

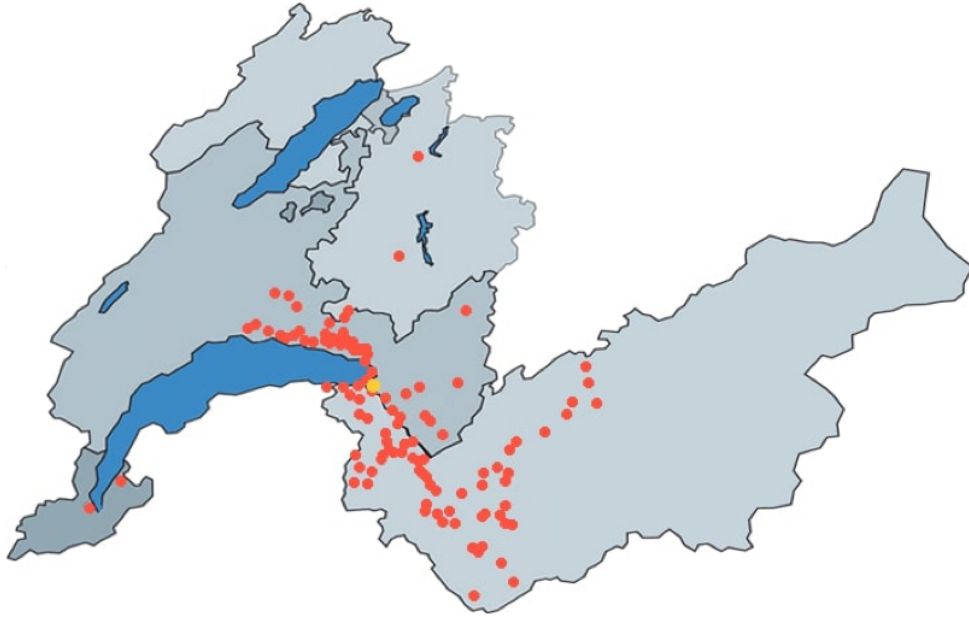


Figure S9: Network map: red dots represent source nodes; yellow dot represents the biowaste treatment facility.

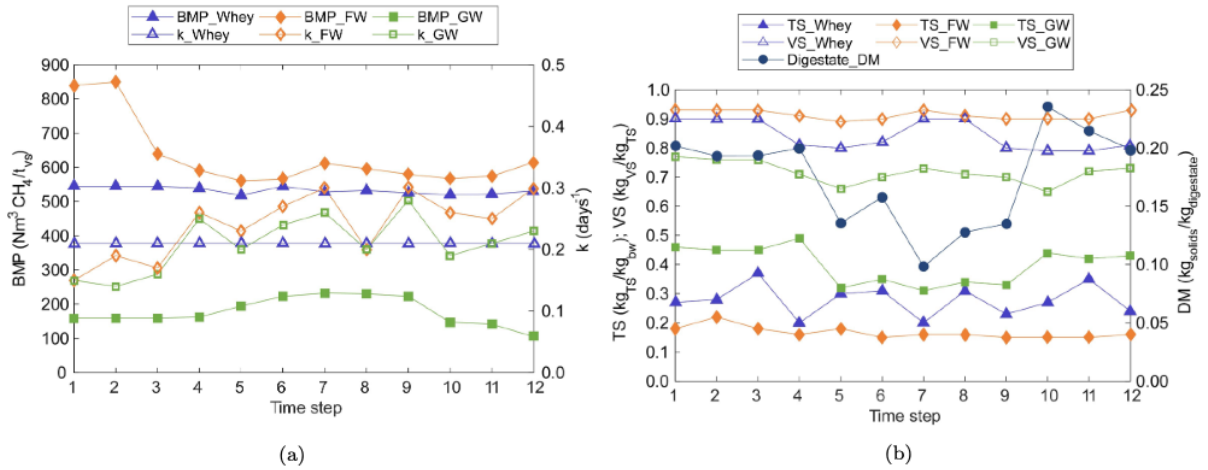


Figure S10: Seasonal pattern per substrate - green waste (GW), food waste (FW) and Whey - of: (a) bio-methane potential (BMP) and kinetic constant (k); (b) total solids (TS), volatile solids (VS) and digestate dry matter (DM)

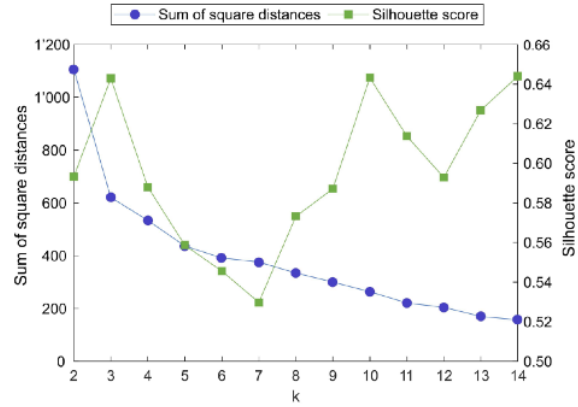


Figure S11: Elbow and silhouette method used for cluster number determination

Table S6: Life cycle inventory processes. Source: Ecoinvent 3.7 Wernet et al. 2016

Reference	Unit	IPCC 2013 GWP 100a (kgCO ₂ -eq)
Biogas purification to methane 96 vol. % [CH]	1 m ³ of methane, 96% by volume	1.69
Treatment of biowaste, municipal incineration with fly ash extraction [CH]	1 kg biowaste	0.032006
Treatment of biowaste by anaerobic digestion [CH]	1 kg biowaste	0.10494
Heat and power co-generation, biogas, gas engine [CH]	1 kwh electricity	0.23577
Machine operation, diesel, ≥ 74.57 kW, low load factor [GLO]	1 hour	23.506
Market for compost [GLO]	1 kg compost	0.0031363
Treatment of wastewater, average, capacity 4.7E10l/year, [CH]	1 m ³ of wastewater	0.28733
Market for heat, district or industrial, other than natural gas [CH]	1 MJ	0.0027729
Market for tap water, [CH]	1 kg	0.00011073
Market for methane, 96% by volume [CH]	1 m ³ of methane, 96% by volume	1.6837
Market for methanol [GLO]	1 kg of methanol	0.65534
Market for formic acid [RER]	1 kg of formic acid	2.3432
Base oil production, petroleum refinery operation [Europe without CH]	1 kg of base oil	1.1821
Diesel production, petroleum refinery operation [Europe without CH]	1 kg of diesel	0.45111
Market for dimethyl ether [RER]	1 kg of DME	1.2856

Table S7: Economic assumptions, **: internal information

Technologies	Cinv1		Cinv2		Cop1		Cop2		Refs
	Value	Unit	Value	Unit	Value	Unit	Value	Unit	
HTL	21	M\$	160	k\$/(t _{dry} /h)	120	\$/h	7.5	k\$/(t _{dry}	Snowden-Swan et al. 2016 Zhu et al. 2014
HTL filter	324	k\$	1.8	k\$/m ²	—	—	—	—	Turton 2018
SOFc	—	—	4.8	k\$/(kW _{el}	—	—	—	—	Rubio-Maya et al. 2011
AEC	—	—	1.1	k\$/(kW _{el}	—	—	0.021	\$/kW _{h_{el}}	Rubio-Maya et al. 2011 Schmidt et al. 2017
SOEC	—	—	4.8	k\$/(kW _{el}	—	—	0.026	\$/kW _{h_{el}}	Rubio-Maya et al. 2011
Methanation	449	k\$	7.7	k\$/(m ³ _{CH₄} /h)	—	—	—	—	Turton 2018
Water scrubbing	1016	k\$	1.0	\$/ (m ³ _{biogas} /h)	3.92	\$/h	0.002	\$/m ³ _{biogas}	Wolfgang Urban et al. 2009
PSA	917	k\$	1	\$/ (m ³ _{biogas} /h)	3.07	\$/h	0.003	\$/m ³ _{biogas}	Wolfgang Urban et al. 2009
MEA	634	k\$	1	\$/ (m ³ _{biogas} /h)	1.13	\$/h	0.008	\$/m ³ _{biogas}	Wolfgang Urban et al. 2009
Membrane	634	k\$	3.1	\$/ (m ³ _{biogas} /h)	7.64	\$/h	0.0007	\$/m ³ _{biogas}	Institute of Chemical engineering 2012
Incineration	—	—	—	—	—	—	97	\$/t _{waste}	**
Digester preparation + operation	—	—	—	—	—	—	155	\$/t _{bio}	**
DME	9.0	M\$	0.88	k\$/(kW	51	\$/h	0.10	\$/kW _h	Tock, Gassner, and Maréchal 2010; Maronese et al. 2015
MeOH (gasification)	10.6	M\$	1.03	k\$/(kW	61	\$/h	0.12	\$/kW _h	Tock, Gassner, and Maréchal 2010; Maronese et al. 2015
FT-fuel	6.0	M\$	0.28	k\$/(kW	34	\$/h	0.03	\$/kW _h	Tock, Gassner, and Maréchal 2010; Maronese et al. 2015
SNG-PSA	4.9	M\$	1.14	k\$/(kW	28	\$/h	0.13	\$/kW _h	Maronese et al. 2015
SNG-MEA	9.8	M\$	0.49	k\$/(kW	56	\$/h	0.06	\$/kW _h	Maronese et al. 2015
HP	30	k\$	0.6	k\$/(kW _{el}	—	—	—	—	Henchoz et al. 2015
CHTG	3.3	M\$	0.16	k\$/(kW	19	\$/h	0.02	\$/kW _h	Mian, Ensinas, and Marechal 2015
Methane/Methanol/FA from CO ₂	130	k\$	1980	\$/ (m ³ _{CO₂} /s)	0.74	\$/h	0.0113	\$/m ³ _{CO₂}	Turton 2018
Digestate disposal	—	—	—	—	—	—	6	\$/m ³	**

Table S8: Key modeling assumptions and parameters

Modeling assumptions	Unit	Default/Value	Reference
Digester			
Usable volume	m^3	1330	**
Average biowaste generation	t/h	3.75	**
Average digester heat required (@55 °C)	kW	107	**
Average methane content (biogas)	—	0.5344	**
Digestate disposal			
Electricity input (Press, centrifuge and screener)	kWh/m^3	20	**
Biogas upgrade			
Biogas inlet (Desulfurization unit)	Nm^3/h	1	Hinge and Laura Bailon Allegue 2014
Electricity input (Desulfurization unit)	kWh/Nm^3	0.0017	Hinge and Laura Bailon Allegue 2014
Biogas inlet (Water scrubbing)	Nm^3	1	Wellinger, Murphy, and Baxter 2013
Electricity input (Water scrubbing)	kWh/Nm^3	0.25	Wellinger, Murphy, and Baxter 2013
Water input (Water scrubbing)	m^3/h	0.06	Wellinger, Murphy, and Baxter 2013
Methane loss (Water scrubbing)	%	2	Wolfgang Urban et al. 2009
Biogas inlet (PSA)	Nm^3	1	Wellinger, Murphy, and Baxter 2013
Electricity input (PSA)	kWh/Nm^3	0.17	Wellinger, Murphy, and Baxter 2013
Methane loss (PSA)	%	1	Wellinger, Murphy, and Baxter 2013
Biogas inlet (MEA)	Nm^3	1	Wellinger, Murphy, and Baxter 2013
Electricity input (MEA)	kWh/Nm^3	0.1	Wellinger, Murphy, and Baxter 2013
Heat required MEA (135°C to 145°C)	kWh/Nm^3	0.515	Wellinger, Murphy, and Baxter 2013
Methane loss (MEA)	%	0.1	Wolfgang Urban et al. 2009
Methane output (Membrane)	Nm^3	1	Wellinger, Murphy, and Baxter 2013
Electricity input (Membrane)	kWh/Nm^3	0.43	Wellinger, Murphy, and Baxter 2013
Methane loss (Membrane)	%	3	Institute of Chemical engineering 2012
AEC			
Water inlet	kg/h	21.7	Suciu et al. 2019
Hydrogen production	kg/h	2.4	Suciu et al. 2019
Oxygen production	kg/h	19.3	Suciu et al. 2019
Electricity input	kW	100.0	Suciu et al. 2019
Heat (91°C to 58°C)	kW	3.1	Suciu et al. 2019
Heat (58°C to 27°C)	kW	1.7	Suciu et al. 2019
SOEC			
Water inlet	kg/h	2.5	Wang et al. 2018
CO_2 input	kg/h	1.12	Wang et al. 2018
Syngas produced	kg/h	0.28	Wang et al. 2018
Oxygen co-produced	kg/h	1.61	Wang et al. 2018
Electricity input	kW	7.32	Wang et al. 2018
Heat (835°C to 133°C)	kW	1.25	Wang et al. 2018
Heat required (178°C to 178°C)	kW	1.46	Wang et al. 2018
Heat required (25°C to 178°C)	kW	0.49	Wang et al. 2018
Heat released (835°C to 800°C)	kW	0.2	Wang et al. 2018
Heat released (164°C to 800°C)	kW	1.33	Wang et al. 2018
Heat released (133°C to 40°C)	kW	0.85	Wang et al. 2018
Heat released (835°C to 50°C)	kW	0.36	Wang et al. 2018
SOFC-GT			
SOFC Gas inlet	kW	133	Suciu et al. 2019 ; Facchinetti, Favrat, and Marechal 2011
CO_2 production	kg/h	Depends on SOFC Gas	—
Electricity production	kW	100	Suciu et al. 2019 ; Facchinetti, Favrat, and Marechal 2011
Heat released (649°C to 260°C)	kW	16.3	Suciu et al. 2019 ; Facchinetti, Favrat, and Marechal 2011
Heat released (110°C to 35°C)	kW	9.4	Suciu et al. 2019 ; Facchinetti, Favrat, and Marechal 2011
Heat released (35°C to 30°C)	kW	1.4	Suciu et al. 2019 ; Facchinetti, Favrat, and Marechal 2011
Methanation			
CO_2 input	kg/h	3,960	Suciu et al. 2019
H_2 input	kg/h	720	Suciu et al. 2019
CH_4 production	kg/h	1,440	Suciu et al. 2019
Electricity input	kW	100	Suciu et al. 2019
Heat released (625°C to 507°C)	kW	138	Suciu et al. 2019
Heat released (507°C to 233°C)	kW	586	Suciu et al. 2019
Heat released (233°C to 228°C)	kW	9.3	Suciu et al. 2019
Heat released (228°C to 227°C)	kW	0.7	Suciu et al. 2019
Heat released (227°C to 215°C)	kW	12.7	Suciu et al. 2019
Heat released (215°C to 203°C)	kW	27.1	Suciu et al. 2019
Heat released (203°C to 187°C)	kW	25.3	Suciu et al. 2019
Heat released (187°C to 28°C)	kW	358	Suciu et al. 2019

Table S8: Key modeling assumptions and parameters (cont.) ; (1): negative values represent net electricity producing units.

Modeling assumptions	Unit	Default/Value	Reference
Formic Acid			
Formic acid production	kg/h	1	Jens et al. 2019
CO ₂ input	kg/h	0.985	Jens et al. 2019
H ₂ input	kg/h	0.045	Jens et al. 2019
Purged gas (LHV: 4.8 MJ/kg)	kg/h	0.03	Jens et al. 2019
Electricity input	kW	0.53	Jens et al. 2019
Heat required (̳220 °C)	kW	2.51	Jens et al. 2019
Methanol			
Methanol production	kg/h	1	Rihko-Struckmann et al. 2010
Water co-produced	kg/h	0.569	Rihko-Struckmann et al. 2010
CO ₂ input	kg/h	1.436	Rihko-Struckmann et al. 2010
H ₂ input	kg/h	0.197	Rihko-Struckmann et al. 2010
Purged gas (LHV: 16.3 MJ/kg)	kg/h	0.064	Rihko-Struckmann et al. 2010
Electricity input	kW	1.34	Rihko-Struckmann et al. 2010
Heat released (̳220 °C)	kW	0.32	Rihko-Struckmann et al. 2010
HTL			
Reactor temperature	°C	340	Castro-Amoedo et al. 2020
Reactor pressure	bar	220	Castro-Amoedo et al. 2020
Inlet solids fraction (wt.)	–	0.2	Castro-Amoedo et al. 2020
Biocrude yield (dry basis)	kg/kg _{feedstock}	0.088	Castro-Amoedo et al. 2020
Gas yield	kg/kg _{feedstock}	0.038	Castro-Amoedo et al. 2020
Bio-char yield	kg/kg _{feedstock}	0.066	Castro-Amoedo et al. 2020
Wastewater generation	kg/kg _{feedstock}	0.81	Castro-Amoedo et al. 2020
Biocrude moisture content	–	0.14	Castro-Amoedo et al. 2020
Heat required (̳340 °C)	kWh/kg _{feedstock}	0.061	Castro-Amoedo et al. 2020
Electricity required	kWh/kg _{feedstock}	0.012	Castro-Amoedo et al. 2020
Biochar LHV	MJ/kg	32.5	Castro-Amoedo et al. 2020
Biocrude LHV	MJ/kg	37.8	Castro-Amoedo et al. 2020
CHTG			
Inlet solids fraction (wt.)	–	0.2	Gassner et al. 2011
Catalytic reactor temperature	°C	350	Gassner et al. 2011
Reactor pressure	bar	250	Mian, Ensinas, and Marechal 2015
Salt separation temperature	°C	415	Gassner et al. 2011
Water absorption pressure	bar	250	Mian, Ensinas, and Marechal 2015
Water absorption pressure stages	–	5	Mian, Ensinas, and Marechal 2015
Gas grid pressure	bar	70	Mian, Ensinas, and Marechal 2015
Gas grid CH ₄ composition	–	0.98	Mian, Ensinas, and Marechal 2015
Gas expander isentropic efficiency	–	0.8	Mian, Ensinas, and Marechal 2015
Liquid expander isentropic efficiency	–	0.82	Mian, Ensinas, and Marechal 2015
Rankine cycle (RC)			
Production level	–	50 bar, superheating of 100 °C	–
Utilisation levels	–	5 bar (152 °C) and 1.98 bar (120 °C)	–
Condensation level	–	0.1 bar (T = 46 °C)	–
Heat Pumps (HP)			
Fluid	–	Ammonia, R717	–
Temperature levels	°C	5/35/60/80/90	Wallerand et al. 2018
Gasification (DME/FT/MeOH/SNG-MEA/SNG-PSA)			
Digestate inlet solids fraction	–	0.75/0.90/0.70/0.80/0.80	Celebi et al. 2019
Fuel output	kWh/kWh _{feedstock}	0.561/0.458/0.570/0.693/0.693	Celebi et al. 2019; Tock, Gassner, and Maréchal 2010; Maronese et al. 2015
Net electricity (1)	kWh/kWh _{feedstock}	–0.048/ – 0.014/ – 0.085/0.037/0.026	Celebi et al. 2019; Tock, Gassner, and Maréchal 2010; Maronese et al. 2015
Heat profiles	kWh/t _{feedstock}	Appendix Table S9	Appendix Table S9
Boiler			
Radiative/Stack temperature	°C	850/100	**
Losses	%	3	**
Excess air flow ratio	–	1.07	**
Air pre-heating temperature	°C	90	**
Heat required air pre-heating (from 25 °C to 90 °C)	kWh _{th} /kWh _{feedstock}	0.015	**
Heat produced (̳850 °C)	kWh _{th} /kWh _{feedstock}	0.51	**
Heat produced (from 850 °C to 100 °C)	kWh _{th} /kWh _{feedstock}	0.41	**
Heat recovery minimum approach temperature	°C	15	**
General assumptions			
SNG LHV	MJ/kg	47.1	Turton 2018
DHN temperatures	°C	60-90	Celebi et al. 2019
SNG grid pressure	bar	50	**
Digestate composition (C/O/H/N)	wt.%	51.5/40.4/6.3/1.3	**
Digestate LHV (dry basis)	MJ/kg	17	**
CEPCI 2019	–	607.5	–
Heat recovery minimum approach temperature	°C	5	–

Table S9: Gasification thermal-enthalpy profiles for: di-methyl ether (DME), Fischer-Tropsch fuels (FT), methanol (MeOH), substitute natural gas coupled with PSA (SNG-PSA) or MEA purification (SNG-MEA) and catalytic hydrothermal gasification (CHTG). θ denotes temperature and h denotes specific enthalpy

θ_{in} [°C]	θ_{out} [°C]	h_{in} [kWh/t _{bw}]	h_{out} [kWh/t _{bw}]	θ_{in} [°C]	θ_{out} [°C]	h_{in} [kWh/t _{bw}]	h_{out} [kWh/t _{bw}]
DME				MeOH			
29	196	0	87	19	196	0	57
37	134	0	24	29	228	0	50
38	208	0	277	30	117	0	74
90	122	0	38	32	208	0	193
111	285	0	69	33	307	0	29
136	146	0	12	35	76	0	39
144	199	0	19	64	76	0	3
158	158	0	359	76	261	0	225
194	194	0	243	122	122	0	369
200	408	0	57	133	133	0	24
268	358	0	294	158	158	0	297
425	548	0	54	194	194	0	149
33	20	8	0	200	408	0	35
67	17	188	0	226	226	0	109
74	17	11	0	232	307	0	12
82	32	72	0	299	321	0	5
86	80	28	0	307	348	0	15
95	17	4	0	875	875	0	724
116	21	4	0	21	19	2	0
140	101	15	0	61	17	108	0
193	84	9	0	75	17	222	0
252	17	236	0	81	81	185	0
255	17	93	0	82	32	59	0
269	269	291	0	98	98	13	0
275	57	75	0	127	81	35	0
515	332	70	0	238	60	68	0
520	392	39	0	288	288	32	0
569	392	8	0	297	17	427	0
842	142	278	0	305	245	61	0
1019	112	5055	0	305	17	174	0
1019	1019	5971	0	314	245	59	0
1419	112	5055	0	330	245	62	0
1419	1419	5055	0	332	74	97	0
FT				508	274	54	0
19	257	0	169	792	142	251	0
23	308	0	62	1019	1019	7744	0
29	228	0	74	1019	112	4572	0
32	208	0	632	SNG-PSA			
33	307	0	38	29	157	0	120
50	324	0	60	29	159	0	10
105	275	0	114	29	196	0	39
154	154	0	4	36	335	0	91
158	158	0	490	38	208	0	361
200	200	0	2	155	155	0	468
226	226	0	160	157	157	0	39
232	298	0	15	161	335	0	81
255	255	0	278	163	335	0	7
258	458	0	32	168	198	0	36
261	408	0	66	194	194	0	110
275	275	0	94	200	308	0	14
292	308	0	5	246	335	0	38
345	345	0	13	875	875	0	973
425	425	0	36	69	17	254	0
72	17	75	0	175	175	113	0
72	17	430	0	192	17	76	0
82	32	98	0	295	295	997	0
195	195	512	0	312	17	461	0
210	97	344	0	330	17	86	0
275	275	44	0	842	142	323	0
291	212	39	0	1019	112	4153	0
292	17	244	0	1019	1019	6274	0
492	17	143	0	CHTG			
492	492	463	0	35	37	0	2
542	392	26	0	44	272	0	287
742	142	314	0	272	292	0	26
1019	112	4807	0	292	317	0	32
1019	1019	7001	0	317	327	0	11
SNG-MEA				327	347	0	22
29	185	0	146	347	357	0	15
29	196	0	39	357	360	0	5
38	208	0	361	360	362	0	5
183	183	0	448	362	365	0	5
189	331	0	70	365	430	0	162
194	194	0	110	410	590	0	156
200	308	0	14	430	445	0	31
875	875	0	969	17	15	2	0
69	17	254	0	304	15	49	0
266	17	99	0	364	15	709	0
295	295	487	0	390	-24	645	0
312	17	288	0	395	393	5	0
842	142	323	0	422	40	68	0
1019	112	4157	0	1017	110	2566	0
1019	1019	6280	0	1017	1017	1673	0