

Innovative Strategies in Sustainable Formaldehyde Production: Integrating Process Optimization, Carbon Capture, and Environmental Assessment

Supplementary Information

Table S1. FORMOX Rate equation of each respective reaction for HYSYS

Reaction	Rate Equation
R2	$\frac{k_{HCHO}K_{CH_3OH}K_{O_2}P_{g,CH_3OH}P_{g,O_2}^{1/2}}{1 + K_{CH_3OH}P_{g,CH_3OH} + K_{H_2O}P_{g,H_2O} + K_{O_2}P_{g,O_2}^{1/2} + K_{CH_3OH}K_{O_2}P_{g,CH_3OH}P_{g,O_2}^{1/2} + K_{H_2O}K_{O_2}P_{g,H_2O}P_{g,O_2}^{1/2}}$
R3	$\frac{k_{CO}K_{O_2}P_{HCHO}P_{g,O_2}^{1/2}}{1 + K_{CH_3OH}P_{g,CH_3OH} + K_{H_2O}P_{g,H_2O} + K_{H_2O}P_{g,H_2O} + K_{CH_3OH}K_{O_2}P_{g,CH_3OH}P_{g,O_2}^{1/2} + K_{H_2O}K_{O_2}P_{g,H_2O}P_{g,O_2}^{1/2}}$
R4	$k_{DME,f}P_{g,CH_3OH} - \frac{k_{DME,f}P_{g,DME}P_{g,H_2O}}{K_{DME}^{eq}P_{g,CH_3OH}}$
R5	$k_{DMM,f}P_{g,HCHO}P_{g,CH_3OH} - \frac{k_{DMM,f}P_{g,DMM}P_{g,H_2O}}{K_{DMM}^{eq}P_{g,CH_3OH}}$
R6	$\frac{k_{DME-HCHO}K_{DME}K_{O_2}P_{g,DME}P_{g,O_2}^{1/2}}{1 + K_{DME}P_{g,DME} + K_{O_2}P_{g,O_2}^{1/2} + K_{DME}K_{O_2}P_{g,DME}P_{g,O_2}^{1/2}}$

Table S2. Stream Results for Direct Air Capture Process (DAC)

Stream	ABSIN	AIR	CACO3F	CAO	CAOH2-1	CAOH2-2	CAOH2 IN	CAOH2 RE	CO2
Temperature (K)	298.15	293.15	298.15	1173.15	573.15	573.34	573.34	573.34	1173.15
Pressure (bar)	1	1.0315	1	1	1	1	1	1	1
Mass Flow (kg/s)	1497.012	138.889	13.889	7.782	11.385	11.385	0.171	11.214	6.107
Mass Fraction									
H2O	0.73509	0.00601	-	-	0.09689	0.09689	0.09689	0.09689	-
CO2	0.05596	0.00061	-	-	-	-	-	-	1.00000
NA2CO3	-	-	-	-	-	-	-	-	-
H3O+	-	-	-	-	-	-	-	-	-
OH-	-	-	-	-	-	-	-	-	-
HCO3-	0.00322	-	-	-	-	-	-	-	-
CO3-2	-	-	-	-	-	-	-	-	-
NA+	0.00121	-	-	-	-	-	-	-	-
NAOH	-	-	-	-	-	-	-	-	-
N2	0.07049	0.75973	-	-	-	-	-	-	-
O2	0.02168	0.23364	-	-	-	-	-	-	-
NAHCO3	-	-	-	-	-	-	-	-	-
CO	-	-	-	-	-	-	-	-	-
H2	-	-	-	-	-	-	-	-	-
CA++	-	-	-	-	-	-	-	-	-
CACO3	-	-	1.00000	-	-	-	-	-	-
CAOH2	0.11236	-	-	-	0.90311	0.90311	0.90311	0.90311	-
CAO	-	-	-	1.00000	-	-	-	-	-

Stream	GASOUT	H2O	NAOH	NAOH-1	NAOH-2	PRD1	PRD1-1	PRD2	RICHOUT	RICHOUT2
Temperature (K)	298.15	298.15	298.15	113.47	647.28	298.15	113.47	1173.15	298.15	298.15
Pressure (bar)	1	1.0315	1.0315	1	1	1	1	1	1	1
Mass Flow (kg/s)	137.969	3.603	0.022	1358.109	1358.131	1358.109	1358.109	13.889	1359.051	1359.05
Mass Fraction										
H2O	-	1.00000	0.92951	0.80965	0.81007	0.80965	0.80965	-	0.80972	0.80972
CO2	-	-	-	0.06162	0.06265	0.06162	0.06162	0.43971	0.06164	0.06164
NA2CO3	-	-	-	-	-	-	-	-	-	-
H3O+	-	-	-	-	-	-	-	-	-	-
OH-	-	-	0.02998	-	0.00001	-	-	-	-	-
HCO3-	-	-	-	0.00356	0.00071	0.00355	0.00356	-	0.00355	0.00355
CO3-2	-	-	-	-	0.00139	-	-	-	-	-
NA+	-	-	0.04052	0.00133	0.00133	0.00133	0.00133	-	0.00133	0.00133
NAOH	-	-	-	-	-	-	-	-	-	-
N2	0.76480	-	-	-	-	-	-	-	-	-
O2	0.23520	-	-	-	-	-	-	-	-	-
NAHCO3	-	-	-	-	-	-	-	-	-	-
CO	-	-	-	-	-	-	-	-	-	-
H2	-	-	-	-	-	-	-	-	-	-
CA++	-	-	-	-	-	-	-	-	-	-
CACO3	-	-	-	-	-	-	-	-	-	-
CAOH2	-	-	-	0.12385	0.12384	0.12385	0.12385	-	0.12376	0.12376
CAO	-	-	-	-	-	-	-	0.56029	-	-

Table S3. Sensitivity results for HX unit

HX Sensitivity								
Cold Outlet Temp (degC)	CO2 Product Flow (kmol/h)	CAPEX (\$)	OPEX (\$/yr)	HX Duty (kW)	Cooler Duty (kW)	Column Height	Column Diameter	
84	501.81	9,808,220	10,134,676	52,538	50,405	16.8	4.2	
88	501.69	9,612,970	9,660,717	56,643	46,159	16.4	4.1	
92	501.56	9,274,040	9,218,699	60,762	41,860	16.4	4.1	
96	501.41	9,308,240	8,809,836	64,894	37,504	16.0	4.0	
100	501.21	9,228,690	8,445,124	69,044	33,069	15.6	3.9	
104	500.96	9,531,820	8,131,042	73,220	28,541	15.6	3.9	
108	500.64	9,704,160	7,860,475	77,472	23,869	15.2	3.8	
110	500.45	10,428,800	7,717,294	79,993	21,076	15.2	3.8	
112	499.87	18,238,500	7,424,918	85,263	15,228	14.8	3.7	

Table S4. Sensitivity Results for Reboiler unit

REB Sensitivity							
REB Temp (degC)	CO2 Product Flow (kmol/h)	HX Temp (degC)	CAPEX (\$)	OPEX (\$/yr)	HX Duty (kW)	Column Height	Column Diameter
116	445.45	88	8,487,940	8,688,735	56,975	14.0	3.5
117	456.24	90	8,673,600	8,648,995	58,910	14.4	3.6
118	467.95	108	11,162,100	6,852,467	80,385	13.6	3.4
119	482.25	110	13,905,100	6,968,681	82,891	14.4	3.6
120	500.45	110	10,428,600	7,717,294	79,993	15.2	3.8
121	525.54	110	10,718,600	9,030,992	79,511	16.8	4.2
122	555.51	104	13,985,700	20,312,288	73,291	24.0	6.0
123	558.27	88	20,179,500	39,815,652	56,785	32.0	8.0

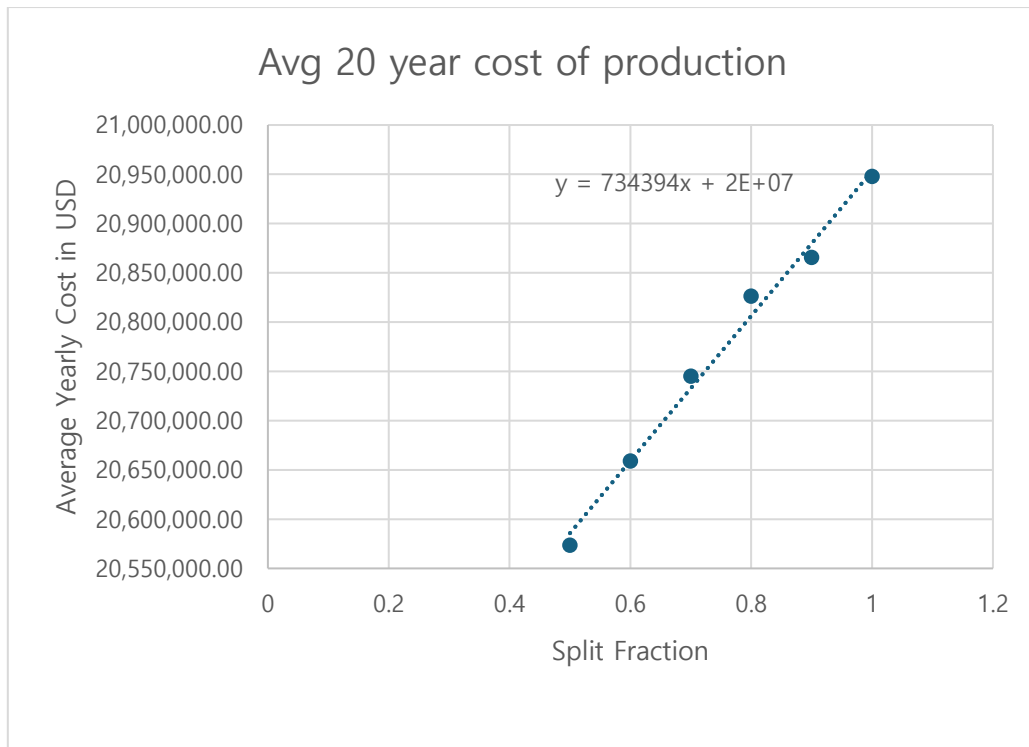


Figure S1. Linear Approximation of costs against varying fractions

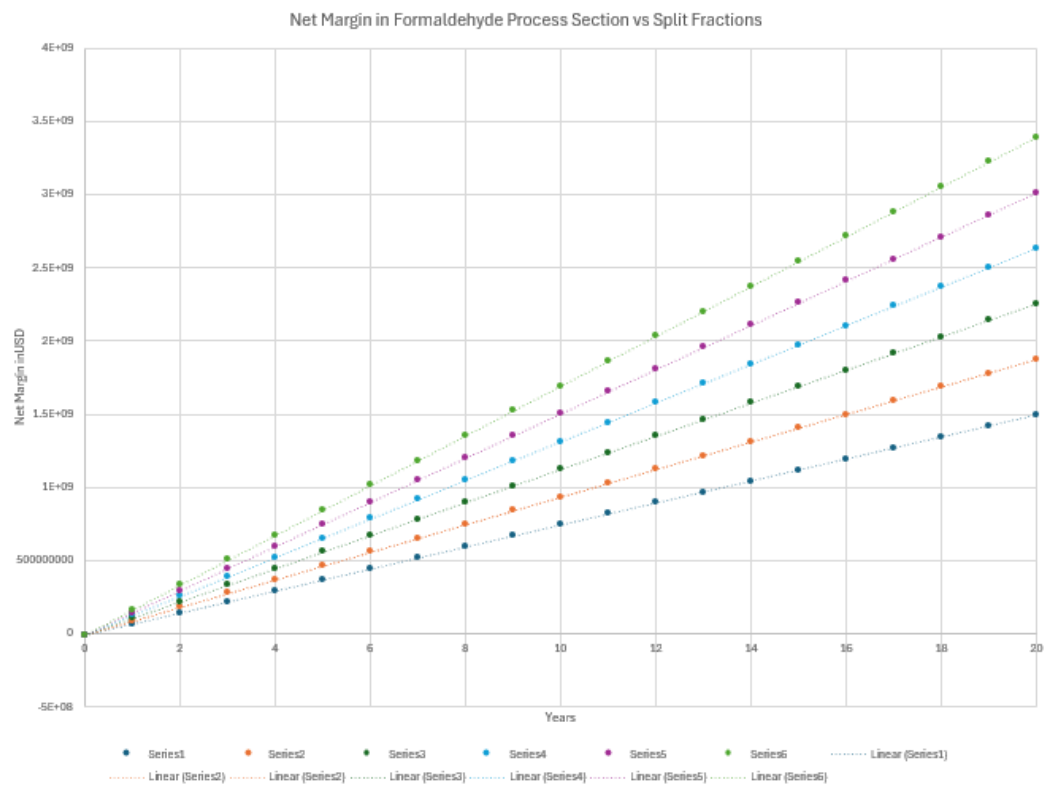


Figure S2. Estimate of net margin (excluding cost of feed) for formaldehyde production vs split fraction where Series 1 to Series 6 represent 0.5-1 Split

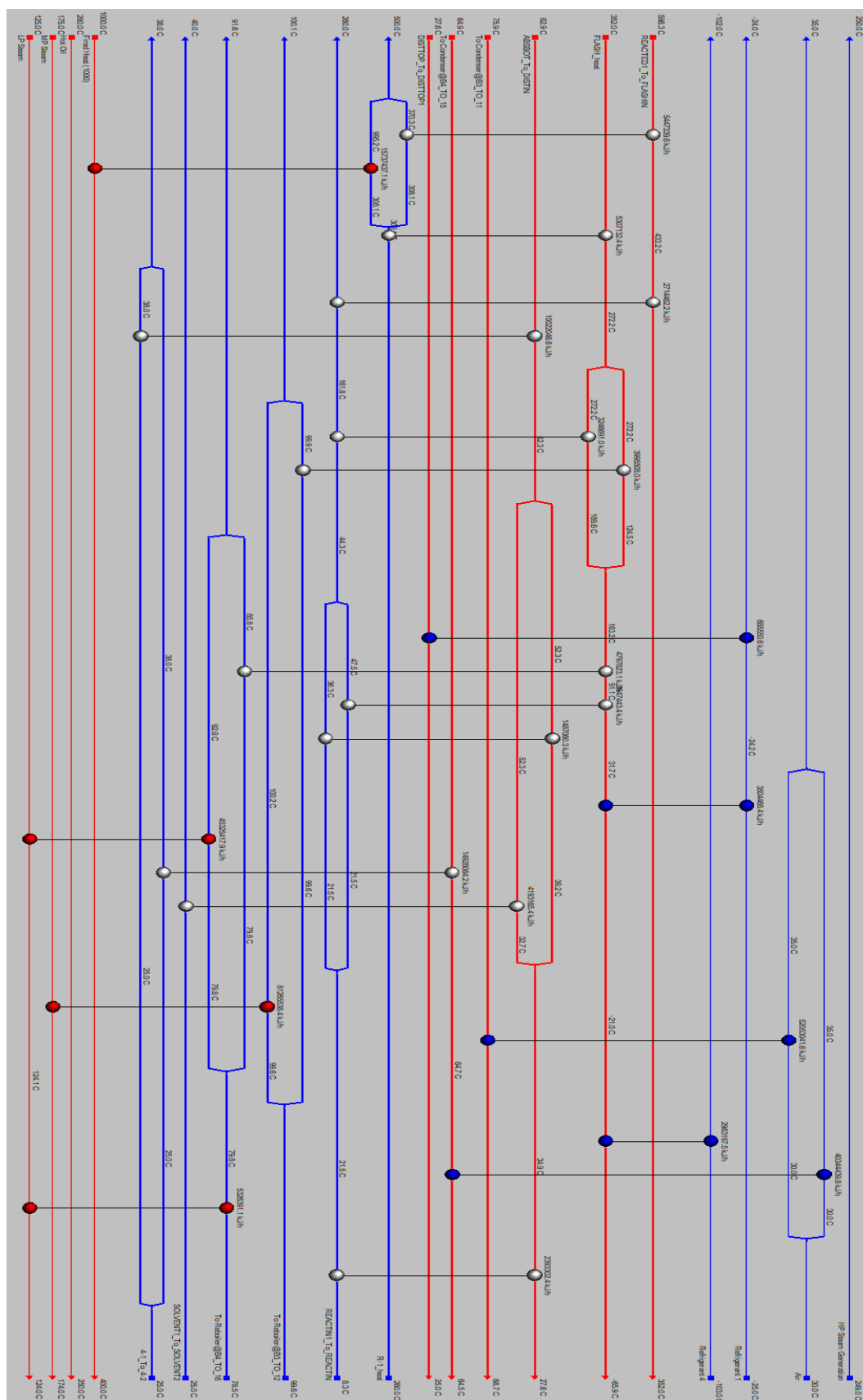


Figure S3. Heat Exchanger Network for Methanol to Formaldehyde Process (Attached in page below)

Table S5. NPV in (\$M) with ECR Cost of 20% and interest rate of 0%

Year	Cost sum	Revenue	Gross profit (M\$)	Depreciation charge (\$M)	Taxable income	Tax paid	Cash flow after tax	Discount factor	Present value of CF	NPV
0.00	11.64	0.00	-11.64	1.94	0.00	0.00	-11.64	1.00	-11.64	-11.64
1.00	23.97	0.00	-23.97	1.94	0.00	0.00	-23.97	1.00	-23.97	-35.61
2.00	48.36	36.32	-12.03	1.94	0.00	0.00	-12.03	1.00	-12.03	-47.64
3.00	98.67	112.24	13.57	1.94	11.63	2.91	10.66	1.00	10.66	-36.98
4.00	111.48	128.45	16.98	1.94	15.04	3.76	13.22	1.00	13.22	-23.76
5.00	114.82	132.31	17.49	1.94	15.55	3.89	13.60	1.00	13.60	-10.16
6.00	118.27	136.28	18.01	1.94	16.07	4.02	13.99	1.00	13.99	3.83
7.00	121.81	140.37	18.55	1.94	16.61	4.15	14.40	1.00	14.40	18.23
8.00	125.47	144.58	19.11	1.94	17.17	4.29	14.82	1.00	14.82	33.04
9.00	129.23	148.91	19.68	1.94	17.74	4.44	15.25	1.00	15.25	48.29
10.00	133.11	153.38	20.27	1.94	18.33	4.58	15.69	1.00	15.69	63.97
11.00	137.10	157.98	20.88	1.94	18.94	4.73	16.14	1.00	16.14	80.12
12.00	141.22	162.72	21.51	1.94	19.57	4.89	16.61	1.00	16.61	96.73
13.00	145.45	167.60	22.15	1.94	20.21	5.05	17.10	1.00	17.10	113.83
14.00	149.82	172.63	22.81	1.94	20.88	5.22	17.60	1.00	17.60	131.43
15.00	154.31	177.81	23.50	1.94	21.56	5.39	18.11	1.00	18.11	149.54
16.00	158.94	183.14	24.20	1.94	22.26	5.57	18.64	1.00	18.64	168.17
17.00	163.71	188.64	24.93	1.94	22.99	5.75	19.18	1.00	19.18	187.36
18.00	168.62	194.30	25.68	1.94	23.74	5.93	19.74	1.00	19.74	207.10
19.00	173.68	200.13	26.45	1.94	24.51	6.13	20.32	1.00	20.32	227.42
20.00	178.89	206.13	27.24	1.94	25.30	6.33	20.92	1.00	20.92	248.34

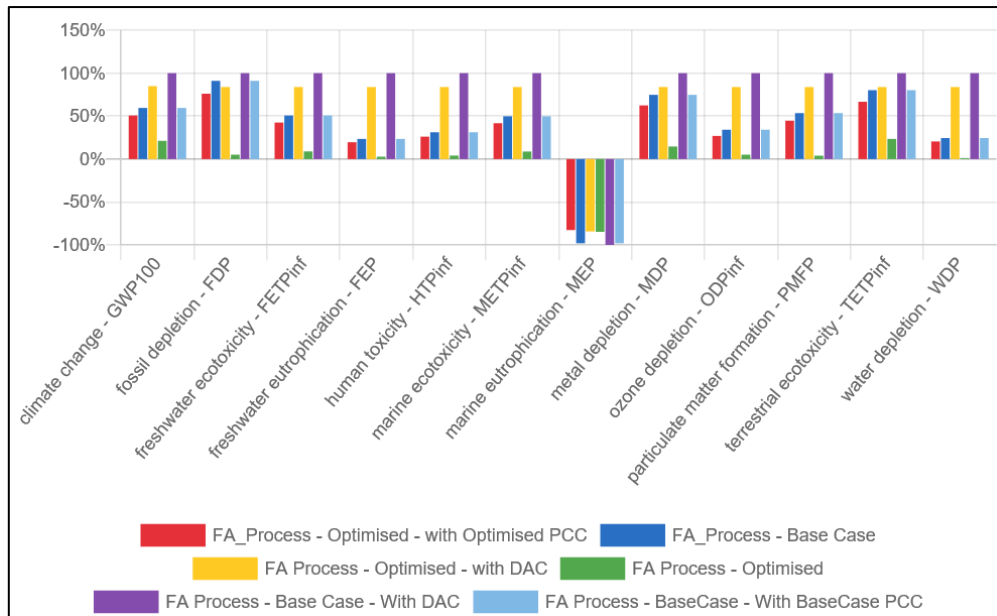


Figure S4: Relative Contribution Indicators of all configurations (Base-case and Optimised)
– Obtained from OpenLCA

Table S6. Energy Allocation for OpenLCA

Trial	Wind		Solar-PV		Biofuels	
	Allocation relative to total electricity requirement	Energy Content (MJ)	Allocation relative to total electricity requirement	Energy Content (MJ)	Allocation relative to total electricity requirement	Energy Content (MJ)
1	0.50	4.47E+07	0.50	4.47E+07	0.00	0.00E+00
2	0.45	4.02E+07	0.45	4.02E+07	0.10	8.94E+06
3	0.40	3.57E+07	0.40	3.57E+07	0.20	1.79E+07
4	0.35	3.13E+07	0.35	3.13E+07	0.30	2.68E+07
5	0.30	2.68E+07	0.30	2.68E+07	0.40	3.57E+07
6	0.25	2.23E+07	0.25	2.23E+07	0.50	4.47E+07
7	0.20	1.79E+07	0.20	1.79E+07	0.60	5.36E+07
8	0.15	1.34E+07	0.15	1.34E+07	0.70	6.25E+07
9	0.10	8.94E+06	0.10	8.94E+06	0.80	7.15E+07
10	0.05	4.47E+06	0.05	4.47E+06	0.90	8.04E+07
11	0.00	0.00E+00	0.00	0.00E+00	1.00	8.94E+07

Table S7. Design Space of individual functional groups with Unique ID number

1	CH ₃	14	CH ₂ COO	27	C ₂ H ₃ O	33	C=C (cycli c)	46	CH ₂ N H ₂
2	CH ₂	15	CHCOO	28	C ₂ H ₂ O	34	CH ₂ (cycli c)	47	CHNH 2
3	CH	16	CCOO	29	C ₂ H ₂ O	35	CH (c yclic)	48	CH ₃ N H
4	C	17	HCOO	30	C ₂ H ₂ O	36	C (cy cllic)	49	CH ₂ N H
5	CH=C	18	COO	31	-O-	37	CH=C H	50	CHNH
6	CH=CH	19	CH ₃ O	32	>CO	38	CH=C (cycli c)	51	CH ₃ N
7	C=C	20	CH ₂ O			39	C=C (cycli c)	52	CH ₂ N
8	OH	21	CH-O			40	O (cy cllic)	53	NH ₂
9	COOH	22	OCH ₂ CH ₂ O H			41	CO (c yclic)	54	CONH 2
10	CH ₃ CO	23	OCHCH ₂ OH			42	CO (c yclic)	55	CONH CH ₃
11	CH ₂ CO	24	OCH ₂ CHOH			43	NH (c yclic)	56	CON (CH ₃) 2
12	CHO	25	-O-OH			44	N (cy cllic)	57	CHNO H
13	CH ₃ COO	26	CO ₃			45	CH=N (cycli c)	58	N=O

Table S8. Stream results for post-combustion carbon capture process

	CLEANGAS	CO2	CONLIQ	FLUEGAS	HOUT	MIN	MOUT	REBREC	REBVAP
Temperature (°C)	19.004	25	25	19	40.420	19.002	40.079	120	120
Pressure (bar)	1.0315	1.9696	1.9696	1.0315	1.9796	1.0315	1.9696	1.9796	1.9796
Mass flowrate (kg/hr)	2188	510	1220	3024	44070	45039	45289	44071	2953
Mass fraction									
MEA	5.98E-06	3.51E-11	1.50E-06	-	0.111	0.119	0.108	0.115	0.007
H ₂ O	0.013	0.007	0.991	0.060	0.820	0.826	0.824	0.819	0.880
CO ₂	3.67E-05	0.992	0.003	0.280	8.66E-08	8.51E-09	8.72E-08	4.14E-05	0.114
H ₃ O ⁺	-	-	1.53E-08	5.29E-08	2.93E-12	5.08E-13	2.93E-12	1.49E-10	-
OH ⁻	-	-	3.12E-10	8.82E-14	4.02E-06	3.97E-06	3.97E-06	3.58E-06	-
HCO ₃ ⁻	-	-	0.003	1.70E-07	0.001	-	-	0.004	-
CO ₃ ²⁻	-	-	3.86E-07	1.21E-13	0.001	0.001	0.001	-	-
MEA ⁺	-	-	0.003	-	0.027	0.022	0.026	0.026	-
MEACOO ⁻	-	-	2.53E-06	-	0.041	0.033	0.040	0.036	-
N ₂	0.987	0.001	6.02E-08	0.661	-	1.15E-09	1.42E-09	8.71E-19	3.71E-14

	RECYC	RICHOUT	RLEAN	RRECY	S3	S9	STRIN	STRLIQ	STRVAP	VOUT
Temperature (°C)	19	32.404	19	19	19	32.290	110	118.939	110.612	40.081
Pressure (bar)	1.0315	1.0315	1.0315	1.0315	1.0315	1.9696	1.9696	1.9796	1.9696	1.0315
Mass flowrate (kg/hr)	45288	45297	8808	36230	9057	45297	45312	46876	1730	45288
Mass fraction										
MEA	0.108	0.042	0.164	0.108	0.108	0.045	0.058	0.093	0.002	0.108
H ₂ O	0.824	0.805	0.835	0.824	0.824	0.804	0.801	0.821	0.498	0.824
CO ₂	1.41E-08	7.48E-07	-	1.41E-08	1.41E-08	6.99E-07	0.001	7.45E-05	0.500	8.72E-08
H ₃ O ⁺	7.05E-13	1.09E-11	7.20E-15	7.05E-13	7.05E-13	1.04E-11	4.43E-10	2.37E-10	-	2.93E-12
OH ⁻	3.25E-06	1.11E-06	-	3.25E-06	3.25E-06	1.15E-06	1.34E-06	2.57E-06	-	3.97E-06
HCO ₃ ⁻	-	0.001	-	-	-	0.003	0.014	0.007	-	0.001
CO ₃ ²⁻	0.001	-	-	0.001	0.001	0.002	-	-	-	0.001
MEA ⁺	0.027	0.058	-	0.027	0.027	0.060	0.057	0.034	-	0.026
MEACOO ⁻	0.040	0.094	-	0.040	0.040	0.087	0.070	0.044	-	0.040
N ₂	1.42E-09	2.372E-05	-	1.42E-09	1.42E-09	2.37E-05	2.37E-05	1.41E-15	0.001	1.42E-09

Table S9. Stream table for the methanol synthesis to formaldehyde production process

	Units	1	2	3	4-1	4-2	5-1	5-2	6	7-1	7-2	8	9	10	11	12	13	14	15	16
Temperature	C	25.00	25.00	25.66	25.00	38.00	38.00	5.00	38.00	154.18	5.00	28.23	37.50	37.50	68.72	99.65	99.65	99.65	64.47	91.56
Pressure	bar	1	1	1	1	106.5	106.5	29.8	106.5	7	1	7	7	7	1	1	1	1	1	1
Mass Flows	kg/hr	2.21E+04	2.16E+04	6.57E+05	6.57E+05	6.57E+05	1.22E+05	1.22E+05	5.36E+05	8.55E+04	8.55E+04	3.61E+04	5.39E+05	3.28E+04	1.02E+04	7.53E+04	7.46E+04	7.08E+02	8.26E+03	1.95E+03
Mass Fractions																				
CO2		9.95E-01	0.00E+00	1.46E-01	1.19E-01	1.19E-01	1.59E-01	1.59E-01	1.10E-01	2.86E-12	2.86E-12	5.36E-01	1.37E-01	1.37E-01	2.39E-11	2.35E-33	2.35E-33	2.35E-33	2.96E-11	5.57E-29
WATER		3.62E-03	1.00E+00	1.47E-01	1.18E-01	1.18E-01	6.35E-01	6.35E-01	3.51E-04	9.02E-01	9.02E-01	7.08E-04	3.74E-04	3.74E-04	1.81E-01	1.00E+00	1.00E+00	1.00E+00	9.87E-03	9.05E-01
METHANOL		0.00E+00	0.00E+00	1.29E-03	1.41E-02	1.41E-02	7.49E-02	7.49E-02	2.99E-04	9.78E-02	9.78E-02	2.05E-02	1.57E-03	1.57E-03	8.19E-01	3.55E-06	3.55E-06	3.55E-06	9.90E-01	9.46E-02
MEA		5.22E-12	0.00E+00	1.50E-11	1.50E-11	1.50E-11	8.13E-11	8.13E-11	3.01E-16	1.16E-10	1.16E-10	8.68E-19	2.82E-16	2.82E-16	1.00E-19	1.31E-10	1.31E-10	1.31E-10	0.00E+00	0.00E+00
METHANE		0.00E+00	0.00E+00	5.43E-02	5.76E-02	5.76E-02	1.92E-02	1.92E-02	6.63E-02	1.22E-16	1.22E-16	6.47E-02	6.62E-02	6.62E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HYDROGEN		0.00E+00	0.00E+00	1.34E-02	1.42E-02	1.42E-02	1.50E-04	1.50E-04	1.74E-02	1.55E-29	1.55E-29	5.05E-04	1.63E-02	1.63E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OXYGEN		0.00E+00	0.00E+00	6.38E-01	6.77E-01	6.77E-01	1.12E-01	1.12E-01	8.05E-01	3.89E-18	3.89E-18	3.77E-01	7.78E-01	7.78E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NITROGEN		1.03E-03	0.00E+00	6.02E-04	6.02E-04	6.02E-04	8.17E-05	8.17E-05	7.20E-04	1.11E-21	1.11E-21	2.75E-04	6.92E-04	6.92E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
FORM		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
DME		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
CO		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHYLAL		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00

	Units	16	17	18	19	20	21	22	23	24	25	26	27	28
Temperature	C	91.56	64.47	64.47	64.47	64.47	25.00	8.27	260.00	400.00	438.75	352.00	-69.13	-69.13
Pressure	bar	1	1	1	1	1	1.013	1	1	1	1.2	1.2	1.2	1.2
Mass Flows	kg/hr	1.95E+03	7.44E+03	8.26E+02	6.92E+03	5.21E+02	1.57E+04	2.26E+04	2.26E+04	2.26E+04	2.26E+04	2.26E+04	1.28E+04	9.84E+03
Mass Fractions														
CO2		5.57E-29	2.96E-11	2.96E-11	2.96E-11	2.96E-11	0.00E+00	9.05E-12	9.05E-12	9.05E-12	9.05E-12	9.05E-12	1.20E-11	5.25E-12
WATER		9.05E-01	9.87E-03	9.87E-03	9.87E-03	9.87E-03	0.00E+00	3.02E-03	3.02E-03	1.85E-01	1.85E-01	1.85E-01	2.41E-06	4.25E-01
METHANOL		9.46E-02	9.90E-01	9.90E-01	9.90E-01	9.90E-01	0.00E+00	3.03E-01	3.03E-01	5.43E-03	5.43E-03	5.43E-03	9.31E-13	1.25E-02
MEA		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANE		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HYDROGEN		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OXYGEN		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.33E-01	1.62E-01	1.62E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NITROGEN		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	7.67E-01	5.32E-01	5.32E-01	5.32E-01	5.32E-01	5.32E-01	9.39E-01	3.79E-03
FORM		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.54E-01	2.54E-01	2.54E-01	1.99E-02	5.58E-01
DME		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.02E-05	2.02E-05	2.02E-05	3.05E-06	4.26E-05
CO		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	2.30E-02	2.30E-02	2.30E-02	4.06E-02	1.90E-04
METHYLAL		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.95E-11	1.95E-11	1.95E-11	2.14E-13	4.46E-11

	Units	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43
Temperature	C	90.00	25.00	25.02	25.00	25.00	40.00	97.30	89.62	27.64	27.64	27.64	25.00	25.00	25.00	21.52
Pressure	bar	1.2	1	1.2	1.2	1.2	1.2	1.2	1.2	5.5	5.5	5.5	5.5	5.5	5.5	1
Mass Flows	kg/hr	9.84E+03	3.87E+03	3.87E+03	5.15E+04	5.15E+04	5.15E+04	3.76E+02	6.10E+04	6.10E+04	4.91E+04	1.19E+04	4.91E+04	1.47E+03	4.76E+04	1.24E+04
Mass Fractions																
CO2		5.25E-12	0.00E+00	0.00E+00	4.06E-14	4.06E-14	4.06E-14	1.37E-10	3.54E-14	3.54E-14	4.39E-14	0.00E+00	4.39E-14	4.39E-14	4.39E-14	1.24E-12
WATER		4.25E-01	1.00E+00	1.00E+00	9.60E-01	9.60E-01	9.60E-01	6.35E-01	8.76E-01	8.76E-01	9.57E-01	5.40E-01	9.57E-01	9.57E-01	9.57E-01	5.18E-01
METHANOL		1.25E-02	0.00E+00	0.00E+00	3.95E-02	3.95E-02	3.96E-02	1.60E-01	3.44E-02	3.44E-02	4.28E-02	0.00E+00	4.28E-02	4.28E-02	4.28E-02	4.16E-02
MEA		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
METHANE		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
HYDROGEN		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
OXYGEN		0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
NITROGEN		3.79E-03	0.00E+00	0.00E+00	4.24E-06	4.24E-06	4.24E-06	9.93E-02	3.69E-06	3.69E-06	4.58E-06	0.00E+00	4.58E-06	4.58E-06	4.58E-06	0.00E+00
FORM		5.58E-01	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-01	8.94E-02	8.94E-02	0.00E+00	4.60E-01	0.00E+00	0.00E+00	0.00E+00	4.40E-01
DME		4.26E-05	0.00E+00	0.00E+00	2.63E-06	2.63E-06	2.63E-06	1.10E-03	2.29E-06	2.29E-06	2.85E-06	0.00E+00	2.85E-06	2.85E-06	2.85E-06	0.00E+00
CO		1.90E-04	0.00E+00	0.00E+00	2.23E-07	2.23E-07	2.23E-07	4.97E-03	1.94E-07	1.94E-07	2.41E-07	0.00E+00	2.41E-07	2.41E-07	2.41E-07	0.00E+00
METHYLAL		4.46E-11	0.00E+00	0.00E+00	1.66E-12	1.66E-12	1.66E-12	1.16E-09	1.44E-12	1.44E-12	1.79E-12	0.00E+00	1.79E-12	1.79E-12	1.79E-12	0.00E+00