

Supplementary Information

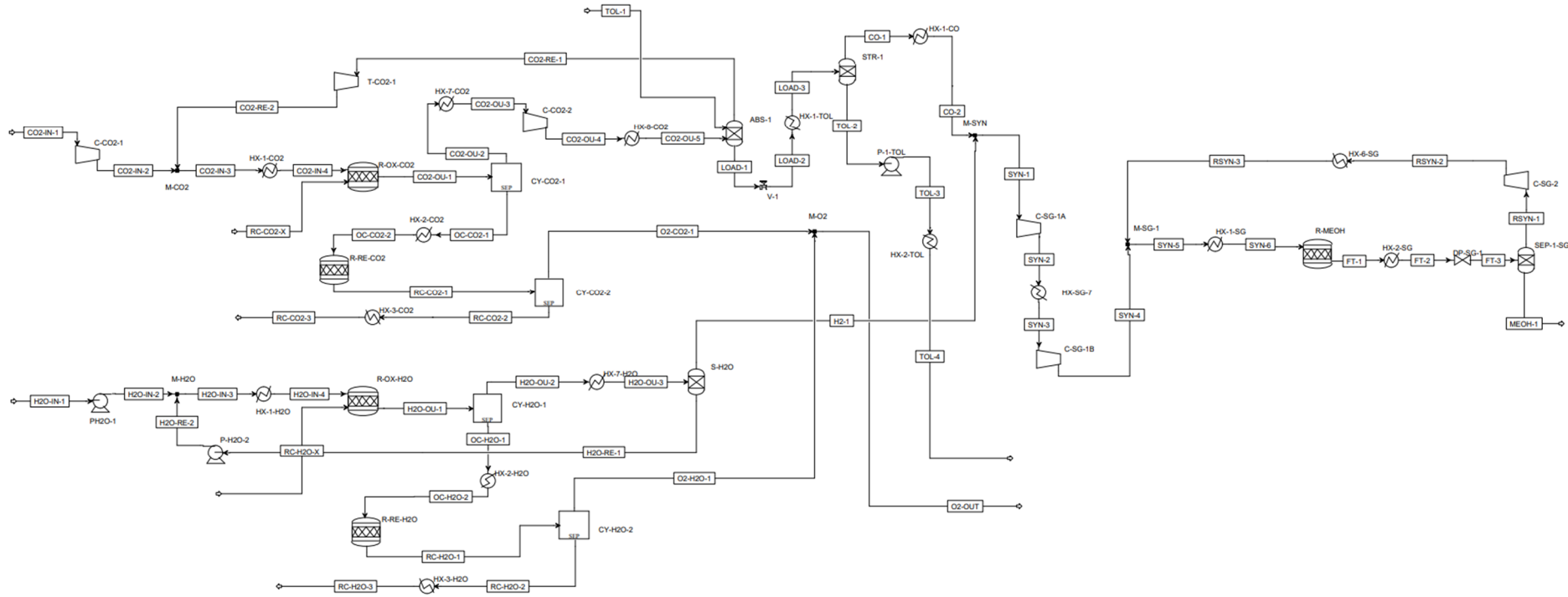


Figure S1. Flowsheet of the Aspen Plus® simulation of synthetic fuel production.

Table S1. Stream information of the Aspen Plus® simulation of synthetic fuel production (part 1).

Variable	Units	CO2-IN-1	CO2-IN-2	CO2-IN-3	CO2-IN-4	CO2-OU-1	CO2-OU-2	CO2-OU-3	CO2-OU-4	CO2-OU-5	CO2-RE-1	CO2-RE-2	CO-1	CO-2	FT-1	FT-2	FT-3	H2-1	H2O-IN-1
Temperature	°C	25.0	191.8	79.5	900.0	900.0	900.0	50.0	319.9	50.0	31.8	-1.7	80.0	40.0	250.0	50.0	49.5	50.0	25.0
Pressure	bar	1.0	5.0	5.0	5.0	1.0	1.0	1.0	10.0	10.0	10.0	5.0	1.0	1.0	50.0	50.0	45.0	1.0	1.0
Molar Vapor Fraction		1.000	1.000	1.000	1.000	0.162	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	0.754	0.755	1.000	0.000
Molar Liquid Fraction		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.246	0.245	0.000	1.000
Molar Solid Fraction		0.000	0.000	0.000	0.000	0.838	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Enthalpy Flow	kW	-2484	-2441	-6185	-5538	-87743	-3849	-4417	-4256	-4420	-3734	-3744	-688	-695	-1772	-2165	-2165	9	-3608
Mole Flows	kmol/h	22.7	22.7	57.0	57.0	351.2	57.0	57.0	57.0	57.0	34.3	34.3	22.7	22.7	90.9	90.9	90.9	45.4	45.4
Mole Fractions																			
H ₂		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.500	0.500	0.500	1.000	0.000
H ₂ O		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
CO ₂		1.000	1.000	0.996	0.996	0.097	0.598	0.598	0.598	0.598	0.993	0.993	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CO		0.000	0.000	0.004	0.004	0.065	0.402	0.402	0.402	0.402	0.007	0.007	1.000	1.000	0.250	0.250	0.250	0.000	0.000
O ₂		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CEO ₂		0.000	0.000	0.000	0.000	0.834	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CE ₂ O ₃		0.000	0.000	0.000	0.000	0.004	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TOLUENE		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
METHANOL		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.250	0.250	0.250	0.000	0.000

Table S1. Stream information of the Aspen Plus® simulation of synthetic fuel production (part 2).

Variable	Units	H2O-IN-2	H2O-IN-3	H2O-IN-4	H2O-OU-1	H2O-OU-2	H2O-OU-3	H2O-RE-1	H2O-RE-2	LOAD-1	LOAD-2	LOAD-3	MEOH-1	O2-CO2-1	O2-H2O-1	O2-OUT	OC-CO2-1	OC-CO2-2
Temperature	°C	25.1	40.1	900.0	900.0	900.0	50.0	50.0	50.1	31.8	29.0	80.0	49.5	1500.0	1500.0	1500.0	900.0	1500.0
Pressure	bar	2.0	2.0	2.0	1.0	1.0	1.0	1.0	2.0	10.0	1.0	1.0	45.0	1.0	0.1	0.1	1.0	1.0
Molar Vapor Fraction		0.000	0.000	1.000	0.162	1.000	0.457	0.000	0.000	0.193	0.219	0.347	0.000	1.000	1.000	1.000	0.000	0.000
Molar Liquid Fraction		1.000	1.000	0.000	0.000	0.000	0.543	1.000	1.000	0.807	0.781	0.653	1.000	0.000	0.000	0.000	0.000	0.000
Molar Solid Fraction		0.000	0.000	0.000	0.838	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000
Enthalpy Flow	kW	-3608	-8985	-6580	-171402	-3620	-5291	-5377	-5376	-382	-382	-39	-1490	160	320	480	-83895	-79794
Mole Flows	kmol/h	45.4	113.6	113.6	702.0	113.6	113.6	68.2	68.2	107.7	107.7	107.7	22.7	11.4	22.7	34.1	294.2	294.2
Mole Fractions																		
H ₂		0.000	0.000	0.000	0.065	0.400	0.400	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
H ₂ O		1.000	1.000	1.000	0.097	0.600	0.600	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CO ₂		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
CO		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.211	0.211	0.211	0.000	0.000	0.000	0.000	0.000	0.000
O ₂		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	1.000	1.000	0.000	0.000
CEO ₂		0.000	0.000	0.000	0.835	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.996	0.996
CE ₂ O ₃		0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.004	0.004
TOLUENE		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.789	0.789	0.789	0.000	0.000	0.000	0.000	0.000	0.000
METHANOL		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.000

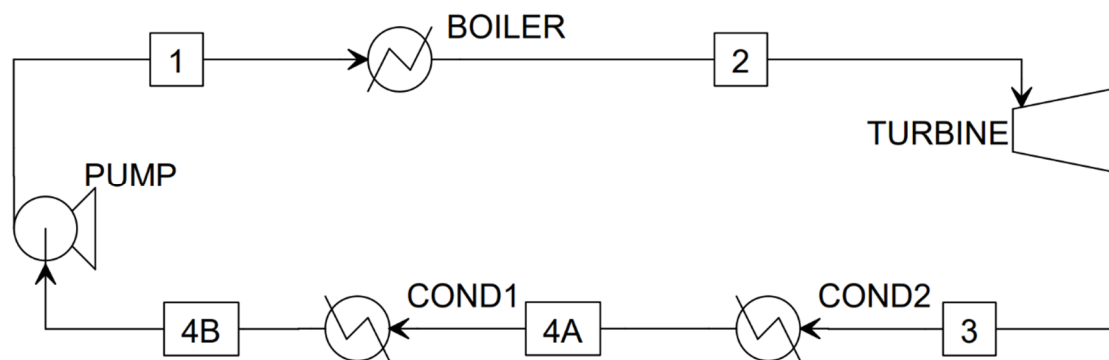


Figure S2. Flowsheet of the Aspen Plus® simulation of the steam Rankine cycle.

Table S2. Stream information of the Aspen Plus® simulation of the steam Rankine cycle.

Variable	Units	1	2	3	4A	4B
Temperature	°C	29.6	538.0	99.6	99.6	20.0
Pressure	bar	163.0	163.0	1.0	1.0	1.0
Molar Vapor Fraction		0.000	1.000	0.894	0.000	0.000
Molar Liquid Fraction		1.000	0.000	0.106	1.000	1.000
Enthalpy Flow	kW	-15832	-12570	-13536	-15554	-15887
Mass Flow	kg/s	1.0	1.0	1.0	1.0	1.0
Mole Fractions						
H ₂ O		1.000	1.000	1.000	1.000	1.000

Table S3. Summary of inputs and results for each scenario. The blue part of the table (R1-R17) shows the input data, while in the green area (R18-R33) the results can be observed. Negative values refer to generation of heat, electricity or water. In the table, W_d and Q_d are electricity and heat consumption of desalination (1.75 and 5.50 kWh/t H₂O respectively). The acronym HHV_{MeOH} stands for the high heating value of methanol (6.36 kWh/kg), while η_{RE} represents the assumed efficiency of an auxiliary renewable energy like PV ($\eta_{RE} = 20\%$) and η_{opt} is the optical efficiency of the heliostats ($\eta_{opt} = 60\%$).

Row	Source/Calculation	Parameter	Units	Baseline	A. Central sHT	B. Central HT	C. Central LT	D. Hybrid LT	E. Decentralized
R1	Solar input data	Solar thermal energy input (peak)	kW	660000	660000	660000	660000	660000	46.5
R2		Cleaning water needs	kg H ₂ O/h	8607	8607	8607	8607	8607	0
R3	DAC Models	Electricity needed	kWh/t CO ₂	366	154	154	130	120	120
R4		Heat needed from solar	kWh/t CO ₂	0	1125	0	0	0	0
R5		Heat needed from waste heat	kWh/t CO ₂	0	0	0	0	0	1750
R6		Heat needed from cogeneration	kWh/t CO ₂	0	0	0	1750	1750	0
R7		Heat needed from methane	kWh/ t CO ₂	1458	0	1458	0	0	0
R8		Oxygen needed	kg O ₂ /t CO ₂	420	0	420	0	0	0
R9		HP Steam produced	kWh/t CO ₂	0	-75	-75	0	0	0
R10		Water consumption	kg H ₂ O /t CO ₂	4700	4700	4700	-1000	0	-1000
R11		Solar heat needed	kWh/t CO ₂	27194	27194	27194	27194	27194	27194
R12		HP Steam produced	kWh/t CO ₂	-3290	-3290	-3290	-3290	-3290	-3290
R13	TCC & Methanol Synthesis Model	Electricity needed	kWh/t CO ₂	746	746	746	746	746	746
R14		Water input required	kg H ₂ O /t CO ₂	568	568	568	568	568	568
R15		Oxygen produced	kg O ₂ /t CO ₂	1123	1123	1123	1123	1123	1123
R16		Methanol produced	kg MeOH/t CO ₂	728	728	728	728	728	728
R17	Rankine Model	Rankine efficiency	%	0%	40%	40%	28%	28%	10%
R18	R1/(R4+R11)	CO ₂ processed (peak)	t CO ₂ /h	24.3	23.3	24.3	24.3	24.3	0.00171
R19	R18*(R10+R14)+R2	Total water demand/production	kg H ₂ O /h	136451	131372	136451	-1889	22381	-0.74
R20	R19* W_d (if R19 < 0, then R20 = 0)	Electricity needed for desalination	kW	239	230	239	0	39	0
R21	R19* Q_d (if R19 < 0, then R20 = 0)	Heat needed for desalination	kW	750	723	750	0	123	0
R22	R5*R18	Waste heat needed for DAC	kW	0	0	0	0	0	3.00
R23	R6*R18	Cogeneration heat needed for DAC	kW	0	0	0	42473	42473	0
R24	R18*(R9+R12)	HP Waste heat	kW	-79845	-78421	-81666	-79845	-79845	-5.63
R25	R24+R21+R22	Total heat available (250-175 °C)	kW	-79095	-77699	-80915	-79845	-79722	-2.64
R26	R25*R17	Electricity produced from waste heat	kW	0	-31079	-32366	-22357	-22322	-0.26
R27	R18*(R3+R13)+R20+R26	Total electricity demand/production	kW	27238	-9870	-10280	-1085	-1254	1.22
R28	R7*R18	Gross energy input through methane	kW	35386	0	35386	0	0	0
R29	R27/ η_{RE} (if R27 < 0, then R29 = 0)	Gross energy input through other RE	kW	136190	0	0	0	0	6.10
R30	R1/ η_{opt} +R28+R29	Total gross energy input	kW	1271576	1100000	1135386	1100000	1100000	83.7
R31	R16*R18	Methanol production	kg MeOH/h	17670	16968	17670	17670	17670	1.25
R32	R31*HHV _{MeOH}	Total energy output through fuel	kW	112402	107937	112402	112402	112402	7.93
R33	R32/R30	Solar-to-fuel efficiency	%	8.84%	9.81%	9.90%	10.22%	10.22%	9.47%