

Comparison of technologies for CO₂ capture from cement production – Part 2: Cost analysis – Supplementary Materials

1. Equipment list for MEA absorption

Equipment lists for the various sections of the MEA absorption process in the baseline scenario are presented in Table S1 - Table S4.

Table S1. Equipment list for the absorption section.

DESCRIPTION	TYPE	SIZE			DESIGN	DESIGN	MATERIAL	EQUIPMENT	EQUIPMENT	DIRECT
		ID	H Packing	H Column	PRESSURE	TEMPERATURE				
<u>Columns</u>		(m)	(m)	(m)	barg	°C				k€2014
Direct Contact Cooler	Vertical	6.2	7	14	1.9		SS304L	1453		3088
Absorber	Vertical	7.8	20	36	1.9		SS304L	5038		7469
DESCRIPTION	TYPE	SIZE			DESIGN	DESIGN	MATERIAL	EQUIPMENT	EQUIPMENT	DIRECT
		Duty	LMTD	Area (Design)	PRESSURE	TEMPERATURE				
<u>Heat Exchangers</u>		(kW)	(K)	(m2)	barg	°C				k€2014
Flue gas reheater	P&F	622	59	333.1	2.0		SS304L	68		350
DCC cooler	P&F	13 485	13	782.0	3.9		SS304L	154		535
Amine wash cooler	P&F	2 530	17	110.1	3.9		SS304L	24		214
DESCRIPTION	TYPE	SIZE		DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT		
		Flow (DESIGN)	Power (DESIGN)	PRESSURE	TEMPERATURE				COST	COST
<u>Fans and Compressors</u>		(m3/h)	(kW)	barg	°C					
Exhaust fan before flue gas reheater	FN CENT TURBO	441 305	2 573	2.0	159	SS304L	748	1 048		
DESCRIPTION	TYPE	SIZE		DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT		
		Flow (DESIGN)	Power (DESIGN)	PRESSURE	TEMPERATURE				COST	COST
<u>Pumps</u>		(l/s)	(kW)	barg	°C					
DCC Circulating pump	Centrifugal	139	35	3.9	82	SS304L	80	265		
Amine water wash pump	Centrifugal	33	8.3	3.9	97	SS316L	54	157		
Rich amine pump	Centrifugal	442	276	6.9	77	SS304L	235	667		
Water make-up pump	Centrifugal	15	7.4	5.9	58	SS304L	47	120		

Table S2. Equipment list for the desorption section.

DESCRIPTION	TYPE	SIZE			DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE	
		Liq Flow (DESIGN) (m3/h)	Gas Flow (DESIGN) (m3/h)	ID (m)							H (m)
Tanks & Vessels											
Lean amine tank	Vertical	1587	0	3.5	13.9	2.8	147	SS316L	295	771	APEA
MEA storage tank	Vertical	0.144	0	2.0	7.9	1.8	58	CS	47	183	APEA
CO2 reflux accumulator	Vertical	48	44981	5.2	7.3	2.1	56	SS304L	341	779	APEA
DESCRIPTION	TYPE	SIZE			DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE	
		ID (m)	H Packing (m)	H Column (m)							
Columns											
Regenerator (stripper)	Vertical	5.2	9	13.5	2.8	146	SS316L	1375	2514	APEA	
DESCRIPTION	TYPE	SIZE			DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE	
		Duty (kW)	LMTD (°)	Area (Design) (m2)							
Heat Exchangers											
LeanRich Heat exchanger	P&F	86 858	10	6 207	9.0	147	SS316L	1568	3819	APEA	
Lean amine cooler	P&F	28 172	25	842	9.0	88	SS316L	214	604	APEA	
Reflux condenser	S&T	32 252	24	1 483	2.5	124	SS316L	413	836	APEA	
Stripper reboiler	Kettle	96 259	11	6187	3.4	156	SS316L	1882	2866	APEA	
DESCRIPTION	TYPE	SIZE		DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE		
		Flow (DESIGN) (l/s)	Power (DESIGN) (kW)								
Pumps											
Lean Amine makeup pump	Centrifugal	0.04	0.03	6.9	58	SS304L	42	71	APEA		
Lean Amine pump	Centrifugal	440.9	354	9.0	147	SS316L	253	711	APEA		
Stripper Reflux pump	Centrifugal	13.3	4.48	4.8	56	SS304L	46	119	APEA		
DESCRIPTION	TYPE	SIZE	DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE			
		Flow (DESIGN) (l/s) - (kg/h)									
Other Equipment											
Amine Filter	Charcoal	55.1	9.0		SS304L	46	77	APEA			
Amine Filter	Candide	55.1	9.0		SS304L	46	77	APEA			
Thermal reclaimer unit		1594	9.0	14	SS316L	516	828	DA4/Recap			

Table S3. Equipment list for the CO₂ compression section and the cooling tower.

DESCRIPTION	TYPE	SIZE		DESIGN	DESIGN	DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Flow In (DESIGN)	Power (DESIGN)								
<u>Compressor train</u>		(m ³ /h)	(kW)	INLET PRESSURE	OUTLET PRESSURE	TEMPERATURE (IN)			COST	COST	SOURCE
3-stage compressor	Centrifugal, horizontal	44 991	8 916	2.1	86.9	56		SS304L	13 048	14 136	APEA

DESCRIPTION	TYPE	SIZE			DESIGN	DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST	COST	SOURCE
		Duty	LMTD	Area (Design)									
<u>Heat Exchangers</u>		(kW)	(K)	(m ²)	PRESSURE	TEMPERATURE			COST	COST			
Intercooler 1	P&F	3 453	35	214	6.0	175		SS304L	45	314		APEA	
Intercooler 2	P&F	3 204	36	196	22.3	177		SS304L	41	251		APEA	
Intercooler 3	P&F	7 730	38	443	86.9	190		SS304L	111	486		APEA	
CO ₂ cooler after pump	S&T	745	9	62	120.3	64		SS304L	116	474		APEA	

DESCRIPTION	TYPE	SIZE		DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Flow (DESIGN)	Power (DESIGN)						
<u>Pumps</u>		(m ³ /h)	(kW)	PRESSURE	TEMPERATURE		COST	COST	SOURCE
CO ₂ pump	Centrifugal	166.9	186.5	220.3	64	CS	307	510	D4.4

DESCRIPTION	TYPE	SIZE				DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST	COST	SOURCE
		Liq Flow (DESIGN)	Gas Flow (DESIGN)	ID	H								
<u>Tanks & Vessels</u>		(m ³ /h)	(m ³ /h)	(mm)	(mm)	PRESSURE	TEMPERATURE			COST	COST		
KO drum after Intercooler 1	Vertical	0.93	11 020	2.3	9.1	5.9	56	SS304L	132		365		APEA
KO drum after Intercooler 2	Vertical	0.22	2575	1.4	5.6	21.8	56	SS304L	89		226		APEA

DESCRIPTION	TYPE	SIZE		EQUIPMENT	DIRECT	COST
		Flow (DESIGN)	(l/s)			
<u>Cooling tower</u>				Cost	Cost	
Complete cooling tower, field assembly	Vertical	2264.1		988	1609	APEA

Table S4. Equipment list for the TEG dehydration section.

DESCRIPTION	TYPE	SIZE			DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST - CEMCAP	DIRECT COST - CEMCAP	COST
		ID	H Packing	H Column						
<u>Columns</u>		(m)	(m)	(m)	barg	°C		k€2014	k€2014	
TEG absorber	Vertical	1.2	2.4	4.08	21.8	58	SS304L	126	285	APEA
TEG stripper	Vertical	0.2	1.6	2.72	2.0	198	SS316L	12	110	APEA

DESCRIPTION	TYPE	SIZE			DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST - CEMCAP	DIRECT COST - CEMCAP	COST
		Duty (kW)	LMTD (K)	Area (Design) (m2)						
<u>Heat Exchangers</u>					barg	°C		k€2014	k€2014	
TEG stripper (reboiler)	Kettle	66	15	3	5.7	198	SS316L	17	89	APEA
TEG stripper (condenser)	P&F	2	20	0.037	2.0	133	SS316L	1	49	APEA
Water Lean TEG Cooler	P&F	15	20	0.55	21.5	67	SS304L	1	49	APEA
Lean/Rich Heat Exchanger	P&F	159	2	58	5.8	198	SS316L	17	168	APEA

DESCRIPTION	TYPE	SIZE		DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST - CEMCAP	DIRECT COST - CEMCAP	COST SOURCE
		Flow (DESIGN) (l/s)	Power (DESIGN) (kW)						
<u>Pumps</u>				barg	°C		k€2014	k€2014	
Water Lean TEG pumps	Centrifugal	0.5	1	21.5	67	SS304L	42	76	APEA

DESCRIPTION	TYPE	SIZE				DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST - CEMCAP	DIRECT COST - CEMCAP	COST
		Liq Flow (DESIGN) (m3/h)	Gas Flow (DESIGN) (m3/h)	ID (mm)	H (mm)						
<u>Tanks & Vessels</u>						barg	°C		k€2014	k€2014	
TEG stripper (Condenser flash)	Horizontal	0.00	128	0.5	2.1	2.0	156	SS316L	12	122	APEA

2. Equipment list for oxyfuel technology

Equipment lists for the various sections of the oxyfuel process in the baseline scenario are presented in Table S5 - Table S7.

Table S5. Equipment list for the oxyfuel core process units, fans, compressors, blowers, expanders, exhaust gas recirculation system and air separation unit.

DESCRIPTION	EQUIPMENT COST	DIRECT COST	COST SOURCE
Clinker cooler, kiln hood and sealings	KE2014	KE2014	
Oxyfuel clinker cooler	2944	3655	DA.4
Oxyfuel kiln hood	102	203	DA.4
Rotary kiln inlet sealing	160	160	DA.4
Rotary kiln outlet sealing	160	160	DA.4

DESCRIPTION	TYPE	SIZE		DESIGN INLET PRESSURE	DESIGN OUTLET PRESSURE	DESIGN INLET TEMPERATURE °C	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE
		Flow (DESIGN) (m ³ /h)	Power (DESIGN) (kW)							
Fans, compressors and blowers				bag	bag			KE2014	KE2014	
Recycle blower		104388	590	1.8	2.0	57	CS	233	326	DA.4
Coder recycle blower		192177	1390	1.8	2.0	190	CS	355	496	DA.4
Sealed O ₂ fan		23390	164	1.8	2.0	96	CS	74	103	DA.4
ORC expander	Turbopander	248	3454	37.6	1.9	179	CS	1880	2327	APEA

DESCRIPTION	TYPE	Size		EQUIPMENT COST	DIRECT COST	COST SOURCE
		Gas flow (DESIGN) (m ³ /s)	O ₂ flow (DESIGN) (ton/d)			
Other equipment				KE2014	KE2014	
Exhaust gas recirculation system		107	-	70	129	DA.4
Cyclone filter in cooler CO ₂ recirculation loop		53	-	441	667	APEA
Electrostatic precipitator filter before ORC cycle	Low voltage	107	-	1013	1616	APEA
Air separation unit (ASU)		-	-	436	19461	DA.4

Table S6. Equipment list for the oxyfuel and waste heat recovery system’s heat exchangers, vessels, electric generator and pumps.

DESCRIPTION	TYPE	SIZE		DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE	
		Duty (kW)	LMTD (K)							Area (Design) (m2)
Heat Exchangers	FG Condenser/cooling water	P&F	15 099	36	153	1.9	SS304L	33	230	APEA
	Dry gas/hot oil, after pre-heater	S&T	18 233	102	2815	1.9	SS304L	1376	2240	APEA
	Hot oil/air preheat	S&T	6 352	156	112	1.9	SS304L	77	287	APEA
	Hot oil/ORC boiler	S&T	3 698	46	221	37.6	SS304L	198	693	APEA
	Hot oil/exhaust preheat (E 105)	S&T	1 182	58	56	1.9	SS304L	45	208	APEA
	Exhaust reheat/CO2 to stack (E106)	S&T	245	65	118	1.9	SS304L	79	277	APEA
	ORC Economizer (hot oil/liquid butane)	S&T	13 525	9	1102	37.6	SS304L	781	1623	APEA
	ORC condenser/cooling water	S&T	12 200	12	1082	1.9	SS304L	520	928	APEA
	Hot oil cooler/cooling water	P&F	959	14	49	1.9	SS304L	24	255	APEA
	Gas/gas heat exchanger, after clinker cooler	P&F	7 578	139	1718	1.9	SS304L	337	1181	APEA

DESCRIPTION	TYPE	SIZE				DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE
		Liq Flow (DESIGN) (m3/h)	Gas Flow (DESIGN) (m3/h)	ID (mm)	H (mm)						
Tanks & Vessels											
Water separator 1	Vertical	5.65	18776	5.8	23.4	1.8	57	SS304L	800	1435	APEA

DESCRIPTION	SIZE		MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE
	Power (DESIGN) (kW)	Output (DESIGN) (kVA)				
Electric generators						
ORC generator	3187	3983	CS	3984	4296	APEA

DESCRIPTION	SIZE		DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE
	Flow (DESIGN) (l/s)	Power (DESIGN) (kW)						
Pumps								
ORC pump	69	352	37.6 barg	64 °C	SS304L	156	329	APEA

Table S7. Equipment list for the CO₂ purification unit.

DESCRIPTION	TYPE	SIZE		DESIGN		DESIGN	DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Flow (DESIGN) (m ³ /h)	Power (DESIGN) (kW)	INLET PRESSURE bar(g)	OUTLET PRESSURE bar(g)							
Fans, Compressors and Expanders												
	Compressor 1-4	Centrifugal horizontal	84508	9288	1.8	23.9	57	SS304L	17389	18880	162014	APEA
	Compressor 5-6	Centrifugal horizontal	5736	4433	11.1	31.9	50	SS304L	2572	2975	2975	APEA
	Vert gas expander	Tuborexander	1444	1302	22.4	1.9	228	SS304L	696	987		APEA

DESCRIPTION	TYPE	SIZE				DESIGN	DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Liq Flow (DESIGN) (m ³ /h)	Gas Flow (DESIGN) (m ³ /h)	D	H							
Tanks & Vessels												
	Water separator 2	Vertical	1.34	30886	3.5	13.8	2.9	56	SS304L	282	592	APEA
	Water separator 3	Vertical	0.56	17718	2.7	10.6	5.4	56	SS304L	179	480	APEA
	Water separator 4	Vertical	0.26	8022	2.0	8.2	10.7	56	SS304L	117	300	APEA
	Water separator 5	Vertical	0.12	3542	1.6	6.2	23.4	56	SS304L	118	298	APEA
Liquid CO ₂ separator	Vertical		97.88	588	1.5	5.9	23.4	-55	SS304L	99	341	APEA

DESCRIPTION	TYPE	SIZE			DESIGN	DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Duty (kW)	LMTD (°C)	Area (Design) (m ²)							
Heat Exchangers - Pipe & Pipe											
	Intercooler 1	PAF	3.087	38	177	2.9	127	SS304L	162014	238	APEA
	Intercooler 2	PAF	2.543	38	146	5.5	127	SS304L	31	228	APEA
	Intercooler 3	PAF	2.305	37	142	10.9	124	SS304L	31	227	APEA
	Intercooler 4	PAF	2.445	38	143	23.9	125	SS304L	31	228	APEA
	Intercooler 5	PAF	2.488	46	120	31.9	142	SS304L	30	247	APEA
Intercooler 6	PAF		6.817	51	292	91.3	153	SS304L	75	421	APEA

DESCRIPTION	TYPE	SIZE		DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Duty (kW)	Pressure bar(g)					
Heat Exchangers - Pipe & Fin								
L T heat exchanger 1 (4 streams)	PAFin	11.702	23.4	-59	SS304L	849	1.697	DA.4

DESCRIPTION	TYPE	SIZE		DESIGN	DESIGN	EQUIPMENT	DIRECT	COST
		Flow (DESIGN) (m ³ /h)	Power (DESIGN) (kW)					
Pumps								
Liquid CO ₂ pump	Centrifugal	205	197	119.9	56	35.1	592	DA.4

DESCRIPTION	TYPE	SIZE			ABSORBENT MASS	DESIGN	DESIGN	MATERIAL	MATERIAL	EQUIPMENT	TOTAL DIRECT	COST
		Flow (DESIGN) (m ³ /s)	Water flow (DESIGN) (kg/h)	D								
Other Equipment												
No. Of trains	2	0.98	143	1.4	2.48	0.849	23.4	59	3A	5	112	339
Molecular sieve, single vessel dimensions												APEA + DA.4

DESCRIPTION	TYPE	SIZE		EQUIPMENT	DIRECT	COST
		Flow (OP) (m ³ /h)	Flow (DESIGN) (t/s)			
Cooling Tower	Vertical	4057	1281.5	398	1045	APEA
Complete cooling tower, field assembly						

3. Equipment list for chilled ammonia process

A list of all process equipment included in the cost estimate by BHGE is provided in Table S8.

Table S8. Equipment list for the chilled ammonia process.

Equipment type	Name	Qty
Pressure vessels	Stripper Condensate Receiver	1
	CO ₂ Dryer Receiver	1
	DCC/NH ₃ Wash/DCH/Absorber Area Drain Sump	1
	Regenerator Area Drain Sump	1
	LT Suction Drum	1
	HT Refrigerant Receiver	1
	Chiller Surge Drum No. 4	1
	Chiller Surge Drum No. 5	1
	Chiller Surge Drum No. 6	1
	Vent Gas-Solution Knock-Out Drum	1
	Regenerator Steam Condensate Receiver	1
	Stripper Steam Condensate Receiver	1
	Appendix Stripper Steam Condensate Receiver	1
	CO ₂ Surge Drum No. 2	1
	CO ₂ Surge Drum No. 3	1
	Liquid CO ₂ Receiver	1
Atmospheric tanks	Auxiliary Tank	1
	Ammonium Sulfate Storage Tank	1
	Sulfuric Acid Storage Tank	1
	Reagent Storage Tank	1
Columns	Direct Contact Cooler Column (DCC)	1
	Absorber Column	1
	Direct Contact Heater Column (DCH)	1
	Regenerator Column	1
	CO ₂ Wash Column	1
	Stripper Column	1
	Appendix Stripper Column	1
	NH ₃ Wash Column	1
Heat exchangers	DCC Circulation Chiller	1
	Absorber Circulation Cooler	1
	Absorber LT Chiller	1
	Lean Solution Cooler	1
	DCH Circulation Water Cooler	1
	Flue Gas Reheater	1
	Rich Solution-Steam Condensate Heat Exchanger	1
	Rich-Lean Heat Exchanger B	1
	Condensate Cooler	1
	Rich-Lean Heat Exchanger C	1
	CO ₂ Wash Cooler	1
	Regenerator Reboiler	1

Equipment type	Name	Qty
	Stripper Overhead Condenser	1
	NH ₃ Rich-Lean Heat Exchanger	1
	Appendix Stripper Bottoms Cooler	1
	Stripper Reboiler	1
	Appendix Stripper Reboiler	1
	NH ₃ Wash A1 Chiller	1
	NH ₃ Wash A2 Chiller	1
	Stripper Feed Heat Exchanger	1
	Refrigerant Condenser	1
	CO ₂ IS Cooler 1	1
	CO ₂ Condenser	1
	CO ₂ Chiller 1	1
	Regeneration Gas Recuperator	1
	Regeneration Gas Heater	1
	Regeneration Gas Cooler	1
Pumps	DCH Circulation Pump	1
	DCH Feed Pump	1
	Regenerator Feed Pump	1
	Absorber A3 Circulation Pump	1
	Circulation Water Pump	1
	DCH A1 Circulation Pump	1
	CO ₂ Wash Circulation Pump	1
	Stripper Reflux Pump	1
	CO ₂ Wash Feed Pump	1
	Stripper Bottoms Pump	1
	Appendix Stripper Bottoms Pump	1
	NH ₃ Wash A1 Circulation Pump	1
	Stripper Feed Pump	1
	Auxiliary Tank Return Pump	1
	Ammonium Sulfate Pump	1
	DCC/NH ₃ Wash/DCH/Absorber Area Drain Sump Pump	1
	Regenerator Area Drain Sump Pump	1
	Sulphuric Acid Feed Pump	1
	Reagent Feed Pump	1
	Solution Knock-out Pump	1
	CO ₂ Pump	1
Compressors	Booster Fan	1
	Back Pressure Turbine with Generator	1
	LT Refrigerant Compressor	1
	CO ₂ Compressor	1
Package units	CO ₂ Dehydration Unit (dessicant in fixed bed)	1
Other	Inlet Isolation Damper	3
	Absorber Solution Mixer	1
	Outlet Isolation Damper	3
	LT Inline Mixer	1

4. Equipment list for membrane-assisted CO₂ liquefaction

Equipment lists for the various sections of the membrane-assisted liquefaction process in the baseline scenario are presented in Table S9 - Table S11.

Table S9. Equipment list for heat exchangers, columns, fans, compressors and expanders in both CO₂ capture and compression section.

DESCRIPTION	TYPE	SIZE		DESIGN PRESSURE	DESIGN TEMPERATURE	MATERIAL	EQUIPMENT		COST SOURCE	
		Duty (kW)	LMTD (K)				Area (Design) (m ²)	Pressure (bar g)		Temperature (°C)
Heat Exchangers - Plate & Frame										
Flue gas/CO2 lean gas HX	P&F	2 250	63	1130	2.0	SS304L	220	743	APEA	
Direct contact cooler	P&F	10 942	17	463	6.5	SS304L	93	383	APEA	
Waste heater 1 (gas/gas)	P&F	2 315	50	171	37.4	SS304L	36	241	APEA	
Waste heater 2 (gas/gas)	P&F	1 818	46	146	11.6	SS304L	31	232	APEA	
Waste heater 3 (gas/gas)	P&F	6 141	74	303	3.2	SS304L	62	350	APEA	
Cooler 1 (gas/water)	P&F	21 392	44	1352	1.8	SS304L	282	824	APEA	
Cooler 2 (gas/water)	P&F	2 314	25	250	1.8	SS304L	52	319	APEA	
Cooler 3 (gas/water)	P&F	6 551	43	338	4.1	SS304L	69	357	APEA	
Cooler 4 (gas/water)	P&F	3 730	32	256	11.4	SS304L	53	321	APEA	
Cooler 5 (gas/water)	P&F	3 330	30	245	36.6	SS304L	51	318	APEA	
Columns										
DESCRIPTION	TYPE	SIZE		DESIGN PRESSURE (bar g)	DESIGN TEMPERATURE (°C)	MATERIAL	EQUIPMENT		COST SOURCE	
Columns	ID (m)	H Packing (m)	H Column (m)				Cost	Cost		
Direct Contact Cooler	Vertical	5.5	5	10	2.0	SS304L	1051	2122	APEA	
Heat Exchangers - Plate & Fin										
DESCRIPTION	TYPE	SIZE		DESIGN PRESSURE (bar g)	DESIGN TEMPERATURE (°C)	MATERIAL	EQUIPMENT		COST SOURCE	
Heat Exchangers - Plate & Fin	Duty (kW)	LMTD (K)	Q/LMTD (m ³ /K)				Pressure (bar g)	Temperature (°C)		Cost
LT heat exchanger 1 (3 streams)	P&F-fin	4 696	9		86.9	-59	SS304L	521	1 041	
LT heat exchanger 2 (2 streams)	P&F-fin	695	6	106 364	0.3	-59	SS304L	165	331	
Refrigerated cooler 1	P&F-fin	4 922	7	730 434	0.1	-44	SS304L	465	929	
Refrigerated cooler 2	P&F-fin	2 516	7	385 777	0.2	-59	SS304L	330	660	
Fans, Compressors and Expanders										
DESCRIPTION	TYPE	SIZE		DESIGN INLET PRESSURE (bar g)	DESIGN OUTLET PRESSURE (bar g)	DESIGN INLET TEMPERATURE (°C)	MATERIAL	EQUIPMENT		COST SOURCE
Fans, Compressors and Expanders	Flow (DESIGN) (m ³ /h)	Power (DESIGN) (kW)	Q/LMTD (m ³ /K)					Pressure (bar g)	Temperature (°C)	
Flue gas blower 1		441393	2531	1.8	2.0	138	SS304L	667	933	D4.4
Flue gas compressor	Centrifugal, horizontal	351368	12143	1.8	3.4	68	SS304L	32515	37434	APEA
Centrifugal gas expander 1	Turboexpander	2367	1920	33.1	10.1	147	SS304L	1077	1494	APEA
Centrifugal gas expander 2	Turboexpander	8731	2036	9.9	3.3	145	SS304L	1140	1715	APEA
Centrifugal gas expander 3	Turboexpander	139982	5320	3.0	2.0	133	SS304L	2886	5720	APEA
Perniate compressor 1	Centrifugal, horizontal	121980	5571	1.8	4.1	56	SS304L	10226	12244	APEA
Perniate compressor 2	Centrifugal, horizontal	36503	5394	4.1	11.6	56	SS304L	5631	6479	APEA
Perniate compressor 3	Centrifugal, horizontal	10952	5248	11.4	37.4	56	SS304L	2375	2887	APEA
Vacuum pump	Water-sealed	619184	9156	1.8	0.0	55	CS	8577	10297	APEA
Small recycle compressor	Centrifugal, horizontal	603	281	9.7	36.6	-60	SS304L	1024	1254	APEA

Table S10. Equipment list for membrane package, vessels, pumps, generators and dehydration equipment in both CO₂ capture and compression section.

DESCRIPTION		SIZE	DESIGN	DESIGN	EQUIPMENT		DIRECT		COST	
Area (Design)		PRESSURE	TEMPERATURE	TEMPERATURE	COST	COST	COST	COST	SOURCE	
Membrane Package		(m2)	bar/g	°C	₩2014	₩2014	₩2014	₩2014		
Membrane		250800	3.3	55	NA		11 506	D4.4		

DESCRIPTION	TYPE	SIZE			DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST	
		Liq Flow (DESIGN)	Gas Flow (DESIGN)	ID							H
Tanks & Vessels											
Water separator 1	Vertical	(m3/h)	(m3/h)	(mm)	(mm)	3.3	56	SS304L	690	1184	AFPA
Water separator 2	Vertical	2.28	38603	3.4	13.5	4.1	56	SS304L	262	600	AFPA
Water separator 3	Vertical	0.68	10952	2.3	9.1	11.4	56	SS304L	244	560	AFPA
Water separator 4	Vertical	0.20	3134	1.5	6.0	36.6	56	SS304L	132	251	AFPA
Water separator 5	Vertical	0.24	121980	5.1	20.2	1.8	56	SS304L	559	1044	AFPA
Main Liquid CO2 separator	Vertical	100.18	1208	1.6	6.3	34.4	-59	SS304L	143	374	AFPA
CO2 purification separator	Vertical	86.46	603	1.4	5.7	9.7	-60	SS304L	59	290	AFPA

DESCRIPTION	TYPE	SIZE		DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST		
		Flow (DESIGN)	Power (DESIGN)							PRESSURE	TEMPERATURE
Pumps											
DOC pump	Centrifugal		109.9	65.6	6.5	82	SS304L	79	218	AFPA	
Water KOI pump	Centrifugal		0.1	0.04	6.4	56	SS304L	42	71	AFPA	
Liquid CO2 pump 1	Centrifugal		24	213	86.9	-60	SS304L	375	623	D4.4	
Liquid CO2 pump 2	Centrifugal		31	118	13.1	40	SS304L	226	375	D4.4	

DESCRIPTION	SIZE		MATERIAL	EQUIPMENT	DIRECT	COST	SOURCE
	Power (DESIGN)	Output (DESIGN)					
	(kW)	(kW/s)					
Generators							
Electric generator 1 (Gas expander 3)	5064	6317	CS	5266	5627	AFPA	AFPA
Electric generator 2 (Gas expander 1&2)	3777	4721	CS	4415	4737	AFPA	AFPA

DESCRIPTION	TYPE	SIZE			ABSORBENT MASS	DESIGN	DESIGN	MATERIAL	MATERIAL	EQUIPMENT	DIRECT	COST		
		Flow (DESIGN)	Water flow (DESIGN)	ID									Length	
Other Equipment														
No. Of trains	2	(m3/s)	(kg/h)	(m)	(m)	TOTAL	PRESSURE	TEMPERATURE		SS304L	3	132	367	AFPA + D4.4
Molecular sieve, single vessel dimensions														
		0.87	155.8	1.4	2.59	0.933	33.5	56	SS304L	3	132	367	AFPA + D4.4	

Table S11. Equipment list for external refrigeration system.

DESCRIPTION	TYPE	SIZE		DESIGN LIMITED TEMPERATURE (K)	DESIGN AREA (DESIGN) (m ²)	DESIGN PRESSURE barg	DESIGN TEMPERATURE °C	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE
		Duty (kW)									
Heat Exchangers - Plate & Frame											
Cooler/condenser	P&F	11 205	12	351.3	11.8	68.4	SS304L	71	347	APEA	
DESCRIPTION	TYPE	SIZE		DESIGN PRESSURE barg	DESIGN TEMPERATURE °C	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE		
		Duty (kW)									
Heat Exchangers - Plate & Fin											
LT Heat Exchanger	P&Fin	2 825	9.3	-47	SS304L	360	720	DA.4			
DESCRIPTION	TYPE	SIZE		DESIGN INLET PRESSURE barg	DESIGN OUTLET PRESSURE barg	DESIGN INLET TEMPERATURE °C	MATERIAL	EQUIPMENT COST	DIRECT COST	COST SOURCE	
		Flow (DESIGN) (m ³ /h)	Power (DESIGN) (kW)								
Fans, Compressors and Expanders											
Cooling media compressor 1	Centrifugal horizontal	3215	340	5.1	9.3	-59	SS304L	894	1244	APEA	
Cooling media compressor 2	Centrifugal horizontal	36083	1498	1.8	4.1	-44	SS304L	3244	4208	APEA	
Cooling media compressor 3	Centrifugal horizontal	17244	2306	4.1	11.8	-16	SS304L	2080	2714	APEA	
DESCRIPTION	SIZE		EQUIPMENT COST		DIRECT COST	COST SOURCE					
	Flow (OP) (m ³ /h)	Flow (DESIGN) (l/s)									
Cooling tower	3341	1020.8	508		871	APEA					
Complete cooling tower, field assembly											

5. Equipment list for calcium looping tail-end configuration

The equipment list for the core process in the baseline scenario is presented in Table S12 and the equipment list for the CO₂ purification unit is presented in Table S13.

Table S12: Equipment list of units.

Limestone grinding plant		
	Limestone Mill	
Mass flow rate, t/h	76.5	
Average particle diameter of milled limestone, μm	~200	
TEC+IC, k€	2,484.2	
Fans		
	CO ₂ fan	Carbonator fan
Type	Sealed	Standard
Volumetric low rate (Design), m ³ /h	102,976	336,873
Head, kPa	20	20
Temperature, °C	400	312.5
Power (Design), kW	690.8	2276.7
MC, k€	124.2	160.4
EMC, k€	73.6	208.5
EIC, k€	59.3	110.7
OC, k€	38.6	72.0
TEC, k€	295.7	551.6
IC, k€	118.3	220.7
Reactors		
	Carbonator	Calciner
Type	CFB, Cooled	CFB, Refractory lined
Volumetric flow, m ³ /h – Nm ³ /h	395,117 – 116,937	365,016 – 83,579
Operating temperature, °C	650	920
Superficial gas velocity, m/s	5	5
Outlet temperature, °C	650	920
Width x Depth, m	4.7 x 4.7	4.5 x 4.5
Height, m	20	20
Thickness of steel, mm	7.0	25
Thickness of refractory, mm	-	200
TEC, k€	7,522	5,273
IC, k€	8,232	5,679
Pumps		
	Condensate pump	Feedwater pump
Type	Vertical canned	Multistage centrifugal
Flow rate, kg/s	77.37	41.94
Head, m H ₂ O	99.06	1645.9
Electricity absorption, kW	75.51	920.4
TEC, k€	19.5	307.2

IC, k€	2.5	13.8
Deaerator		
Type	Tank Car	
Feedwater mass flow, kg/s	39.84	
Pressure, bar	3.614	
Temperature, °C	140	
Total storage volume, l	18072	
Overall height, m	5.186	
Overall length, m	5.53	
Storage tank		
-Thickness, mm	12.7	
-Outer diameter, m	2.286	
-Total length, m	5.53	
Heater		
-Thickness, mm	12.7	
-Outer diameter, m	2.286	
-Total length, m	2.595	
TEC, k€	194.1	
IC, k€	17.0	
Regenerative Feedwater Preheater		
Type	Includes condensing section, drain cooler	
Shell pressure, bar	0.36	
Saturation temperature, °C	73.37	
Feedwater mass flow rate, kg/s	38.68	
Heat transfer rate, MW	4.96	
Feedwater Heater Tube		
-Type	Bare Tube	
-Material,	Stainless Steel	
-Layout in crossflow	Rotated Square 45°	
-Design point water pressure, bar	4.926	
-Number of tubes in heater,	430	
-Length, m	9.43	
-Outer diameter, mm	15.88	
-Thickness, mm	1.25	
Feedwater Heater Shell		
-Material,	Carbon Steel	
-Steam pressure, bar	0.36	
-Overall length, m	10.5	
-Overall outer diameter, mm	812	
-Shell wall thickness, mm	4.762	
TEC, k€	144.2	
IC, k€	10.9	

Condenser	
Type	Shell & tube
Heat rejection, MW	76.7
Pressure, bar	0.07
Temperature, °C	39.03
Non-condensable removal system,	Vacuum Pump
Water depth in hotwell, m	0.59
Volume water stored in hotwell, l	11,690
Condenser Tube	
-Material,	Stainless steel
-Length, m	7.0
-Outer diameter, m	25.4
-Thickness, mm	0.71
Condenser Shell	
-Material,	Carbon steel
-Thickness, mm	12.7
-Length x Width x Height, m	9.1 x 2.8 x 4.8
TEC, k€	671.8
IC, k€	207.1
Cooling Tower for steam cycle condenser heat rejection	
Type	Crossflow, Film Fill
Heat rejection, MW	77.0
Total number of cells in tower	4
Number of rows	1
Length per row, m	40.05
Length per cell, m	10.01
Width at top of cell, m	10.78
Width at bottom of cell, m	8.31
Height, m	9.81
Basin area, m ²	405.9
Fan diameter, m	6.68
TEC, k€	817.5
IC, k€	408.6
Steam Turbine and electric generator	
Type	Condensing, Non-Reheat
Capacity, MVA	52.5
Throttle Pressure, bar	110.5
Throttle Temperature, °C	532.0
Throttle Mass flow, kg/s	39.84
Exhaust End Type	Down Draft
Number of stages,	20
Generator Power, MW	44.97
Generator Efficiency, %	98.08

Overall Steam Turbine and Generator Length, m	14.96					
Overall Steam Turbine and Generator Width, m	4.03					
Overall Steam Turbine and Generator Weight, kg	162,150					
Foundation Length, m	16.78					
Foundation Width, m	4.8					
TEC, k€	8,550.9					
IC, k€	872.9					
CO ₂ Compression and Purification Unit						
TEC, k€	31,873					
IC, k€	6,009					
ASU						
Oxygen produced, tpd	1,359.9					
TEC+IC, k€	43,775					
Heat exchangers						
	Flue gases Cooler	HT CO ₂ Cooler 1	HT CO ₂ Cooler 2	LT CO ₂ Cooler	Purge Cooler	O ₂ preheater
Type	Bare Tube	Bare Tube	Bare Tube	Bare Tube	Bare Tube	Bare Tube
Design point hot stream temperature, °C	650	920	400	276.9	920	316.5
Design point operating pressure, bar	115.7	114.42	124.42	4.62	134.4	1.03
Area, m²	289.6	748.2	122.5	437.8	24	112.8
Duty, MW	9.7	29.9	3.9	9.0	1.6	1.9
Material	T22	T91	Carbon Steel	Carbon Steel	Carbon Steel	Stainless Steel
Weight, kg	4,070	14,530	2,140	6,160	1,060	654
Surface cost, k€	24.4	152.6	6.4	18.5	3.2	4.6
Auxiliary equipment cost, k€	24.4	152.6	6.4	18.5	3.2	4.6
TEC, k€	48.8	305.1	12.8	37.0	6.4	9.2
IC, k€	12.2	76.3	3.2	9.2	1.6	2.3

Table S13: Equipment list for the CO2 purification unit

DESCRIPTION	TYPE	SIZE		DESIGN	DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST		
		Flow (DESIGN) (m³/h)	Power (DESIGN) (kW)								INLET PRESSURE	OUTLET PRESSURE
Fans, Compressors and Exhausters	Compressor 1-4	Centrifugal, horizontal	95242	10955	1.8		25.3	56	SS304L	26074	27241	AFEA
	Compressor 5-6	Centrifugal, horizontal	6717	5594	12.2		91.3	48	SS304L	2715	3179	AFEA

DESCRIPTION	TYPE	SIZE					DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Liq Flow (DESIGN) (m³/h)	Gas flow (DESIGN) (m³/h)	ID (mm)	H (mm)		DESIGN PRESSURE barg	DESIGN TEMPERATURE °C		EQUIPMENT COST K£2014	COST K£2014	SOURCE
Tanks & Vessels	Water separator 1	Vertical	6.00	99246	4.7	18.9	1.8	56	SS304L	483	968	AFEA
	Water separator 2	Vertical	1.44	44812	3.6	14.5	2.9	56	SS304L	249	612	AFEA
	Water separator 3	Vertical	0.66	20088	2.8	11.1	5.5	56	SS304L	169	476	AFEA
	Water separator 4	Vertical	0.30	8889	2.1	8.4	11.1	56	SS304L	127	342	AFEA
	Water separator 5	Vertical	0.13	3789	1.6	6.4	24.8	56	SS304L	125	289	AFEA
	Liquid CO2 separator	Vertical	136.4	195	1.6	6.3	24.8	-55	SS304L	119	365	AFEA

DESCRIPTION	TYPE	SIZE			DESIGN PRESSURE barg	DESIGN TEMPERATURE °C	MATERIAL	EQUIPMENT COST M€2014	DIRECT COST M€2014	COST SOURCE	
		Duty (kW)	LMTD (°)	Area (Design) (m2)							
Heat Exchangers - Plate & Frame	Gas/gas Heat Exchanger 1	PA-F	116	44	10	2.9	124	SS304L	4	94	AFEA
	Flue gas cooler before CPU	PA-F	1122	9	349	1.8	63	SS304L	71	351	AFEA
	Intercooler 1	PA-F	3388	35	210	2.9	121	SS304L	44	305	AFEA
	Intercooler 2	PA-F	3019	37	179	5.6	124	SS304L	38	239	AFEA
	Intercooler 3	PA-F	2652	37	188	11.3	125	SS304L	36	236	AFEA
	Intercooler 4	PA-F	2393	38	171	25.3	126	SS304L	40	239	AFEA
	Intercooler 5	PA-F	3134	41	167	34.3	133	SS304L	40	266	AFEA
Intercooler 6	PA-F	8746	48	483	91.3	146	SS304L	102	463	AFEA	

DESCRIPTION	TYPE	SIZE	DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Duty (kW)	PRESSURE barg	TEMPERATURE °C		COST K£2014	COST K£2014	SOURCE
Heat Exchangers - Plate & Fin								
L1T heat exchanger 1 (4 streams)	PA-Fin	15530	24.8	-55	SS304L	824	1030	DA4

DESCRIPTION	TYPE	SIZE		DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Flow (DESIGN) (m³/h)	Power (DESIGN) (kW)	PRESSURE barg	TEMPERATURE °C		COST K£2014	COST K£2014	SOURCE
Pumps									
Liquid CO2 pump	Centrifugal	303	291	119.9	65	SS304L	489	812	DA4

DESCRIPTION	TYPE	SIZE			ABSORBENT MASS TOTAL	DESIGN PRESSURE bar(g)	DESIGN TEMPERATURE °C	MATERIAL	MATERIAL COST	EQUIPMENT COST	TOTAL DIRECT COST	COST SOURCE	
		Flow (DESIGN) (m3/s)	Water flow (DESIGN) (kg/s)	ID (m)									Length (m)
Other Equipment	No. Of trains												
Molecular sieve, single vessel dimensions	2	1.06	159.6	1.5	2.50	0.950	24.8	58	3A, SS304L	4	125	384	AFEA + DA4

6. Equipment list for calcium looping integrated configuration

The equipment list for the core process in the baseline scenario is presented in Table S14 and the equipment list for the CO₂ purification unit is presented in Table S15.

Table S14: Equipment list of the core process units.

Kiln risers			
Design volumetric flow, Nm ³ /h			45,156
Design temperature, °C			1080
Diameter, m			2
Length, m			12
Thickness of steel, mm			12
Thickness of refractory, mm			200
TEC, k€			67.6
IC, k€			139.4
Ducts			
	Lean-CO ₂ duct	Decarb gas duct	CO ₂ -rich gas duct
Type	Insulated	Refractory	Insulated
Design volumetric flow, Nm ³ /h	121,076	39,446	75,058
Design temperature, °C	280	670	400
Design gas velocity, m/s	15	15	15
Diameter, m	2.3	1.8	2.1
Length, m	70	40	120
Steel, kg/m ²	90	90	90
Refractory/Insulation, kg/m ²	14	318	14
TEC, k€	190.3	160.4	261.9
IC, k€	265,9	285.7	444.9
Fans			
	CO ₂ fan	III Air fan	Lean-CO ₂ fan
Type	Sealed	Standard	Standard
Design flow rate, m ³ /h	222,255	160,887	90,720
Head, kPa	11	4	8
Temperature, °C	400	265.2	265.2
Power, kW	847	229	278
MC, k€	182.4	52.8	39.6
EMC, k€	84.0	26.4	30.0
EIC, k€	79.9	23.8	20.9
OC, k€	52.0	15.4	13.6
TEC, k€	398.4	118.4	104.1
IC, k€	159.4	47.4	41.6
Reactors			
	Carbonator	Calcliner	

Type	Gooseneck - Refractory	Oxyfuel – Refractory
Volumetric flow, m ³ /h – Nm ³ /h	137,763 – 39,446	524,337 – 120,059
Outlet temperature, °C	668.3	920
Solid-gas ratio, kg/m ³ – kg/Nm ³	4.69 – 12.32	0.51 – 2.21
Diameter, m	1.8	3.5
Length, m	120	45
Thickness of steel, mm	12	25
Thickness of refractory, mm	150	200
TEC, k€	3,454.8	4,118.4
IC, k€	included in “Tower structure”	
Tower Structure, k€	40,314.5	

Suspension Preheater/Cooler			
	CO ₂ Preheater	Kiln Preheater	Sorbent cooler
# Stages	3	2	1
1st stage	High efficiency	High efficiency	High efficiency
Gas mass flow rate, kg/s	77.24	17.06	40.06
Solid mass flow rate, kg/s	38.89	22.44	154.22
Design gas velocity, m/s	15	15	15
Inlet gas temperature, °C	804.7	749.8	273.7
Inlet solid temperature, °C	60.0	60.0	742.9
Outlet temperature, °C	614.0	434.6	621.5
Solid-gas ratio, kg/m ³ – kg/Nm ³	0.23 – 0.90	0.47 – 1.93	1.48 – 4.93
Riser duct			
Diameter, mm	3470	1676	2970
Length, m	5	5	5
Thickness of refractory, mm	100	130	150
Steel, kg/m ²	80	80	80
Feed pipe			
Diameter, mm	1047	397	734
Length, m	10	10	10
Thickness of refractory, mm	100	130	150
Steel, kg/m ²	80	80	80
Cyclone			
# cyclones	2	2	2
Diameter, mm	5235	2833	3668
Height, m	6	4	4
Thickness of refractory, mm	100	130	150
Steel, kg/m ²	80	80	80
2nd stage	Standard efficiency	Standard efficiency	

Suspension Preheater/Cooler			
Gas mass flow, kg/s	77.24	17.06	
Solid mass flow, kg/s	42.58	24.19	
Design gas velocity, m/s	15	15	
Inlet temperature of gas, °C	885.0	1078.5	
Inlet temperature of solid, °C	614.0	434.6	
Outlet temperature, °C	804.7	749.8	
Solid-gas ratio, kg/m ³ – kg/Nm ³	0.23 – 0.99	0.38 – 1.93	
Riser duct			
Diameter, mm	3819	2010	
Length, m	5	5	
Thickness of refractory, mm	180	200	
Steel, kg/m ²	80	80	
Feed pipe			
Diameter, mm	916	639	
Length, m	10	10	
Thickness of refractory, mm	180	200	
Steel, kg/m ²	80	80	
Cyclone			
# cyclones	1	1	
Diameter, m	6540	4566	
Height, m	8	6	
Thickness of refractory, mm	180	200	
Steel, kg/m ²	80	80	
3rd stage	Standard efficiency		
Gas mass flow, kg/s	77.24		
Solid mass flow, kg/s	40.91		
Design gas velocity, m/s	15		
Inlet temperature of gas, °C	920.0		
Inlet temperature of solid, °C	804.7		
Outlet temperature, °C	885.0		
Solid-gas ratio, kg/m ³ – kg/Nm ³	0.22 – 0.95		
Riser duct			
Diameter, mm	4018		
Length, m	5		
Thickness of refractory, mm	200		
Steel, kg/m ²	80		
Feed pipe			
Diameter, mm	934		
Length, m	10		
Thickness of refractory, mm	200		

Suspension Preheater/Cooler			
Steel, kg/m ²	80		
Cyclone			
# cyclones	1		
Diameter, mm	6673		
Height, m	8		
Thickness of refractory, mm	200		
Steel, kg/m ²	80		
TEC, k€	500.4	150.3	402.4
IC, k€	846.2	255.7	included in “Tower structure”

Pumps		
	Condensate pump	Feedwater pump
Type	Multistage centrifugal	Multistage centrifugal
Design flow rate, kg/s	31.24	25.28
Head, m H ₂ O	198.1	975.4
Electricity absorption, kW	75.75	327.7
TEC, k€	95.9	177.1
IC, k€	2.5	5.9
Deaerator		
Type	Tank Car	
Design feedwater mass flow, kg/s	24.02	
Design pressure, bar	3.89	
Design temperature, °C	142.6	
Total storage volume, l	10922	
Overall height, m	4.665	
Overall length, m	4.841	
Storage tank		
-Thickness, mm	11.11	
-Outer diameter, m	1.896	
-Total length, m	4.841	
Heater		
-Thickness, mm	11.11	
-Outer diameter, m	1.896	
-Total length, m	2.464	
TEC, k€	143.0	
IC, k€	10.7	
Condenser		
Type	Shell & tube	
Design heat rejection, MW	49.3	

Design pressure, bar	0.07
Design temperature, °C	39.03
Non-condensable removal system,	Vacuum Pump
Water depth in hotwell, m	0.45
Volume water stored in hotwell, l	7,080
Condenser Tube	
-Material,	Stainless steel
-Length, m	6.7
-Outside diameter, m	25.4
-Thickness, mm	0.71
Condenser Shell	
-Material,	Carbon steel
-Thickness, mm	9.5
-Length x Width x Height, m	8.4 x 2.3 x 4.0
TEC, k€	486.2
IC, k€	139.6
Cooling Tower	
Type	Crossflow, Film Fill
Design heat rejection, MW	49.4
Total number of cells in tower	4
Number of rows	1
Length per row, m	32.09
Length per cell, m	8.02
Width at top of cell, m	9.03
Width at bottom of cell, m	7.05
Height, m	7.86
Basin area, m ²	285.1
Fan diameter, m	5.35
TEC, k€	641.9
IC, k€	283.0
Steam Turbine and electric generator	
Type	Condensing, Non-Reheat
Design capacity, MVA	27.9
Throttle Pressure, bar	63.0
Throttle Temperature, °C	460.0
Throttle Mass flow, kg/s	24.02
Exhaust End Type	Down Draft
Number of stages,	18
Generator Power, MW	23.88
Generator Efficiency, %	97.65
Overall Steam Turbine and Generator Length, m	11.94

Overall Steam Turbine and Generator Width, m					3.51				
Overall Steam Turbine and Generator Weight, kg					102,100				
Foundation Length, m					13.58				
Foundation Width, m					4.2				
TEC, k€					5,460.5				
IC, k€					584.0				
CO2 Compression and Purification Unit									
TEC, k€					28,911				
IC, k€					6,712				
ASU									
Oxygen produced, tpd					1,163.4				
TEC+IC, k€					39,863				
Heat exchangers									
	III Air Cooler SH	III Air Cooler EVA	III Air Cooler ECO	Decarb gas HT Cooler	Lean-CO2 gas HT Cooler	CO2-rich gases HT cooler 1	CO2-rich gases HT cooler 2	CO2-rich gases LT cooler	O2 preheater
Type	Bare Tube	Bare Tube	Bare Tube	Bare Tube	Bare Tube	Bare Tube	Bare Tube	Bare Tube	Bare Tube
Design point gas temperature, °C	1,049.8	630.2	347.4	668.3	621.5	614.0	400.0	283.3	320.4
Design point operating pressure, bar	65.2	65.2	76.6	81.6	65.2	65.2	66.8	13.6	1.036
Area, m²	273.6	499.6	452.1	332.8	343.4	897.6	385.5	2328.9	201.7
Duty, MW	13.2	8.3	2.3	9.4	8.3	20.3	3.4	8.9	1.5
Material	T91	Carbon Steel	Carbon Steel	T22	Carbon Steel	Carbon Steel	Carbon Steel	Carbon Steel	Stainless Steel
Weight, kg	4,270	7,800	6,380	4,030	5,360	14,020	5,410	50,300	1,170
Surface cost, k€	44.8	23.4	19.1	24.2	16.1	42.1	16.2	150.9	8.2
Auxiliary equipment cost, k€	44.8	23.4	19.1	24.2	16.1	42.1	16.2	150.9	8.2
TEC, k€	89.7	46.8	38.3	48.4	32.2	84.1	32.5	301.8	16.4
IC, k€	22.4	11.7	9.6	12.1	8.0	21.0	8.1	75.5	4.1

Table S15: Equipment list for the CO₂ purification unit.

DESCRIPTION	TYPE	SIZE		DESIGN	DESIGN	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Flow (DESIGN)	Power (DESIGN)							
Fans, Compressors and Expanders		(m³/h)	(kW)	bang	bang	°C		k€2014	k€2014	APEA
	Compressor L-4	86893	9455	1.8	24.2	56	SS304L	Z2461	Z5016	APEA
Compressor S-6	Centrifugal horizontal	6203	9207	12.2	91.3	49	SS304L	Z3811	3144	APEA

DESCRIPTION	TYPE	SIZE		ID	H	DESIGN		MATERIAL	EQUIPMENT	DIRECT	COST
		Lq Flow (DESIGN)	Gra Flow (DESIGN)			PRESSURE	TEMPERATURE				
Tanks & Vessels		(m³/h)	(m³/h)	(mm)	(mm)	bang	°C	k€2014	k€2014		
	Water separator 1	5.40	86879	4.5	18.1	1.8	56	SS304L	398	815	APEA
	Water separator 2	1.25	38266	3.5	13.9	2.9	56	SS304L	253	592	APEA
	Water separator 3	0.86	17975	2.7	10.7	5.4	56	SS304L	179	481	APEA
	Water separator 4	0.26	8044	2.0	8.2	10.8	56	SS304L	117	330	APEA
	Water separator 5	0.12	3488	1.5	6.2	23.7	56	SS304L	102	241	APEA
Liquid CO2 separator	Vertical	118.4	198	1.5	6.0	23.7	-55	SS304L	97	340	APEA

DESCRIPTION	TYPE	SIZE		DESIGN		DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Duty	LMTD	Area (Design)	PRESSURE					
Heat Exchangers - Pains & Fumes		(kW)	(K)	(m²)	bang	°C		k€2014	k€2014	
	Gases heat exchanger 1	126	47	3.0	3.0	123	SS304L	4	94	APEA
	Rare gas cooler before CPU	984	9	306	1.8	63	SS304L	63	316	APEA
	Intercooler 1	2914	30	214	3.0	119	SS304L	45	307	APEA
	Intercooler 2	2609	31	168	5.5	123	SS304L	39	241	APEA
	Intercooler 3	2460	31	174	11.0	124	SS304L	37	238	APEA
	Intercooler 4	2184	32	177	24.2	125	SS304L	37	239	APEA
	Intercooler 5	2816	35	179	33.5	136	SS304L	43	271	APEA
	Intercooler 6	7382	38	449	81.3	148	SS304L	113	482	APEA

DESCRIPTION	TYPE	SIZE	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Duty	PRESSURE				
Heat Exchangers - Pains & Fin		(kW)	bang	°C	k€2014	k€2014	D4.4
Lt Heat exchanger 1 (4 streams)	PAFin	13.875	23.7	-55	SS304L	714	1.429

DESCRIPTION	TYPE	SIZE	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST
		Flow (DESIGN)	Power (DESIGN)				
Pumps		(m³/h)	(kW)	bang	°C		
Liquid CO2 pump	Centrifugal	239	249	113.9	65	SS304L	428

DESCRIPTION	TYPE	SIZE	DESIGN	MATERIAL	EQUIPMENT	DIRECT	COST											
		Flow (DESIGN)	Water flow(DESIGN)					TOTAL	PRESSURE	TEMPERATURE	COST	SOURCE						
Other Equipment		No. Of Trains	(m³/s)	(gpm)	(mm)	Length	(m)	2.49	0.666	(g)	PRE SSURE	DESIGN	TEMPERATURE	MATERIAL	EQUIPMENT	TOTAL DIRECT	COST	SOURCE
Molecular sieve, single vessel dimensions		2	0.97	MA.8	1.4	2.49	0.666	23.7	56	SA-SS304L	112	388	APEA + D4.4					