

Supplementary Digital Materials:

Evaluating the potential of e-fuels for decarbonizing European truck transport: A techno-economic and life cycle approach

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S1. List of abbreviations

CC - Climate Change
CCU - Carbon Capture and Utilization
CH₄ - Methane
CO₂ - Carbon dioxide
FT - Fischer-Tropsch
FTS - Fischer-Tropsch Synthesis
H₂ - Hydrogen
MeOH - Methanol
PtL - Power-to-Liquid
RFNBO - Renewable Fuels of Non-Biologic Origin
rWGS- Reverse Water-Gas Shift
SAF - Sustainable Aviation Fuels

S2. Methodology

The methodological framework applied for the economic and environmental performance assessment of the investigated fuel pathways is illustrated in **Figure S1**.

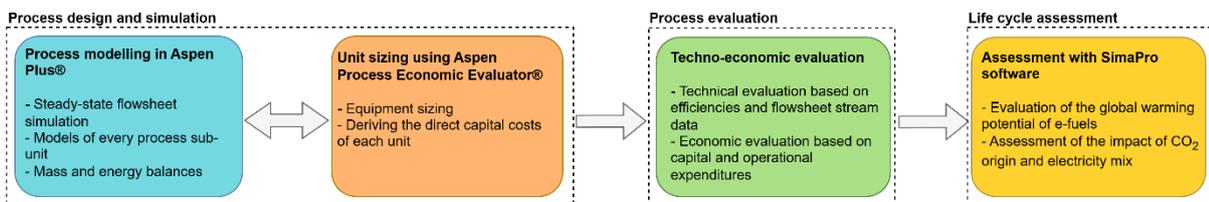


Figure S1: Integrated workflow for techno-economic evaluation (TEA) and life-cycle assessment (LCA) of the studied processes.

S3. Country codes and commodities prices

The countries considered for the present study as well as the corresponding abbreviations and local electricity prices p_E (€/MWh) [1] and diesel prices p_{FD} (€/MWh¹) [2] are listed in **Table S1**. Market price of fossil methanol is fixed at 535 €/t [3].

¹ Energy-specific diesel prices (€/MWh) are computed from volume-specific prices (€/L), assuming 36.9 MJ_{LHV}/L.

Table S1: European countries, corresponding abbreviations, and electricity and fossil diesel prices (€/MWh) considered in this study.

Abbreviation	Country	P _E	P _{FD}	Abbreviation	Country	P _E	P _{FD}
AT	Austria	201.58	155.12	IT	Italy	233.27	162.93
BE	Belgium	193.77	165.85	LV	Latvia	135.21	156.10
BG	Bulgaria	143.39	125.85	LT	Lithuania	158.37	155.12
HR	Croatia	227.82	151.22	LU	Luxembourg	177.43	144.39
CZ	Czechia	182.88	136.59	NL	Netherlands	201.95	169.76
DK	Denmark	122.96	180.49	PL	Poland	199.22	143.41
EE	Estonia	142.02	151.22	PT	Portugal	131.13	159.02
FI	Finland	79.38	161.95	RO	Romania	170.62	146.34
FR	France	163.81	162.93	SK	Slovakia	195.14	147.32
DE	Germany	227.82	161.95	SI	Slovenia	154.28	153.17
GR	Greece	195.14	154.15	ES	Spain	139.30	141.46
HU	Hungary	211.48	152.20	SE	Sweden	95.72	156.10
IE	Ireland	270.04	166.83				

S4. Modeling details – Technoeconomic Assessment

S4.1. E-methanol

Table S2: Net production costs for e-methanol production.

Net Production Costs (NPC)		
	Value	Unit
Total NPC _t	555,901,722.00	€/a
Mass specific NPC _m	1.40	€/kg
Volume specific NPC _v	1.11	€/l
Energy specific NPC _e	0.25	€/kWh
Total NPC		
ARC	29,133,484.30	€/a
ACC	73,599,941.28	€/a
Total Opex	453,168,296.42	€/a

Table S3: Capital expenditures for e-methanol production.

Capex-FCI		
	Value	Unit
Total electrolysis costs	630,594,898.27	€
Total equipment costs	342,642,533.01	€
Capex-TCI		
FCI	973,237,431.28	€
WC	108,137,492.36	€

Table S4: Energy analysis of the e-methanol route.

Energy Analysis		
	Value	Unit
Heating demand with heat recovery (Q)	30.10	MW
Heating demand without heat recovery (Q)	125.81	MW
Process energy demand		
M-C1	18.58	MW
M-C2	10.79	MW
M-C3	1.27	MW
Process heating demand Q (no heat integration)		
M-H1	17.02	MW
M-H3	21.47	MW
M-H5	16.67	MW
M-D1	70.65	MW
Cooling water demand		
Cooling water from 15 °C to 30 °C	23,256,617.40	m ³ /a

S4.2. FTS-diesel

Table S5: Net production costs for FTS-diesel production.

Net Production Costs (NPC)		
	Value	Unit
Total NPC _t	512,186,286.98	€/a
Mass specific NPC _m	7.16	€/kg
Volume specific NPC _v	5.21	€/l
Energy specific NPC _e	0.59	€/kWh
Total NPC		
ARC	33,138,364.31	€/a
ACC	141,523,831.94	€/a
Total Opex	337,524,090.72	€/a

Table S6: Capital expenditures for FTS-diesel production.

Capex-FCI		
	Value	Unit
Total electrolysis costs	717,280,612.69	€
Total equipment costs	1,154,137,873.02	€
Capex-TCI		
FCI	1,871,418,485.71	€
WC	207,935,387.30	€

Table S7: Energy analysis of the FTS-diesel route.

Energy Analysis		
	Value	Unit
Heating demand with heat recovery (Q)	51.25	MW
Heating demand without heat recovery (Q)	192.57	MW
Process energy demand		
R-C1	4.98	MW
R-C2	3.19	MW
F-C1	19.15	MW
F-C2	0.16	MW
F-P1	0.02	MW
F-P2	0.01	MW
Process heating demand Q (no heat integration)		
D-D1	7.79	MW
D-D2	5.35	MW
D-D3	2.43	MW
R-H1	164.35	MW
F-H1	11.51	MW
F-H2	1.01	MW
F-H5	0.13	MW
Cooling water demand		
Cooling water from 15 °C to 30 °C	41,983,896.23	m ³ /a

S5. Stream tables

S5.1. E-methanol production

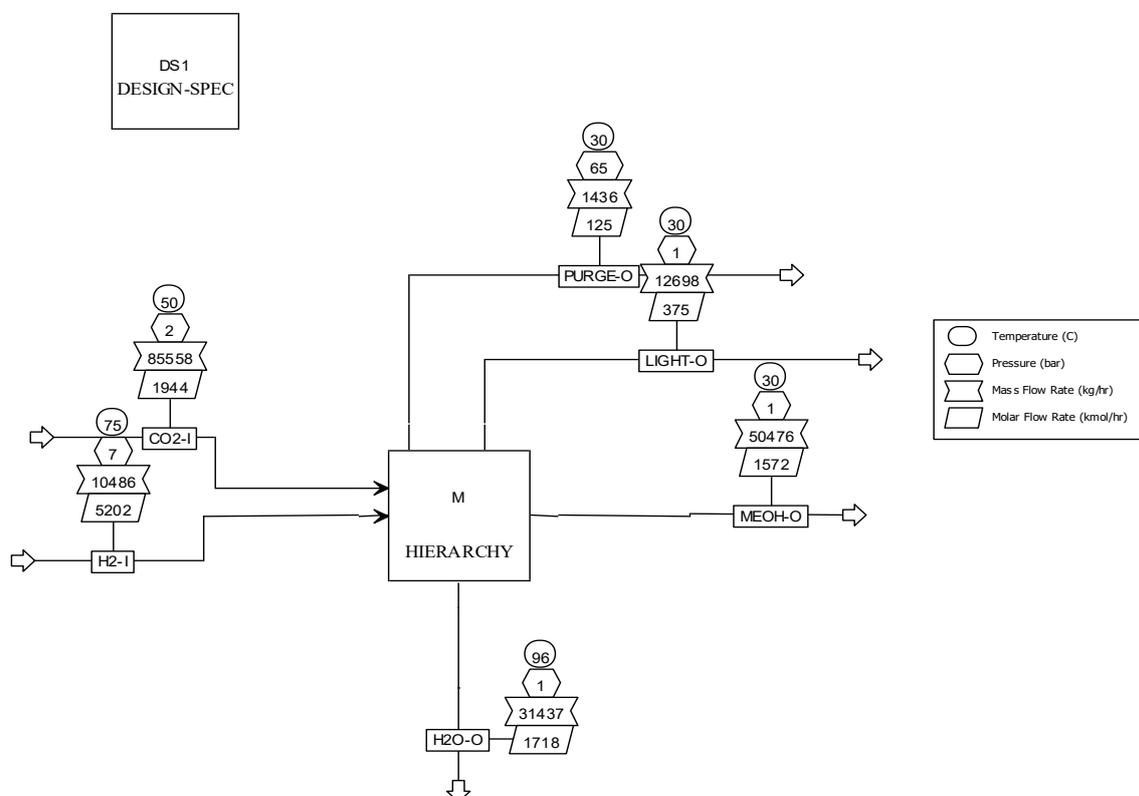


Figure S2: Simplified flowsheet for e-methanol production.

Table S8: Stream table for e-methanol production.

	Units	CO2-I	H2-I	MEOH-O	PURGE-O	H2O-O	LIGHT-O
Phase		Vapor	Vapor	Liquid	Vapor	Liquid	Vapor
Temperature	C	50	75	30	30	96.1	30
Pressure	bar	1.51	7	1.01	65	1.01	1.01
Mass Density	kg/cum	2.49	0.49	593.80	29.82	704.47	1.37
Average MW		44.01	2.02	32.11	11.46	18.30	33.86
Mass Flows	kg/hr	85557.84	10486.09	50475.57	1436.26	31436.51	12697.76
H2O	kg/hr	0.00	0.00	0.00	1.17	30335.39	0.00
CO2	kg/hr	85557.84	0.00	416.53	1139.78	0.00	9893.25
H2	kg/hr	0.00	10486.09	0.26	193.13	0.00	134.04
CO	kg/hr	0.00	0.00	0.27	90.31	0.00	80.07
CH3OH	kg/hr	0.00	0.00	50058.51	11.88	1101.12	2590.40

S5.2. FT-diesel

Table S9: Stream table for FT-diesel production.

	Units	CO2-I	DIESEL-O	GAS-O	H2-I	H2-I2	H2O-O1	H2O-O3	NAPHTA-O	PURGE-O1	PURGE-O2	SAF-O	WAX-O2
Phase		Vapor	Liquid	Vapor	Vapor	Vapor	Liquid	Liquid	Liquid	Vapor	Vapor	Liquid	Liquid
Temperature	C	50	15	15	75	75	30	30	15	30	20	15	15
Pressure	bar	1.51	1.01	1.01	7.00	7.00	10.90	26.00	1.01	26.00	35.00	1.01	2.91
Mass Density	kg/m ³	2.49	727.79	1.35	0.49	0.49	956.96	957.27	689.74	12.91	3.61	744.66	756.88
Average MW		44.01	253.28	31.76	2.02	2.02	18.02	18.02	88.99	12.63	2.56	174.55	387.96
Mass Flows	kg/hr	85557.84	9072.26	486.53	11907.14	146.93	24291.81	43865.29	1657.67	3072.61	133.72	13893.39	1136.97
CO	kg/hr	0.00	0.00	92.02	0.00	0.00	0.01	0.04	0.23	2009.65	15.00	0.00	0.00
H2	kg/hr	0.00	0.00	5.22	11907.14	146.93	0.01	0.03	0.00	285.64	103.09	0.00	0.00
H2O	kg/hr	0.00	0.00	20.00	0.00	0.00	24290.81	43858.72	27.75	6.17	1.75	0.00	0.00
CO2	kg/hr	85557.84	0.00	159.71	0.00	0.00	0.98	6.36	5.73	408.64	3.14	0.00	0.00
N2	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CH4	kg/hr	0.00	0.00	33.57	0.00	0.00	0.00	0.06	0.21	310.06	2.95	0.00	0.00
C2H6	kg/hr	0.00	0.00	3.72	0.00	0.00	0.00	0.01	0.23	7.10	0.06	0.00	0.00
C3H8	kg/hr	0.00	0.00	15.51	0.00	0.00	0.00	0.01	2.52	10.02	4.10	0.00	0.00
C4H10	kg/hr	0.00	0.00	43.45	0.00	0.00	0.00	0.02	30.06	12.46	3.53	0.00	0.00
C5H12	kg/hr	0.00	0.00	51.96	0.00	0.00	0.00	0.02	129.92	9.78	0.03	0.00	0.00
C6H14	kg/hr	0.00	0.00	38.69	0.00	0.00	0.00	0.01	357.96	6.89	0.02	0.01	0.00
C7H16	kg/hr	0.00	0.00	18.34	0.00	0.00	0.00	0.00	605.17	3.56	0.02	0.74	0.00
C8H18	kg/hr	0.00	0.00	4.33	0.00	0.00	0.00	0.00	497.87	1.51	0.01	289.15	0.00
C9H20	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.65	0.02	995.09	0.00
C10H22	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.26	0.01	1195.89	0.00
C11H24	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.01	2139.34	0.00
C12H26	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05	0.00	1989.16	0.00
C13H28	kg/hr	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	1863.42	0.00
C14H30	kg/hr	0.00	0.43	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	1724.31	0.00
C15H32	kg/hr	0.00	12.86	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1541.14	0.00
C16H34	kg/hr	0.00	839.33	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2006.73	0.00
C17H36	kg/hr	0.00	2872.67	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	142.79	0.05
C18H38	kg/hr	0.00	2309.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	5.32	0.51

C19H40	kg/hr	0.00	1761.22	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.29	5.94
C20H42	kg/hr	0.00	1027.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	55.93
C21H44	kg/hr	0.00	220.35	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	138.29
C22H46	kg/hr	0.00	25.59	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	134.32
C23H48	kg/hr	0.00	2.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	86.33
C24H50	kg/hr	0.00	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	80.50
C25H52	kg/hr	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	63.99
C26H54	kg/hr	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	61.26
C27H56	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	43.47
C28H58	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	37.01
C29H60	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	29.81
C30H62	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	12.32
C30+	kg/hr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	387.24

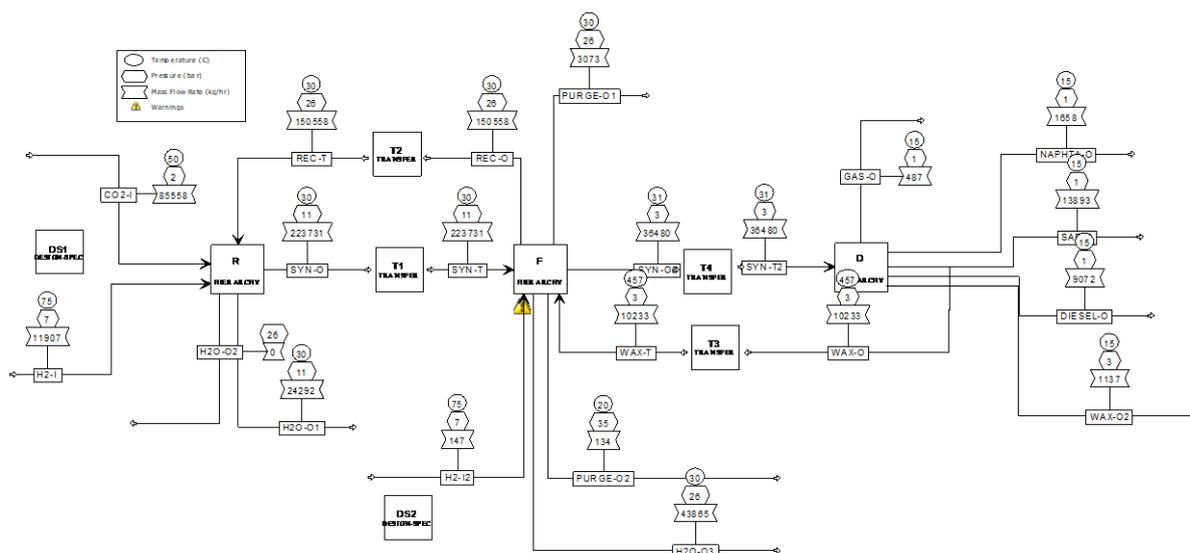


Figure S3: Simplified flowsheet for FT-diesel production.

S6. Modeling details – Life Cycle Assessment

The climate change damage category (CC) of e-fuels (e-methanol (e-MeOH) and Fischer-Tropsch diesel (FTD)) is assessed for different European countries (see **Table S1**). Modeling details are shown in the tables below for the Austrian case.

S6.1. Hydrogen production

Table S10: Base case modeling for hydrogen production.

Hydrogen production via alkaline electrolysis (base case)			
Output	Hydrogen _{Alk} ^a	1	kgH ₂
products	Oxygen ^a	8	kg/kgH ₂
Inputs	Water, deionised {Europe without Switzerland} market for water, deionised Cut-off, U	9	kg/kgH ₂
	Electricity, medium voltage {AT} market for electricity, medium voltage Cut-off, U ^b	53.4	kWh/kgH ₂
	Polyphenylene sulfide {GLO} market for polyphenylene sulfide Cut-off, U ^c	4.76E-05	kg/kgH ₂

Polysulfone {GLO} market for polysulfone Cut-off, U	3.17E-05	kg/kgH ₂
Zirconium oxide {GLO} market for zirconium oxide Cut-off, U	1.43E-04	kg/kgH ₂
Steel, low-alloyed {GLO} market for steel, low-alloyed Cut-off, U	0.08	kg/kgH ₂
Nickel, class 1 {GLO} market for nickel, class 1 Cut-off, U	2.73E-03	kg/kgH ₂
Tetrafluoroethylene {GLO} market for tetrafluoroethylene Cut-off, U	8.37E-05	kg/kgH ₂

^aOxygen by-product can be valorized. Thus, an economic allocation between hydrogen and oxygen is considered. Assuming prices of €760/t H₂ [4] and €160/t O₂ [5], 37% of the environmental impact is attributed to hydrogen, while the remaining 63% is allocated to oxygen.

^bElectricity is modeled using “*Electricity, medium voltage {XX} | electricity, medium voltage, residual mix | Cut-off, U*” (reference year: 2023; with **XX** representing the ISO code of the considered country), except for Austria, where “*Electricity, medium voltage {AT} | market for electricity, medium voltage | Cut-off, U*” (reference year: 2021) is considered due to the lack of corresponding data set for the residual mix. This is valid for all electricity-related entries.

^cData related to the electrolyzer materials are retrieved from Krishnan et al. [6].

When renewable hydrogen is considered, the process is modeled as in **Table S10**, the only modification being the modified electricity-related data set:

- Solar (PV) panels: “*Electricity, low voltage {AT} | electricity production, photovoltaic, 570kWp open ground installation, multi-Si | Cut-off, U*” is considered, which is consistent with the large-scale PV deployment necessary to cover the process electricity requirements
- Wind turbines: “*Electricity, high voltage {AT} | electricity production, wind, 1-3MW turbine, onshore | Cut-off, U*” is considered, which represents 93.3% of the wind-based electricity in the Austrian market.

Table S11: Modeling for green hydrogen production (PV panels).

Green hydrogen production via alkaline electrolysis			
Output products	<i>Green Hydrogen_Alk</i>	1	kgH ₂
	<i>Oxygen</i>	8	kg/kgH ₂
Inputs	Water, deionised {Europe without Switzerland} market for water, deionised Cut-off, U	9	kg/kgH ₂
	Electricity, low voltage {AT} electricity production, photovoltaic, 570kWp open ground installation, multi-Si Cut-off, U	53.4	kWh/kgH ₂
	Polyphenylene sulfide {GLO} market for polyphenylene sulfide Cut-off, U	4.76E-05	kg/kgH ₂
	Polysulfone {GLO} market for polysulfone Cut-off, U	3.17E-05	kg/kgH ₂
	Zirconium oxide {GLO} market for zirconium oxide Cut-off, U	1.43E-04	kg/kgH ₂
	Steel, low-alloyed {GLO} market for steel, low-alloyed Cut-off, U	0.08	kg/kgH ₂
	Nickel, class 1 {GLO} market for nickel, class 1 Cut-off, U	2.73E-03	kg/kgH ₂
	Tetrafluoroethylene {GLO} market for tetrafluoroethylene Cut-off, U	8.37E-05	kg/kgH ₂

Table S12: Modeling for green hydrogen production (wind turbine).

Green hydrogen production via alkaline electrolysis			
Output products	<i>Green Hydrogen_Alk (wind)</i>	1	kgH ₂
	<i>Oxygen</i>	8	kg/kgH ₂
Inputs	Water, deionised {Europe without Switzerland} market for water, deionised Cut-off, U	9	kg/kgH ₂
	Electricity, high voltage {AT} electricity production, wind, 1-3MW turbine, onshore Cut-off, U	53.4	kWh/kgH ₂
	Polyphenylene sulfide {GLO} market for polyphenylene sulfide Cut-off, U	4.76E-05	kg/kgH ₂
	Polysulfone {GLO} market for polysulfone Cut-off, U	3.17E-05	kg/kgH ₂
	Zirconium oxide {GLO} market for zirconium oxide Cut-off, U	1.43E-04	kg/kgH ₂
	Steel, low-alloyed {GLO} market for steel, low-alloyed Cut-off, U	0.08	kg/kgH ₂
	Nickel, class 1 {GLO} market for nickel, class 1 Cut-off, U	2.73E-03	kg/kgH ₂
	Tetrafluoroethylene {GLO} market for tetrafluoroethylene Cut-off, U	8.37E-05	kg/kgH ₂

S6.2. CO₂ capture

CO₂ is assumed to be captured via chemical absorption process using monoethanolamine (MEA) as solvent. Energy demand (heating (electrically-powered), cooling, electricity for pumping) are derived from correlations developed by Kim et al. [7], assuming an inlet CO₂ concentration of 20 mol%, a flue gas flow rate of 2.75 kmol/s, and a capture rate of 90%. MEA requirements are based on [8].

Table S13: Modeling of the MEA-based carbon capture process at the cement plant.

CO₂ capture via MEA-based chemical absorption (base case, cement plant)			
Output product	<i>Captured CO₂</i>	1	tCO _{2,capt}
Inputs	Monoethanolamine {GLO} market for monoethanolamine Cut-off, U	1.5	kg/tCO _{2,capt}
	Electricity, medium voltage {AT} market for electricity, medium voltage Cut-off, U	987.90	kWh/ tCO _{2,capt}
	Water, cooling, unspecified natural origin, AT	48.49	m ³ / tCO _{2,capt}
Emissions to air	Carbon dioxide, fossil	0.111	t/ tCO _{2,capt}

Table S14: Modeling of carbon capture process at cement plants, using solar-based electricity.

CO₂ capture using solar-based electricity (cement plant)			
Output product	<i>Captured CO₂_PV</i>	1	tCO _{2,capt}
Inputs	Monoethanolamine {GLO} market for monoethanolamine Cut-off, U	1.5	kg/tCO _{2,capt}
	Electricity, low voltage {AT} electricity production, photovoltaic, 570kWp open ground installation, multi-Si Cut-off, U	987.90	kWh/ tCO _{2,capt}
	Water, cooling, unspecified natural origin, AT	48.49	m ³ / tCO _{2,capt}
Emissions to air	Carbon dioxide, fossil	0.111	t/ tCO _{2,capt}

Table S15: Modeling of carbon capture process at cement plants, using wind-based electricity.

CO₂ capture using wind-based electricity (cement plant)			
Output product	<i>Captured CO₂_wind</i>	1	tCO _{2,capt}
Inputs	Monoethanolamine {GLO} market for monoethanolamine Cut-off, U	1.5	kg/tCO _{2,capt}
	Electricity, high voltage {AT} electricity production, wind, 1-3MW turbine, onshore Cut-off, U	987.90	kWh/ tCO _{2,capt}
	Water, cooling, unspecified natural origin, AT	48.49	m ³ / tCO _{2,capt}
Emissions to air	Carbon dioxide, fossil	0.111	t/ tCO _{2,capt}

For scenarios considering the capture of biogenic CO₂ from biogas plants, the entry for “Emissions to air” is replaced by “Carbon dioxide, biogenic”.

Table S16: Modeling of MEA-based carbon capture at biogas plants.

CO₂ capture via MEA-based chemical absorption (biogas plant)			
Output product	<i>Captured CO₂_biogenic</i>	1	tCO _{2,capt}
Inputs	Monoethanolamine {GLO} market for monoethanolamine Cut-off, U	1.5	kg/tCO _{2,capt}
	Electricity, medium voltage {AT} market for electricity, medium voltage Cut-off, U	987.90	kWh/ tCO _{2,capt}
	Water, cooling, unspecified natural origin, AT	48.49	m ³ / tCO _{2,capt}
Emissions to air	Carbon dioxide, biogenic	0.111	t/ tCO _{2,capt}

Table S17: Modeling of carbon capture process at biogas plants, using solar-based electricity.

CO₂ capture using solar-based electricity (biogas plant)			
Output product	<i>Captured CO₂_biogenic+PV</i>	1	tCO _{2,capt}
Inputs	Monoethanolamine {GLO} market for monoethanolamine Cut-off, U	1.5	kg/tCO _{2,capt}
	Electricity, low voltage {AT} electricity production, photovoltaic, 570kWp open ground installation, multi-Si Cut-off, U	987.90	kWh/ tCO _{2,capt}
	Water, cooling, unspecified natural origin, AT	48.49	m ³ / tCO _{2,capt}
Emissions to air	Carbon dioxide, biogenic	0.111	t/ tCO _{2,capt}

S6.3. E-methanol production and combustion

Table S18: Base case modeling of e-MeOH production.

e-MeOH production via direct route (base case)			
Output product	<i>e-MeOH</i>	1	tMeOH
Inputs	<i>Captured CO₂</i>	1.709	t/tMeOH
	<i>Hydrogen_Alk</i>	0.209	t/tMeOH
	Electricity, medium voltage {AT} market for electricity, medium voltage Cut-off, U ^d	1.2134	MWh/tMeOH
	Water, cooling, unspecified natural origin, AT	58.9	m ³ /tMeOH
Emissions to air	Carbon dioxide, fossil	0.220	t/tMeOH
	Hydrogen	0.007	t/tMeOH

Carbon monoxide, fossil	0.003	t/tMeOH
Methanol	0.052	t/tMeOH

Includes compression and heating requirements

If biogenic CO₂ is used as feedstock, the emissions to air are replaced by “Carbon dioxide, biogenic” and “Carbon monoxide, biogenic”. Moreover, if renewable electricity is used to power the e-MeOH production process, the electricity entry in **Table S18** is replaced by “*Electricity, low voltage {AT}| electricity production, photovoltaic, 570kWp open ground installation, multi-Si | Cut-off, U*” or “*Electricity, high voltage {AT}| electricity production, wind, 1-3MW turbine, onshore | Cut-off, U*”.

e-MeOH production (BIO scenario)

Output product	<i>e-MeOH_biogenic</i>	1	tMeOH
Inputs	<i>Captured CO₂_biogenic</i>	1.709	t/tMeOH
	<i>Hydrogen_Alk</i>	0.209	t/tMeOH
	Electricity, medium voltage {AT} market for electricity, medium voltage Cut-off, U	1.2134	MWh/tMeOH
	Water, cooling, unspecified natural origin, AT	58.9	m ³ /tMeOH
Emissions to air	Carbon dioxide, biogenic	0.220	t/tMeOH
	Hydrogen	0.007	t/tMeOH
	Carbon monoxide, biogenic	0.003	t/tMeOH
	Methanol	0.052	t/tMeOH

e-MeOH production (PV scenario)

Output product	<i>e-MeOH_PV</i>	1	tMeOH
Inputs	<i>Captured CO₂_PV</i>	1.709	t/tMeOH
	<i>Green Hydrogen_Alk</i>	0.209	t/tMeOH
	Electricity, low voltage {AT} electricity production, photovoltaic, 570kWp open ground installation, multi-Si Cut-off, U	1.2134	MWh/tMeOH
	Water, cooling, unspecified natural origin, AT	58.9	m ³ /tMeOH
Emissions to air	Carbon dioxide, fossil	0.220	t/tMeOH
	Hydrogen	0.007	t/tMeOH
	Carbon monoxide, fossil	0.003	t/tMeOH
	Methanol	0.052	t/tMeOH

e-MeOH production (PV+BIO scenario)

Output product	<i>e-MeOH_biogenic+PV</i>	1	tMeOH
Inputs	<i>Captured CO₂_biogenic+PV</i>	1.709	t/tMeOH
	<i>Green Hydrogen_Alk</i>	0.209	t/tMeOH
	Electricity, low voltage {AT} electricity production, photovoltaic, 570kWp open ground installation, multi-Si Cut-off, U	1.2134	MWh/tMeOH
	Water, cooling, unspecified natural origin, AT	58.9	m ³ /tMeOH
Emissions to air	Carbon dioxide, biogenic	0.220	t/tMeOH
	Hydrogen	0.007	t/tMeOH
	Carbon monoxide, biogenic	0.003	t/tMeOH
	Methanol	0.052	t/tMeOH

e-MeOH production (BIO+RENH2 scenario)			
Output product	<i>e-MeOH_biogenic+renH2</i>	1	tMeOH
Inputs	<i>Captured CO₂_biogenic</i>	1.709	t/tMeOH
	<i>Green Hydrogen_Alk</i>	0.209	t/tMeOH
	Electricity, medium voltage {AT} market for electricity, medium voltage Cut-off, U	1.2134	MWh/tMeOH
	Water, cooling, unspecified natural origin, AT	58.9	m ³ /tMeOH
Emissions to air	Carbon dioxide, biogenic	0.220	t/tMeOH
	Hydrogen	0.007	t/tMeOH
	Carbon monoxide, biogenic	0.003	t/tMeOH
	Methanol	0.052	t/tMeOH

e-MeOH production (WIND scenario)			
Output product	<i>e-MeOH_wind</i>	1	tMeOH
Inputs	<i>Captured CO₂_wind</i>	1.709	t/tMeOH
	<i>Green Hydrogen_Alk (wind)</i>	0.209	t/tMeOH
	Electricity, high voltage {AT} electricity production, wind, 1-3MW turbine, onshore Cut-off, U	1.2134	MWh/tMeOH
	Water, cooling, unspecified natural origin, AT	58.9	m ³ /tMeOH
Emissions to air	Carbon dioxide, fossil	0.220	t/tMeOH
	Hydrogen	0.007	t/tMeOH
	Carbon monoxide, fossil	0.003	t/tMeOH
	Methanol	0.052	t/tMeOH

The combustion of *e-MeOH*, *e-MeOH_PV*, and *e-MeOH_wind* releases “Carbon dioxide, fossil”, while for *e-MeOH_biogenic*, *e-MeOH_biogenic+ PV*, and *e-MeOH_biogenic+renH2*, the associated emissions to air are “Carbon dioxide, biogenic”.

Table S19: Combustion of e-MeOH.

e-MeOH combustion			
Output product	<i>Energy delivered by eMeOH combustion</i>	1	MJ
Inputs	<i>e-MeOH</i>	0.050505051	kg/MJ
Emissions to air	Carbon dioxide, fossil	0.069444444	kg/MJ

S6.4. Synthetic diesel production and combustion

Table S20: Base case modeling for FT-diesel production.

FT-diesel production			
Output products	<i>FT-diesel^e</i>	1	tFTD
	<i>By-products (Naphtha, SAF, Wax)^e</i>	1.839	t/tFTD
Inputs	<i>Captured CO₂</i>	9.431	t/tFTD
	<i>Hydrogen_Alk</i>	1.329	t/tFTD
	Electricity, medium voltage {AT} market for electricity, medium voltage Cut-off, U ^f	8.6814	MWh/tFTD
	Water, cooling, unspecified natural origin, AT	586.98	m ³ /tFTD

Emissions to air	Carbon monoxide, fossil	0.233312299	t/tFTD
	Hydrogen	0.043423936	t/tFTD
	Carbon dioxide, fossil	0.062993404	t/tFTD
	Methane	0.038201698	t/tFTD
	Ethane	0.001198863	t/tFTD
	Propane	0.003266057	t/tFTD
	Butane	0.006551684	t/tFTD
	Pentane	0.006808413	t/tFTD
	Hexane	0.005026369	t/tFTD
	Heptane	0.002415437	t/tFTD
	N-octane	0.000644894	t/tFTD
	Nonane	7.30206E-05	t/tFTD
	Decane	2.93196E-05	t/tFTD
	Undecane	1.8942E-05	t/tFTD
	Dodecane	5.9302E-06	t/tFTD
	Tridecane	1.94026E-06	t/tFTD
	Tetradecane	6.73798E-07	t/tFTD
	Pentadecane	2.08952E-07	t/tFTD
	Hexadecane	1.65172E-07	t/tFTD
	Heptadecane	6.82E-08	t/tFTD
Alkanes, C18	2.00301E-08	t/tFTD	
Alkanes, C19, branched	6.31567E-09	t/tFTD	
Alkanes, C20, branched	2.16861E-09	t/tFTD	

^eAs by-products are valorized, an energy-based allocation is introduced. Assuming lower heating values of diesel, naphtha, SAF, and wax being, respectively, equal to 12.19 kWh/kg, 12.47 kWh/kg, 11.94 kWh/kg, and 11.53 kWh/kg [9], 36% of the environmental impact is attributed to FT-diesel, while the remaining 64% is supported by the by-products.

^fIncludes compression and heating requirements.

The base case model in **Table S20** is modified as follows for the considered scenarios:

Scenario	CO ₂ input	Hydrogen input	Electricity input	Emissions to air
BIO	<i>Captured CO₂ _biogenic</i>	<i>Hydrogen_ Alk</i>	Electricity, medium voltage {AT} market for electricity, medium voltage Cut-off, U	Carbon monoxide, biogenic Carbon dioxide, biogenic
PV	<i>Captured CO₂ _PV</i>	<i>Green Hydrogen_ Alk</i>	Electricity, low voltage {AT} electricity production, photovoltaic, 570kWp open ground installation, multi-Si Cut-off, U	Carbon monoxide, fossil Carbon dioxide, fossil
PV+BIO	<i>Captured CO₂ _biogenic+PV</i>	<i>Green Hydrogen_ Alk</i>	Electricity, low voltage {AT} electricity production, photovoltaic, 570kWp open ground installation, multi-Si Cut-off, U	Carbon monoxide, biogenic Carbon dioxide, biogenic
BIO+RENH2	<i>Captured CO₂ _biogenic</i>	<i>Green Hydrogen_ Alk</i>	Electricity, medium voltage {AT} market for electricity, medium voltage Cut-off, U	Carbon monoxide, biogenic Carbon dioxide, biogenic
WIND	<i>Captured CO₂ _wind</i>	<i>Green Hydrogen_ Alk (wind)</i>	Electricity, high voltage {AT} electricity production, wind, 1-3MW turbine, onshore Cut-off, U	Carbon monoxide, fossil Carbon dioxide, fossil

The combustion of FT-diesel in the base case, and PV and WIND scenarios releases “Carbon dioxide, fossil”, while for BIO, PV+BIO, and BIO+REH2 scenarios, the associated emissions to air are “Carbon dioxide, biogenic”.

Table S21: Combustion of FT-diesel.

FT-diesel combustion			
Output product	Energy delivered by FT-diesel combustion	1	MJ
Inputs	FT-diesel	0.02283105	kg/MJ
Emissions to air	Carbon dioxide, fossil	0.071047217	kg/MJ

S7. Climate change breakdown

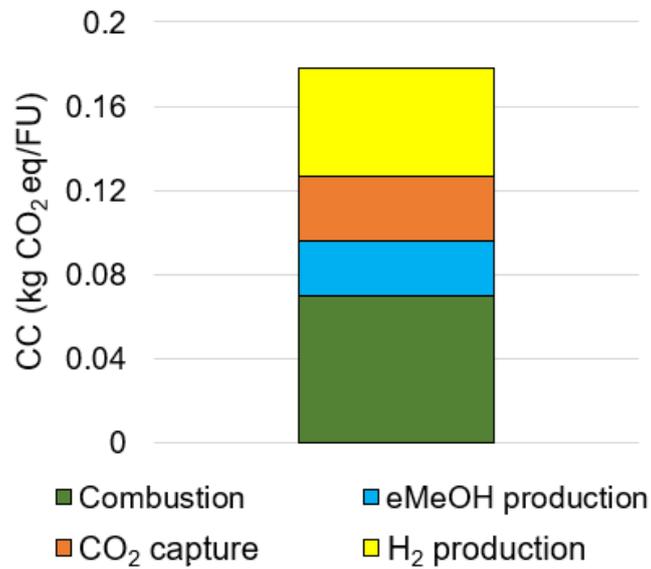


Figure S4: Characterization of Scenario “AT” for CC of e-methanol production in Austria, assessed using EF 3.1 method (v1.04).

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