4.1	$283,720	
4.1	$494,870	$3,835,060
1.4	$2,367,120	
3.3	$69,300	
3.7	$1,170,310	
2.3	$276,000	

TOTAL	$11,576,414

Cost Factor	**Installed Cost**	
2.9	$4,000,260	
2.3	$311,742	
2.3	$0	needed for demineralized water
4.1	$0	needed for divalent cation removal
4.1	$0	needed for divalent cation removal
1.4	$4,822,322	
3.3	$0	
3.7	$931,605	
2.3	$0	
TOTAL	$10,065,929	

steps

Fixed OpEx; Taxes	
	Increase CapEx by 20x (to include outfall too)
	Increase CapEx by 10x
	Increase CapEx by 10x
	Increase CapEx by 10x
$462.04	Keep labor the same, multiply CapEx by 0.25
$1,783.13	
$300	
$1,850	

BoP Electricity	Fixed OpEx	Check sum	Notes	Total cost
$150	$350	$1,838		$1,839
$17	$21	$117		$115
$17	$210	$531	1 megaton to 7709 tc	$504
$17	$245	$669	500 to 100 mA/cm^2	$587
$42	$246	$756	$0.02 to $0.049/kWh	$677
$42	$663	$1,881	20x intake CapEx	$1,980
$20	$25	$138		

Fixed OpEx $/ton	**Waste $/ton**

a Acid process

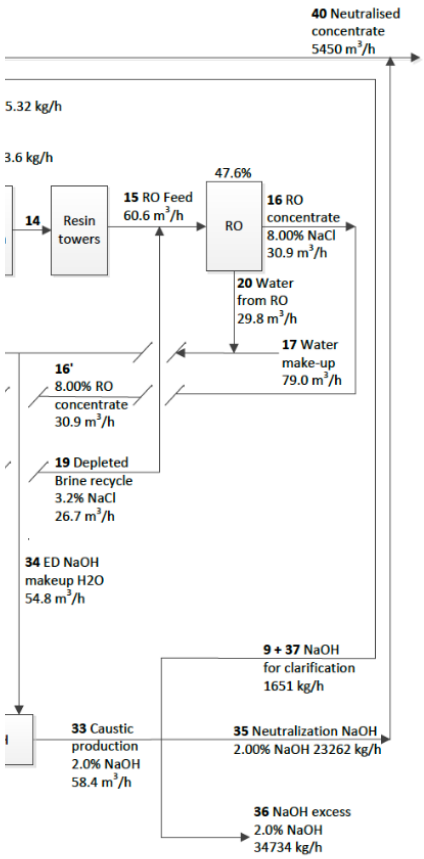
	$9	
	$54	
	$63.00	$20
TOTAL		**$436**

Capital cost %	Electricity cost %	Replacements %
$0	$0	$0
$0	$0	$0
$0	$0	$0
$0	$0	$0
$0	$1	$0
$0	$0	$0
$0	$0	$0
$1	$1	$1

Co-locate with desalination pla

Co-locate with power plant usir seawater coolin

Stand-alone pla



Cost ($/kg)

$667.00 (assuming 100 mA/cm2 and 2.5 V)

$250.02

$163.97