Supplementary Information for

Global Assessment of the Emission Impacts of Chemical Recycling Technologies for Plastics

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Supplementary Table S1. Polymer details of greenhouse gas (GHG) emissions from primary and recycled plastics in 2050 in the solvent-based recycling scenarios compared to the Reference scenario (GtCO$_2$e)

	Reference	Realistic	Ambitious	High Ambitious	Extreme
LDPE (primary)	0.23	0.23	0.22	0.16	0.11
LDPE (recycled)		0.01	0.02	0.11	0.18
LLDPE (primary)	0.35	0.34	0.33	0.23	0.17
LLDPE (recycled)		0.01	0.02	0.17	0.27
HDPE (primary)	0.49	0.47	0.43	0.30	0.25
HDPE (recycled)		0.03	0.08	0.29	0.35
PP (primary)	0.71	0.73	0.77	0.85	0.92
PP (recycled)		0.05	0.14	0.33	0.52
PET (primary)	0.98	0.96	0.93	0.91	0.90
PET (recycled)		0.22	0.74	0.95	1.23
PVC (primary)	0.47	0.46	0.46	0.45	0.41
PVC (recycled)		0.03	0.10	0.23	0.68
PS (primary)	0.27	0.27	0.26	0.21	0.15
PS (recycled)		0.01	0.02	0.12	0.24
ABS (primary)	0.10	0.10	0.09	0.08	0.06
ABS (recycled)		0.01	0.01	0.07	0.13
Total (primary)	3.60	3.56	3.50	3.18	2.99
Total (recycled)		0.37	1.13	2.29	3.61

Supplementary Table S2. Sensitivity of GHG emissions per polymer in 2050 in the Realistic scenario of solvent-based recycling (GtCO$_2$e)

		MRF loss rate		Collection and MRF energy consumption		Polymer recovery rate		Solvent-based recycling and solvent / anti-solvent recovery energy consumption		Solvent and antisolvent recovery rate		Solvent and antisolvent amount	
	Realistic	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
Total	3.93	3.92	3.93	3.92	3.93	3.95	3.92	3.90	3.94	4.53	3.86	3.82	4.02
LDPE	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.24	0.23	0.23	0.23
LLDPE	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.36	0.35	0.35	0.35
HDPE	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.52	0.50	0.49	0.51
PP	0.78	0.78	0.78	0.78	0.78	0.79	0.78	0.77	0.79	0.83	0.77	0.76	0.80
PET	1.19	1.19	1.19	1.19	1.19	1.20	1.19	1.18	1.19	1.66	1.15	1.13	1.25
PVC	0.50	0.50	0.50	0.49	0.50	0.50	0.49	0.49	0.50	0.53	0.49	0.49	0.50
PS	0.28	0.28	0.28	0.28	0.28	0.28	0.27	0.27	0.28	0.28	0.27	0.27	0.28
ABS	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.11	0.10	0.10	0.10

Note: See Materials and Methods for the sensitivity ranges applied per polymer. MRF = Material recovery facility.

Supplementary Table S3. Sensitivity of GHG emissions per polymer in 2050 in the Extreme scenario of solvent-based recycling (GtCO$_2$e)

		MRF loss rate		Collection and MRF energy consumption		Polymer recovery rate		Solvent-based recycling and solvent / anti-solvent recovery energy consumption		Solvent and antisolvent recovery rate		Solvent and antisolvent amount	

	Extreme	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
Total	6.60	6.58	6.66	6.54	6.66	6.84	6.52	6.37	6.83	5.98	11.5	5.64	7.56
LDPE	0.29	0.29	0.29	0.29	0.29	0.30	0.29	0.27	0.31	0.28	0.39	0.25	0.33
LLDPE	0.44	0.43	0.44	0.43	0.44	0.45	0.43	0.41	0.46	0.42	0.58	0.38	0.49
HDPE	0.61	0.61	0.62	0.60	0.62	0.63	0.60	0.58	0.64	0.58	0.80	0.54	0.68
PP	1.45	1.44	1.46	1.43	1.47	1.51	1.44	1.36	1.54	1.37	2.01	1.24	1.66
PET	2.13	2.12	2.15	2.12	2.14	2.21	2.12	2.10	2.16	1.90	4.74	1.81	2.45
PVC	1.10	1.10	1.10	1.09	1.10	1.13	1.08	1.07	1.13	0.92	1.81	0.92	1.27
PS	0.39	0.39	0.40	0.39	0.40	0.40	0.38	0.38	0.40	0.35	0.74	0.34	0.45
ABS	0.19	0.19	0.20	0.19	0.20	0.21	0.18	0.19	0.20	0.16	0.42	0.16	0.23

Note: See Materials and Methods for the sensitivity ranges applied per polymer.

Supplementary Table S4. Technology details of GHG emissions from plastics in 2050 in the depolymerization scenarios compared to the Reference scenario (GtCO$_2$e)

	Reference	Realistic	High Ambitious	Extreme
Enzymatic Hydrolysis (primary)	0.98	0.77	0.71	0.63
Enzymatic Hydrolysis (recycled)		0.25	0.29	0.38
Methanolysis (primary)	0.98	0.97	0.65	0.42
Methanolysis (recycled)		0.01	0.41	0.70
Glycolysis (primary)	0.98	0.73	0.66	0.56
Glycolysis (recycled)		0.12	0.16	0.21

Supplementary Table S5. Sensitivity of GHG emissions in 2050 in the Realistic scenario of PET depolymerization scenarios (GtCO$_2$e)

		MRF loss rate		Collection and MRF energy consumption		Monomer recovery rate		Depolymerization (incl., solvent recovery) energy consumption		NaOH production energy consumption for Enzymatic Hydrolysis & Solvent recovery rate for Methanolysis and Glycolysis	
	Realistic	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
Enzymatic Hydrolysis	1.00	0.99	1.01	0.99	1.00	1.01	1.00	0.98	1.01	0.99	1.01
Methanolysis	1.03	1.03	1.04	1.03	1.04	1.05	1.02	1.02	1.05	1.02	1.12
Glycolysis	0.86	0.85	0.87	0.85	0.86	0.87	0.85	0.85	0.86	0.87	0.85

Note: See Materials and Methods for the sensitivity ranges applied.

Supplementary Table S6. Sensitivity of GHG emissions in 2050 in the Extreme scenario of PET depolymerization scenarios (GtCO$_2$e)

		MRF loss rate		Collection and MRF energy consumption		Monomer recovery rate		Depolymerization (incl., solvent recovery) energy consumption		NaOH production energy consumption for Enzymatic Hydrolysis & Solvent recovery rate for Methanolysis and Glycolysis	
	Extreme	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper

Enzymatic Hydrolysis	1.01	1.00	1.02	0.99	1.02	1.03	1.01	0.98	1.04	0.99	1.02
Methanolysis	1.12	1.10	1.13	1.10	1.13	1.16	1.08	1.07	1.16	1.09	1.33
Glycolysis	0.77	0.76	0.79	0.76	0.79	0.79	0.76	0.76	0.78	0.79	0.76

Note: See Materials and Methods for the sensitivity ranges applied.

Supplementary Table S7. Polymer details of GHG emissions from primary and recycled plastics in 2050 in the pyrolysis scenarios compared to the Reference scenario (GtCO$_2$e)

	Reference	Realistic	Ambitious	High Ambitious	Extreme
LDPE (primary)	0.23	0.22	0.21	0.19	0.14
LDPE (recycled)		0.02	0.04	0.06	0.15
LLDPE (primary)	0.35	0.33	0.32	0.29	0.22
LLDPE (recycled)		0.03	0.06	0.09	0.22
HDPE (primary)	0.49	0.46	0.44	0.40	0.29
HDPE (recycled)		0.05	0.08	0.13	0.31
PP (primary)	0.71	0.66	0.63	0.59	0.44
PP (recycled)		0.07	0.12	0.20	0.48
PS (primary)	0.27	0.27	0.24	0.21	0.17
PS (recycled)		0.01	0.04	0.06	0.10
Total (primary)	2.05	1.94	1.83	1.69	1.26
Total (recycled)		0.18	0.33	0.55	1.26

Supplementary Table S8. GHG emission intensity of producing a tonne of recycled polymers via closed-loop pyrolysis vs primary production per polymer (kgCO$_2$e/kg)

	Pyrolysis (closed-loop) recycling	Primary production
LDPE	6.76	4.77
LLDPE	6.96	4.76
HDPE	6.78	4.73
PP	6.74	4.47
PS	5.74	6.48

Supplementary Table S9. 1-1 Pyrolysis oil replacement sensitivity of GHG emissions in the closed-loop pyrolysis "Realistic and Extreme" scenario in 2050 (GtCO$_2$e)

		Pyrolysis oil: 1-1 replacement to light naphtha	
	Reference	Realistic	Extreme
Total	2.05	2.13	2.61
LDPE	0.23	0.24	0.31
LLDPE	0.35	0.36	0.45
HDPE	0.49	0.51	0.62
PP	0.71	0.74	0.95
PS	0.27	0.28	0.27

Supplementary Table S10. Sensitivity of GHG emissions per polymer in 2050 in the Realistic scenario of pyrolysis scenarios (GtCO$_2$e)

		Pretreatment loss rate		Collection and pretreatment energy consumption		Pyrolysis oil and styrene recovery rate		Pyrolysis oil and styrene replacement rate		Pyrolysis energy consumption	
	Realistic	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
Total	2.116	2.101	2.135	2.107	2.125	2.117	2.115	2.116	2.118	2.101	2.132
LDPE	0.241	0.239	0.244	0.240	0.242	0.241	0.241	0.241	0.242	0.239	0.243
LLDPE	0.362	0.359	0.366	0.360	0.364	0.362	0.362	0.362	0.362	0.359	0.365
HDPE	0.505	0.501	0.510	0.503	0.508	0.505	0.505	0.505	0.506	0.501	0.509
PP	0.731	0.725	0.739	0.727	0.735	0.731	0.731	0.731	0.732	0.725	0.738

PS	0.276	0.277	0.277	0.276	0.277	0.278	0.276	0.277	0.276	0.276	0.277

Note: See Materials and Methods for the sensitivity ranges applied.

Supplementary Table S11. Sensitivity of GHG emissions per polymer in 2050 in the Extreme scenario of pyrolysis scenarios ($GtCO_2e$)

		Pretreatment loss rate		Collection and pretreatment energy consumption		Pyrolysis oil and styrene recovery rate		Pyrolysis oil and styrene replacement rate		Pyrolysis energy consumption	
	Extreme	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
Total	2.519	2.426	2.647	2.457	2.581	2.539	2.509	2.527	2.532	2.419	2.797
LDPE	0.294	0.282	0.310	0.287	0.301	0.294	0.294	0.293	0.296	0.281	0.327
LLDPE	0.436	0.418	0.459	0.425	0.447	0.436	0.436	0.435	0.438	0.418	0.484
HDPE	0.601	0.575	0.633	0.585	0.616	0.600	0.601	0.600	0.604	0.575	0.669
PP	0.916	0.876	0.967	0.892	0.940	0.916	0.917	0.914	0.922	0.876	1.021
PS	0.273	0.274	0.278	0.268	0.278	0.293	0.260	0.285	0.272	0.269	0.296

Note: See Materials and Methods for the sensitivity ranges applied.

Supplementary Table S12. Polymer details of GHG emissions from primary and recycled plastics in 2050 in the gasification and F-T (Fischer–Tropsch) synthesis scenarios compared to the Reference scenario ($GtCO_2e$)

	Reference	Realistic	Ambitious	High Ambitious	Extreme
LDPE (primary)	0.23	0.22	0.22	0.21	0.19
LDPE (recycled)		0.02	0.04	0.07	0.11
LLDPE (primary)	0.35	0.34	0.33	0.31	0.29
LLDPE (recycled)		0.04	0.06	0.10	0.17
HDPE (primary)	0.49	0.47	0.46	0.44	0.41
HDPE (recycled)		0.05	0.09	0.14	0.24
PP (primary)	0.71	0.68	0.66	0.63	0.59
PP (recycled)		0.08	0.13	0.22	0.37
PET (primary)	0.98	0.94	0.91	0.87	0.79
PET (recycled)		0.09	0.15	0.24	0.41
PS (primary)	0.27	0.26	0.26	0.24	0.22
PS (recycled)		0.02	0.04	0.07	0.12
Total (primary)	3.03	2.91	2.83	2.71	2.49
Total (recycled)		0.30	0.50	0.84	1.42

Supplementary Table S13. GHG emission intensity of producing a tonne of recycled polymers via closed-loop gasification and F-T synthesis vs primary production per polymer ($kgCO_2e/kg$)

	Pyrolysis closed-loop recycling	Primary production
LDPE	13.42	4.77
LLDPE	13.38	4.76
HDPE	13.40	4.73
PP	14.63	4.47
PS	15.75	6.48
PET	17.33	6.54

Supplementary Table S14. Polymer details of GHG emissions from primary and recycled plastics in 2050 in the gasification and methanol synthesis scenarios compared to the Reference scenario ($GtCO_2e$)

	Reference	Realistic	Ambitious	High Ambitious	Extreme
LDPE (primary)	0.23	0.22	0.21	0.19	0.17
LDPE (recycled)		0.07	0.12	0.19	0.32
LLDPE (primary)	0.35	0.33	0.31	0.29	0.25

LLDPE (recycled)		0.11	0.18	0.30	0.50
HDPE (primary)	0.49	0.46	0.44	0.40	0.34
HDPE (recycled)		0.15	0.26	0.41	0.69
PP (primary)	0.71	0.66	0.63	0.59	0.51
PP (recycled)		0.27	0.45	0.75	1.26
PET (primary)	0.98	0.91	0.87	0.79	0.66
PET (recycled)		0.11	0.18	0.27	0.44
PS (primary)	0.27	0.26	0.25	0.23	0.20
PS (recycled)		0.03	0.04	0.06	0.10
Primary	3.03	2.83	2.71	2.49	2.12
Recycled	0.00	0.74	1.23	1.99	3.31

Supplementary Table S15. GHG emission intensity of producing a tonne of recycled polymers via closed-loop gasification and methanol synthesis vs primary production per polymer (kgCO$_2$e/kg)

	Pyrolysis closed-loop recycling	Primary production
LDPE	25.54	4.77
LLDPE	26.16	4.76
HDPE	25.75	4.73
PP	29.37	4.47
PS	10.14	6.48
PET	11.95	6.54

Supplementary Table S16. Sensitivity of GHG emissions per polymer in 2050 in the Realistic scenario of gasification and F-T synthesis scenarios (GtCO$_2$e)

		Pretreatment loss rate		Collection and pretreatment energy consumption		Syngas recovery rate		F-T oil replacement rate		Gasification and F-T synthesis energy consumption	
	Realistic	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
Total	3.198	3.198	3.198	3.194	3.202	3.197	3.199	3.183	3.205	3.165	3.231
LDPE	0.245	0.245	0.245	0.245	0.246	0.245	0.246	0.244	0.246	0.243	0.248
LLDPE	0.369	0.369	0.369	0.368	0.369	0.369	0.369	0.367	0.370	0.365	0.373
HDPE	0.518	0.518	0.518	0.517	0.519	0.518	0.518	0.515	0.519	0.512	0.524
PP	0.753	0.752	0.753	0.751	0.754	0.752	0.753	0.748	0.755	0.744	0.761
PS	0.286	0.286	0.286	0.286	0.287	0.286	0.286	0.285	0.287	0.284	0.289
PET	1.027	1.027	1.027	1.026	1.028	1.027	1.027	1.023	1.029	1.018	1.036

Note: See Materials and Methods for the sensitivity ranges applied.

Supplementary Table S17. Sensitivity of GHG emissions per polymer in 2050 in the Extreme scenario of gasification and F-T synthesis scenarios (GtCO$_2$e)

		Pretreatment loss rate		Collection and pretreatment energy consumption		Syngas recovery rate		F-T oil replacement rate		Gasification and F-T synthesis energy consumption	
	Extreme	lower	upper	lower	upper	lower	upper	lower	upper	lower	upper
Total	3.864	3.862	3.866	3.844	3.884	3.861	3.867	3.795	3.898	3.709	4.019
LDPE	0.299	0.299	0.299	0.297	0.300	0.298	0.299	0.293	0.302	0.286	0.312
LLDPE	0.448	0.448	0.449	0.446	0.451	0.448	0.449	0.440	0.453	0.429	0.468
HDPE	0.630	0.630	0.631	0.627	0.634	0.630	0.631	0.618	0.637	0.603	0.658
PP	0.950	0.950	0.951	0.945	0.956	0.949	0.952	0.931	0.960	0.908	0.992
PS	0.335	0.335	0.335	0.334	0.337	0.335	0.336	0.330	0.338	0.324	0.346
PET	1.200	1.200	1.201	1.195	1.206	1.200	1.200	1.182	1.209	1.158	1.243

Note: See Materials and Methods for the sensitivity ranges applied.

Supplementary Table S18. Sensitivity of GHG emissions per polymer in 2050 in the Realistic scenario of gasification and methanol synthesis scenarios (GtCO$_2$e)

		Pretreatment loss rate		Collection and pretreatment energy consumption		Syngas recovery rate		Gasification and methanol synthesis energy consumption	
	Realistic	lower	upper	lower	upper	lower	upper	lower	upper
Total	3.570	3.569	3.571	3.562	3.578	3.568	3.572	3.556	3.584
LDPE	0.290	0.290	0.290	0.289	0.290	0.290	0.290	0.288	0.291
LLDPE	0.438	0.438	0.438	0.437	0.439	0.438	0.438	0.436	0.440
HDPE	0.610	0.609	0.610	0.608	0.611	0.609	0.610	0.607	0.612
PP	0.931	0.930	0.931	0.928	0.933	0.930	0.931	0.927	0.934
PS	0.285	0.285	0.285	0.284	0.285	0.285	0.285	0.284	0.286
PET	1.017	1.017	1.018	1.015	1.019	1.017	1.018	1.014	1.021

Note: See Materials and Methods for the sensitivity ranges applied.

Supplementary Table S19. Sensitivity of GHG emissions per polymer in 2050 in the Extreme scenario of gasification and methanol synthesis scenarios (GtCO$_2$e)

		Pretreatment loss rate		Collection and pretreatment energy consumption		Syngas recovery rate		Gasification and methanol synthesis energy consumption	
	Realistic	lower	upper	lower	upper	lower	upper	lower	upper
Total	3.864	5.619	5.626	5.586	5.658	5.615	5.630	5.556	5.688
LDPE	0.299	0.508	0.509	0.505	0.511	0.508	0.509	0.503	0.514
LLDPE	0.448	0.775	0.776	0.771	0.780	0.774	0.776	0.767	0.784
HDPE	0.630	1.067	1.068	1.061	1.074	1.066	1.069	1.056	1.080
PP	0.950	1.797	1.799	1.788	1.808	1.796	1.800	1.780	1.816
PS	0.335	0.319	0.319	0.316	0.322	0.319	0.320	0.314	0.324
PET	1.200	1.153	1.155	1.144	1.163	1.152	1.156	1.137	1.171

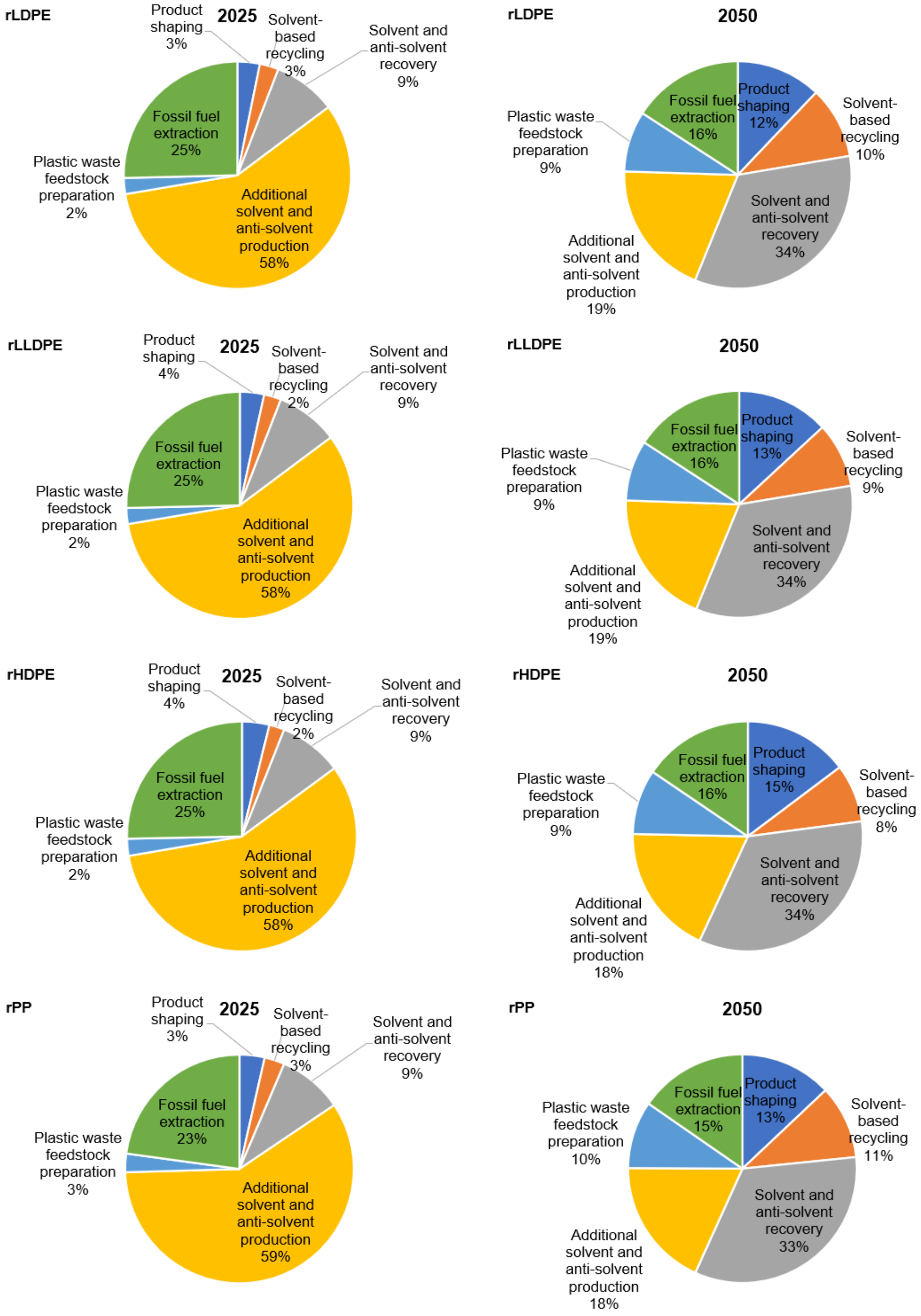
Note: See Materials and Methods for the sensitivity ranges applied.

Supplementary Table S20. Global Examples of Chemical Recycling Plants by Technology Type and Operational Status

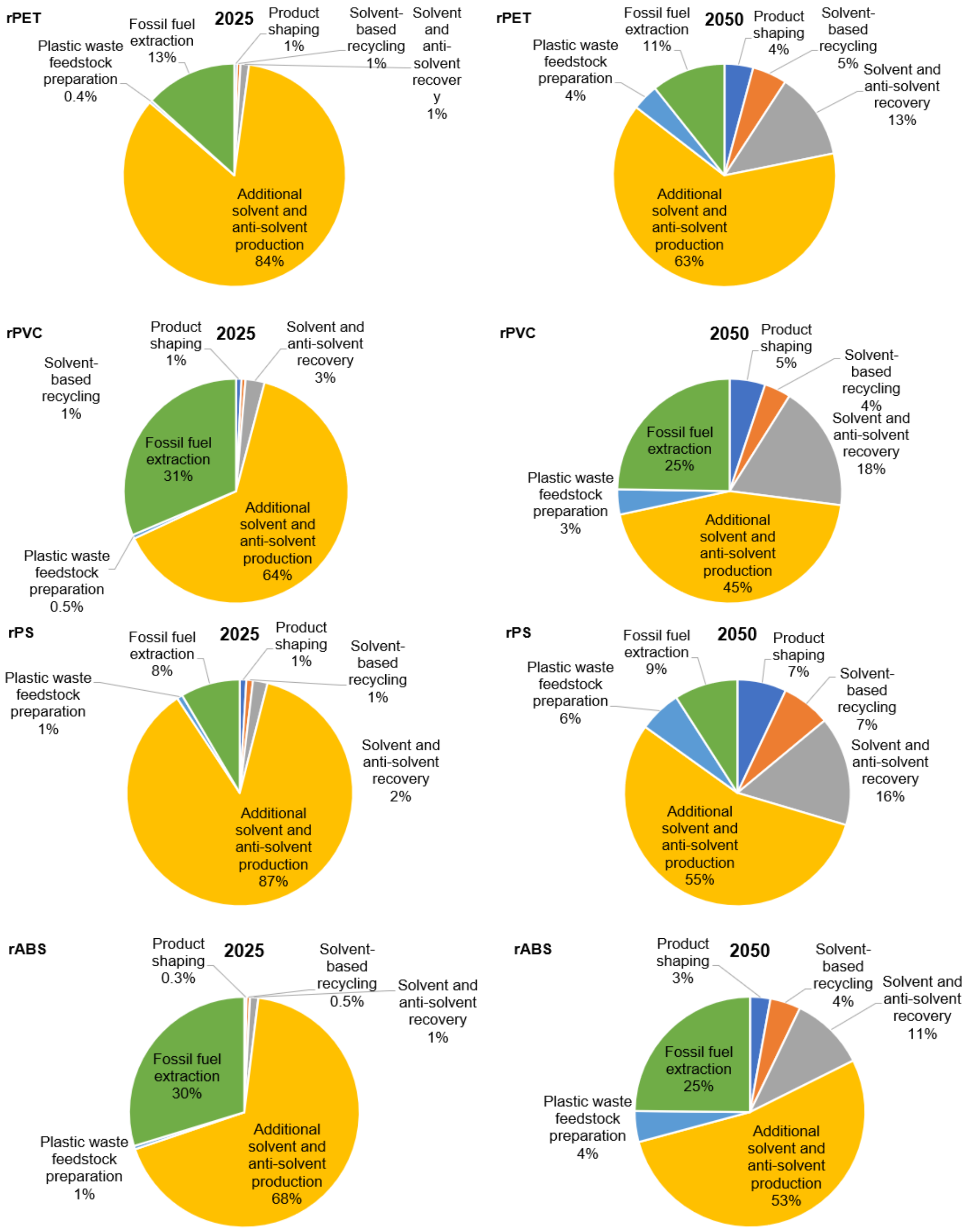
Plant Name	Status	Process type	Plastic polymers	Capacity (latest available data)
Ironton Facility/PureCycle	Operational	Dissolution	PP	~50,000 tonnes/year
CreaSolv Pilot Plant	Pilot - Closed (2019-2021)	Dissolution	PEs	46,2 tonnes over 2 years
CreaSolv Demonstration plant– Lober/CreaSolv	Pilot - Closed (2018-2021)	Dissolution	PEs, PP	
MultiCycle CreaSolv Pilot plant	Pilot - Operational	Dissolution	PEs, PP PET, PA	
CreaSolv PVC Prototype recycling plant	Operational	Dissolution	PVC	
revolPET/RITTEC Umwelttechnik GmbH	Pilot-Unknown	Depolymerization (Hydrolysis)	PET	
Denka	Operational	Pyrolysis - Closed Loop	PS	3,000 tonnes/year
Alterra		Pyrolysis	PEs, PP, PS	60 tonnes/day
Regenyx/Amsty	Closed	Pyrolysis	PS	4,400 tonnes/year
Rewind PET/Axens		Depolymerization (Glycolysis)	PET	
Rewind Mix/Axens		Pyrolysis	PEs, PP	
TAC/Plastic Energy		Pyrolysis	PEs, PP	
Caojing/BASF	Operational	Depolymerization	PA	500 tonnes/year
OMV ReOil Plant	Operational	Pyrolysis	PEs, PP	
OMV ReOil Pilot Plant	Pilot - Operational	Pyrolysis	PE, PP	
Trinity Oaks Tyler/New Hope Energy	Operational	Pyrolysis	PE, PET, PS, PP	
Atlanta Plant/Nexus Circular	Operational	Pyrolysis	PEs, PS, PP	
Honeywell	Operational	Pyrolysis		
Plastic Energy	Operational	Pyrolysis	MPW	
Plastic Energy	Operational	Pyrolysis	MPW	
Clermont-Ferrand Demonstration Plant/Carbios	Operational	Depolymerization	PET	40,000-tonne/year
Clariter	Pilot - Operational	Pyrolysis	PEs, PS, PP	
Clariter	Operational	Pyrolysis	PEs, PS, PP	60,000 tonnes/year
Greenback	Operational	Pyrolysis	PEs, PS, PP	3,000 tonnes/year
GR3N	Pilot - Operational	Depolymerization	PET	40,000 tonnes/year
Pilot Plant/BlueAlp	Pilot - Operational	Pyrolysis	Mixed Plastic Waste	3000 tonnes/year
Commercial Prototype Plant/BlueAlp		Pyrolysis	Mixed Plastic Waste	24,500 tonnes/year
Orlen Unipetrol	Closed	Pyrolysis		
Quantafuel	Operational	Pyrolysis	Mixed Plastic Waste	20,000 tonnes/year
Revalyu Resources	Operational	Depolymerization	PET	160 PET tonnes/day
Corsair	Operational	Pyrolysis	Mixed Plastic Waste	
Eastman Chemical Company	Operational	Gasification, Glycolysis, Methanolysis	PET	110,000 tonnes/year

Note: This table presents selected examples of chemical recycling plants worldwide with publicly available data and is not intended as a comprehensive inventory of all existing facilities. PA = Polyamide. MPW = Mixed Plastic Waste.

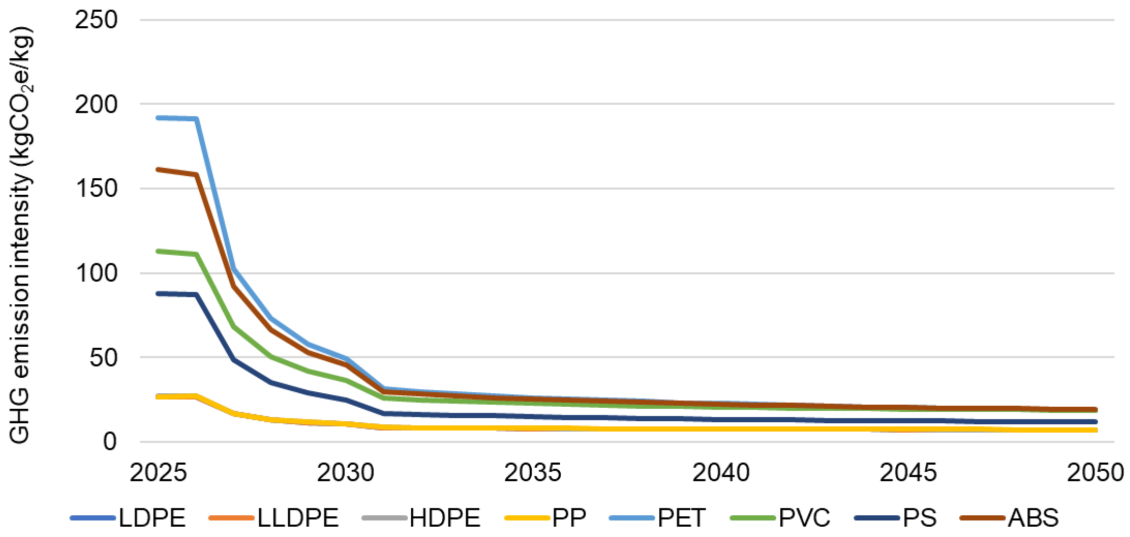
Supplementary Figures *(referred in the main text)*



Supplementary Fig. S1. GHG emission contribution of production stages per polymer (LDPE, LLDPE, HDPE, PP) in 2025 and 2050 in the Realistic scenario of solvent-based recycling scenarios



Supplementary Fig. S2. GHG emission contribution of production stages per polymer (PET, PVC, PS, ABS) in 2025 and 2050 in the Realistic scenario of solvent-based recycling scenarios

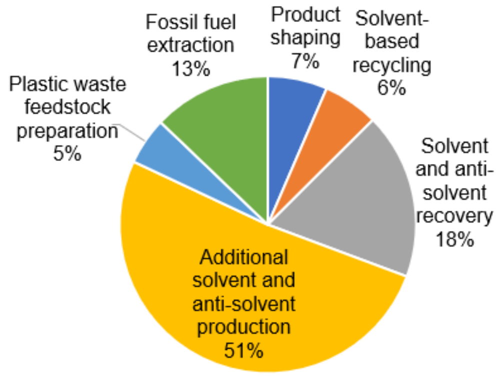


Supplementary Fig. S3. Changes in GHG emission intensity for solvent-based recycling by polymer type over the modeling horizon in the Realistic scenario (kgCO$_2$e/kg)

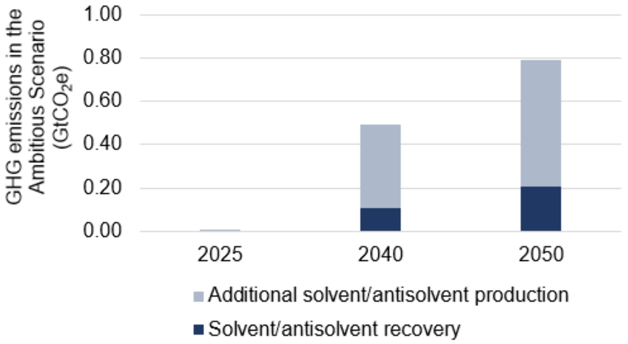
Note: The emission intensity levels for LDPE, LLDPE, HDPE, and PP are similar and show overlapping ranges in the chart. All plastic polymer types exhibit consistent trends and comparable intensity levels across all analyzed scenarios (i.e., Realistic, Ambitious, High ambitious, and Extreme scenarios).

GHG emission intensity of producing a tonne of recycled plastic via solvent-based process vs primary production per polymer (kgCO$_2$e/kg)

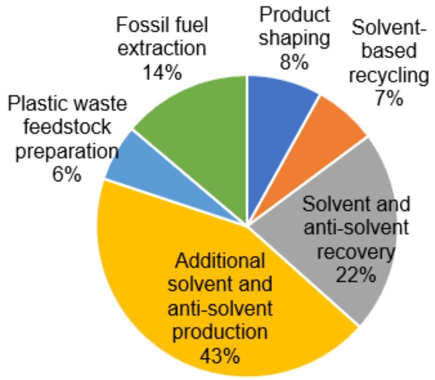
	Solvent and non-solvent production included	*Only solvent and non-solvent loss included*	*Primary production*
LDPE	*26.55*	*5.79*	*4.77*
LLDPE	*26.55*	*5.79*	*4.76*
HDPE	*26.95*	*5.93*	*4.73*
PP	*26.80*	*5.98*	*4.47*
PET	*192.27*	*8.76*	*6.54*
PVC	*113.00*	*12.48*	*4.77*
PS	*88.02*	*7.17*	*6.48*
ABS	*161.12*	*9.77*	*5.01*



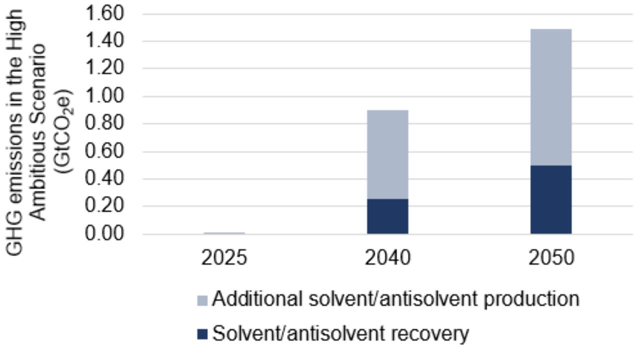
GHG emission contribution of production stages for solvent-based recycling in the Ambitious Scenario in 2050



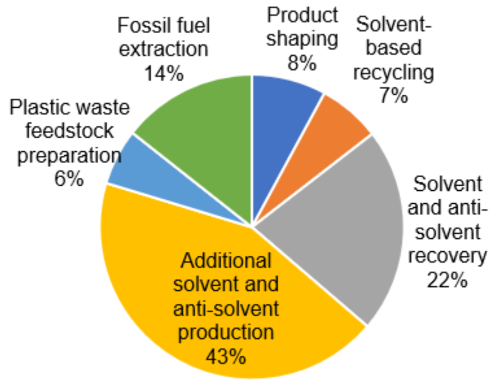
	2025	2040	2050
Total solvent/antisolvent demand (Mtonnes)	0.16	1,846	3,562
from recovery (%)	0%	90%	92%
from additional production (%)	100%	10%	8%



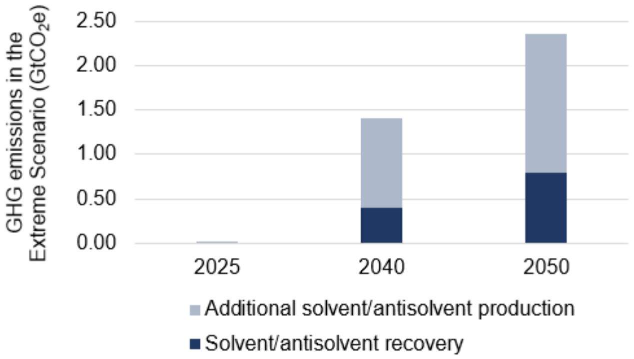
GHG emission contribution of production stages for solvent-based recycling in the High Ambitious Scenario in 2050



	2025	2040	2050
Total solvent/antisolvent demand (Mtonnes)	0.16	4,431	8,600
from recovery (%)	0%	90%	91%
from additional production (%)	100%	10%	9%

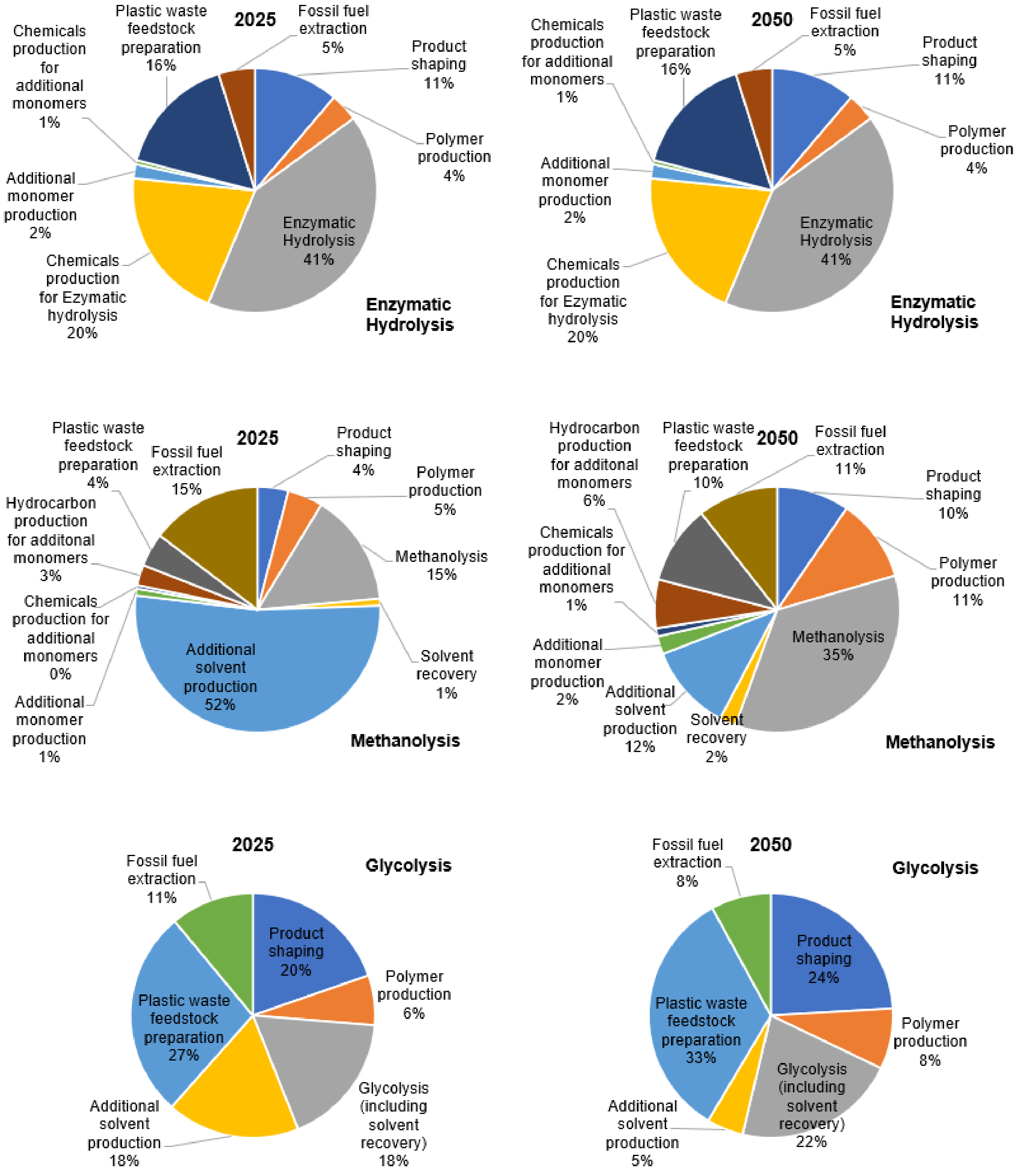


GHG emission contribution of production stages for solvent-based recycling in the Extreme Scenario in 2050

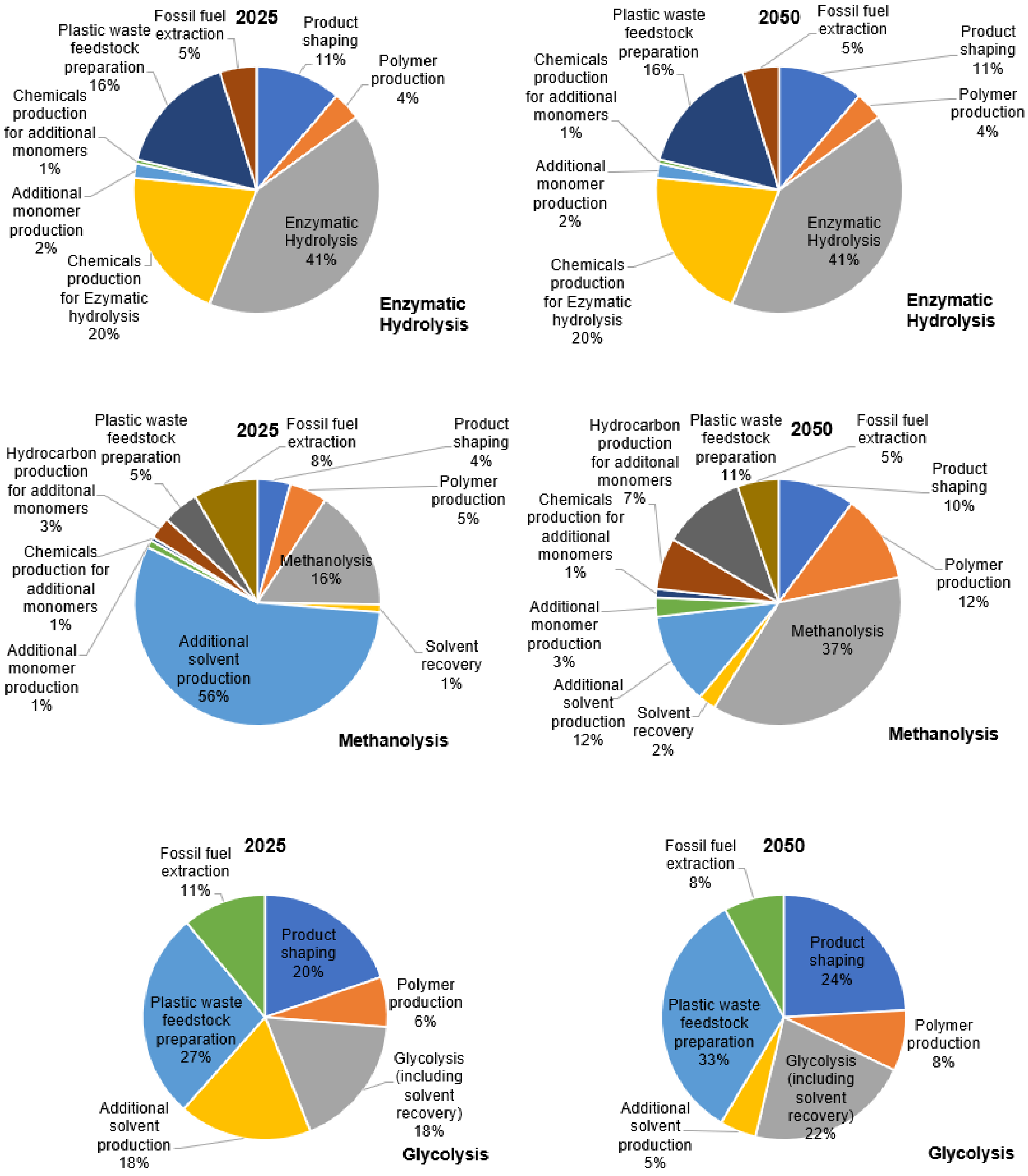


	2025	2040	2050
Total solvent/antisolvent demand (Mtonnes)	0.16	7,040	13,676
from recovery (%)	0%	89%	91%
from additional production (%)	100%	11%	9%

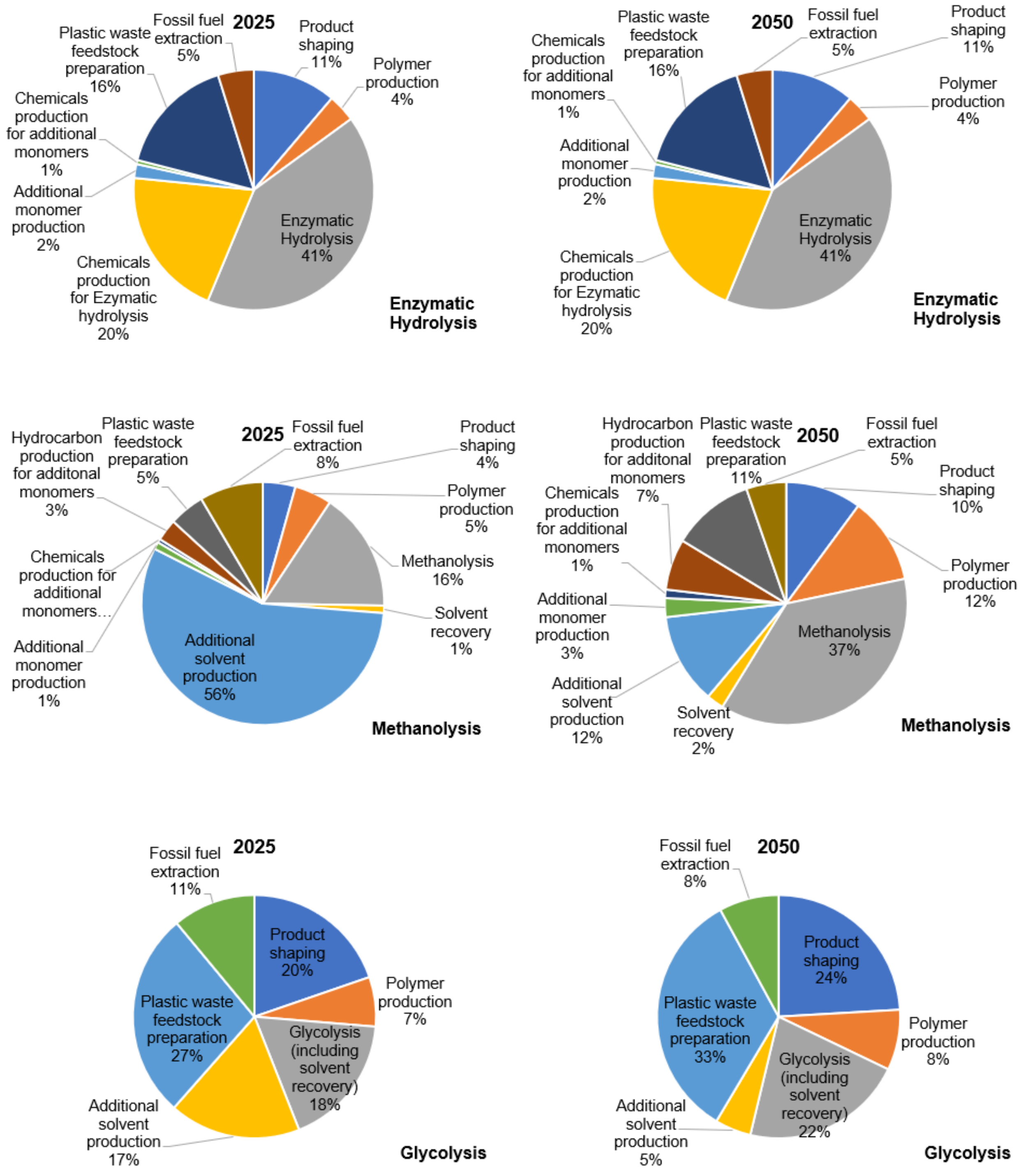
Supplementary Fig. S4. GHG emission contribution of production stages in 2050 and demand for and GHG emissions from solvent/anti solvent recovery and additional production in the Ambitious, High ambitious, and Extreme scenarios of solvent-based recycling scenarios.



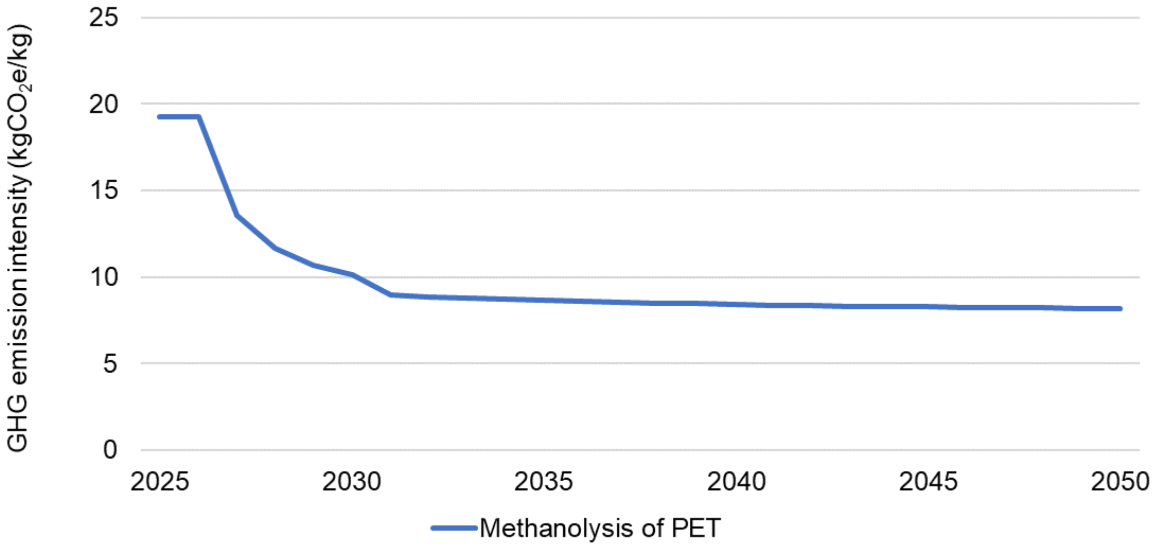
Supplementary Fig. S5. GHG emission contribution of production stages in 2025 and 2050 in the Realistic *s*cenario of PET depolymerization



Supplementary Fig. S6. GHG emission contribution of production stages in 2025 and 2050 in the High Ambitious scenario of PET depolymerization



Supplementary Fig. S7. GHG emission contribution of production stages in 2025 and 2050 in the Extreme scenario of PET depolymerization

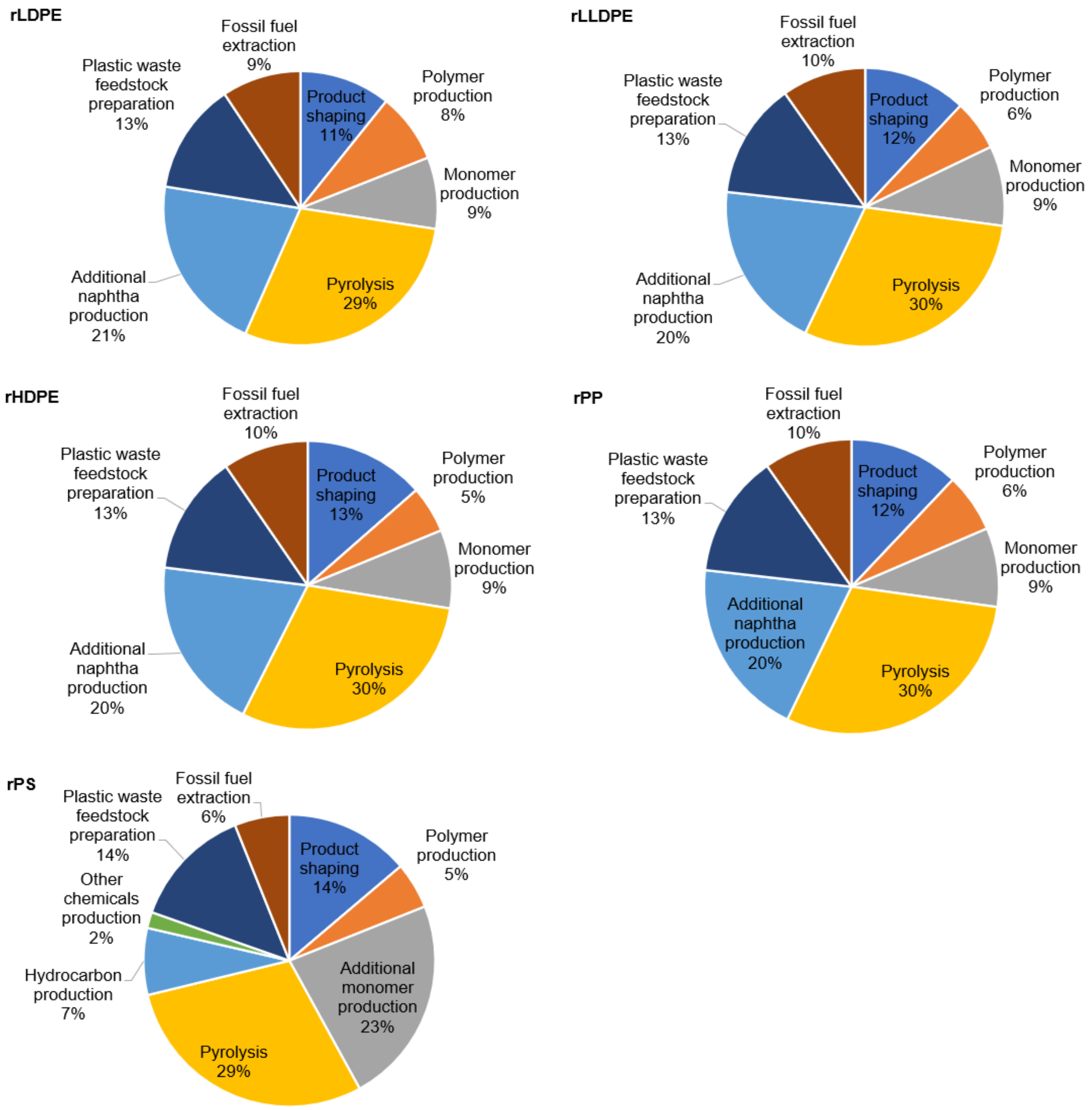


Supplementary Fig. S8. Changes in GHG emission intensity for PET methanolysis over the modeling horizon in the Realistic scenario (kgCO$_2$e/kg)

Note: PET exhibits consistent trends and comparable intensity levels across all analyzed scenarios (i.e., Realistic, Ambitious, High ambitious, and Extreme scenarios).

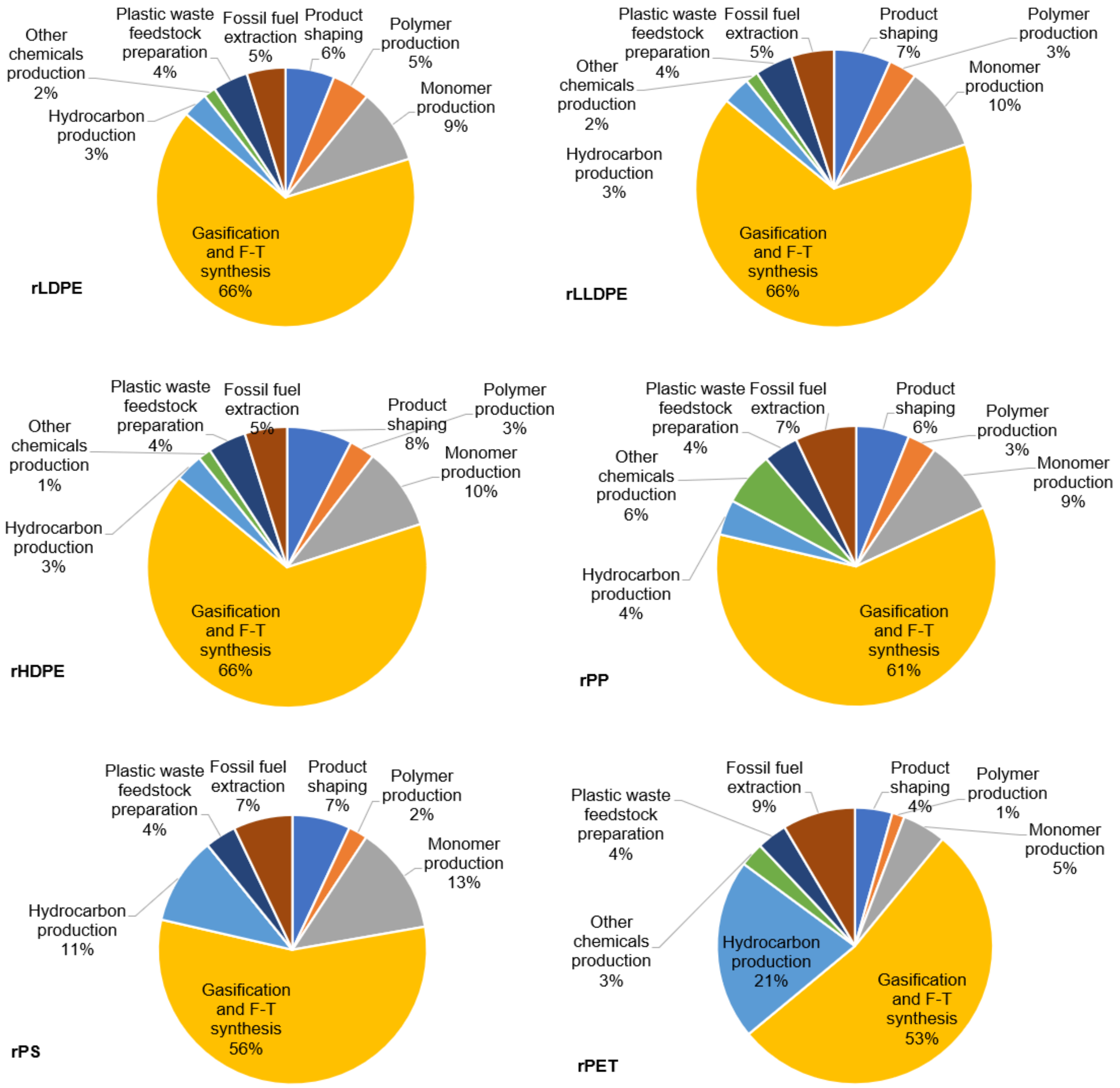
GHG emission intensity of producing a tonne of recycled PET via depolymerization vs primary production per polymer (kgCO2e/kg)

	Solvent production included	*Only solvent loss included*	*Primary production*
Glycolysis	*3.97*	*3.20*	*6.54*
Enzymatic Hydrolysis		*6.99*	*6.54*
Methanolysis	*19.28*	*7.53*	*6.54*



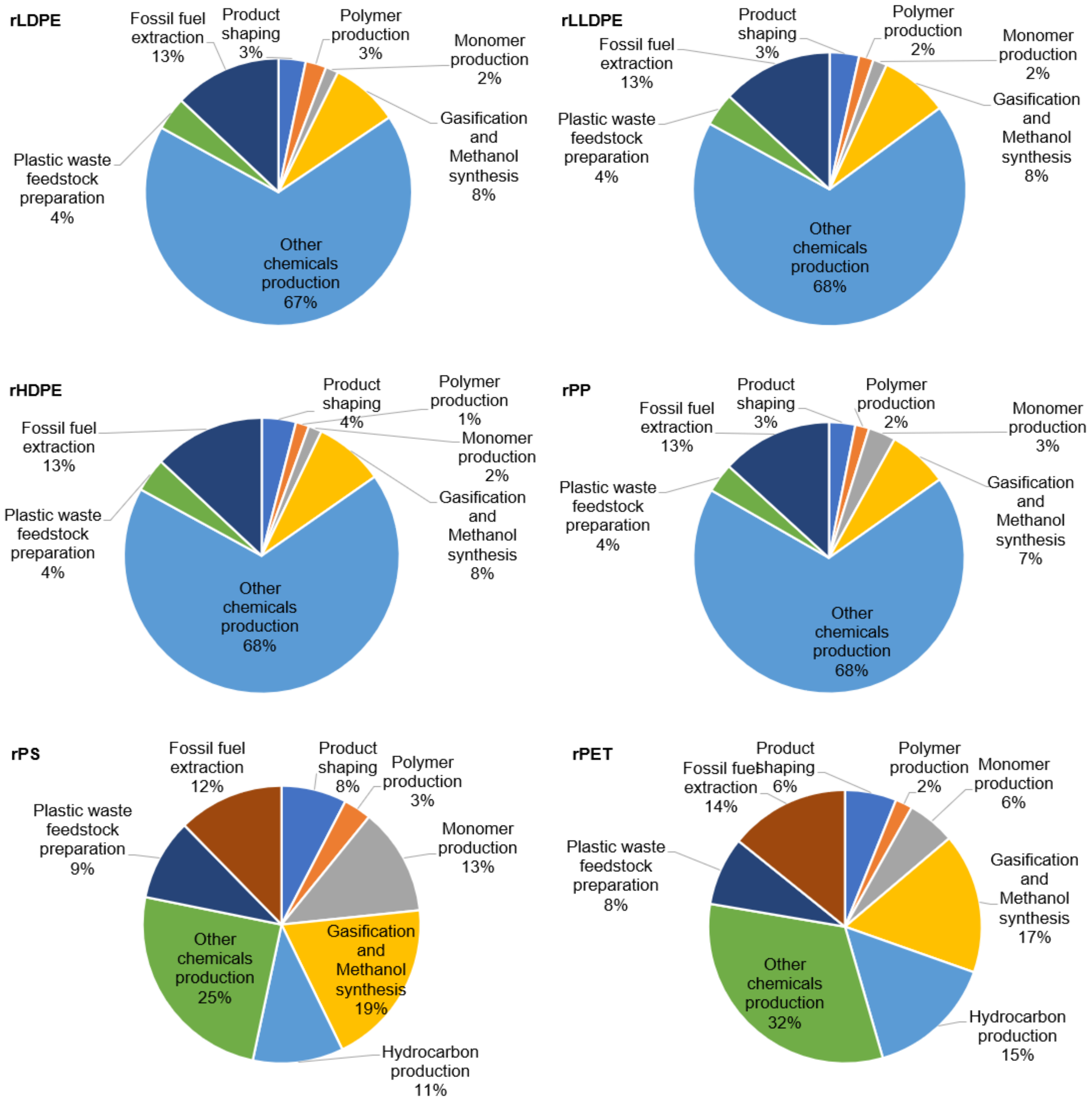
Supplementary Fig. S9. GHG emission contribution of production stages per polymer in 2050 in the Realistic, Ambitious, High ambitious, and Extreme scenarios of pyrolysis recycling scenarios

Note: The changes in contribution shares are negligible across scenarios and years.



Supplementary Fig. S10. GHG emission contribution of production stages per polymer in 2050 in the Realistic, Ambitious, High ambitious, and Extreme scenarios of gasification and F-T synthesis scenarios

Note: The changes in contribution shares are negligible across scenarios and years.



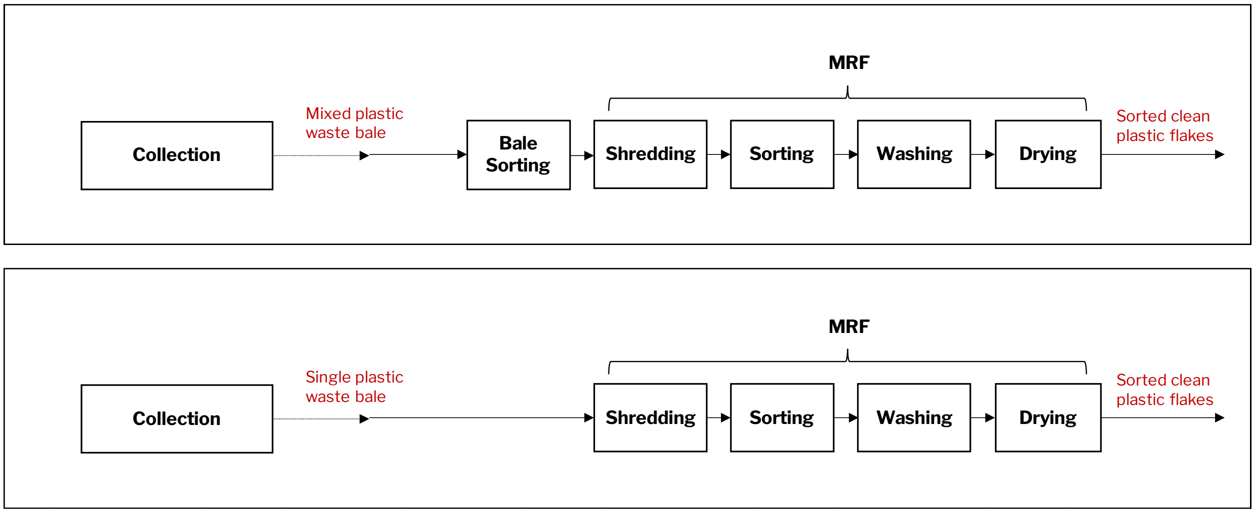
Supplementary Fig. S11. GHG emission contribution of production stages per polymer in 2050 in the Realistic, Ambitious, High ambitious, and Extreme scenarios of gasification and methanol synthesis scenarios

Note: The changes in contribution shares are negligible across scenarios and years.

Supplementary Methods

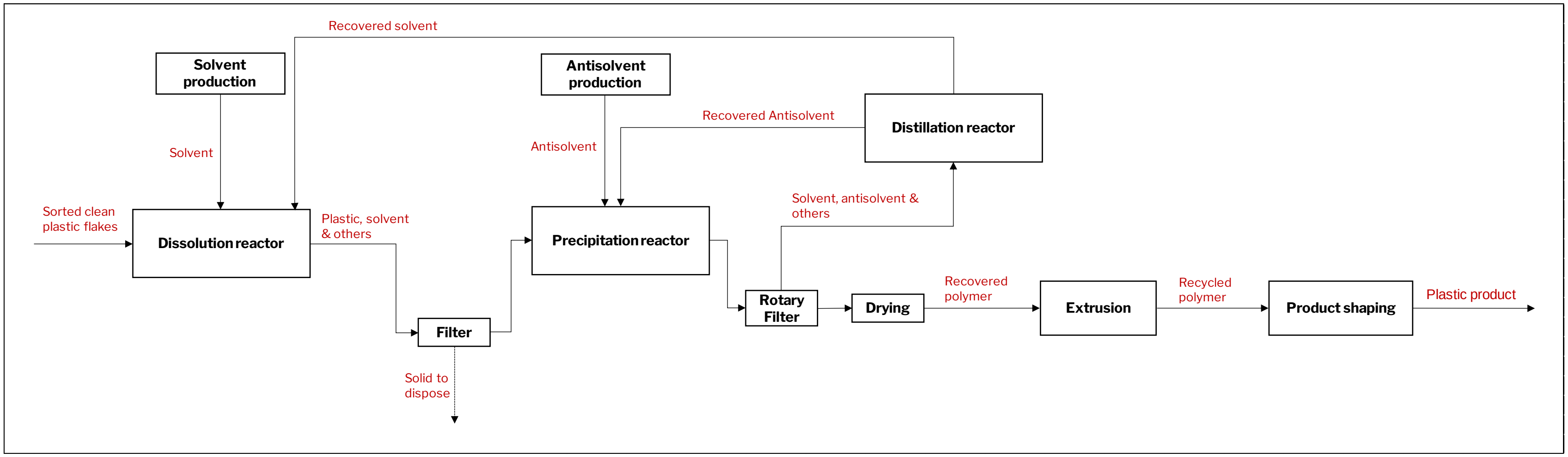
This section details the chemical recycling modeling components within the authors' existing primary plastic production framework. For comprehensive information on primary plastic production modeling for individual polymers, please refer to Karali et al. *(1)*.

a. Chemical recycling technologies production value chain and material flow charts



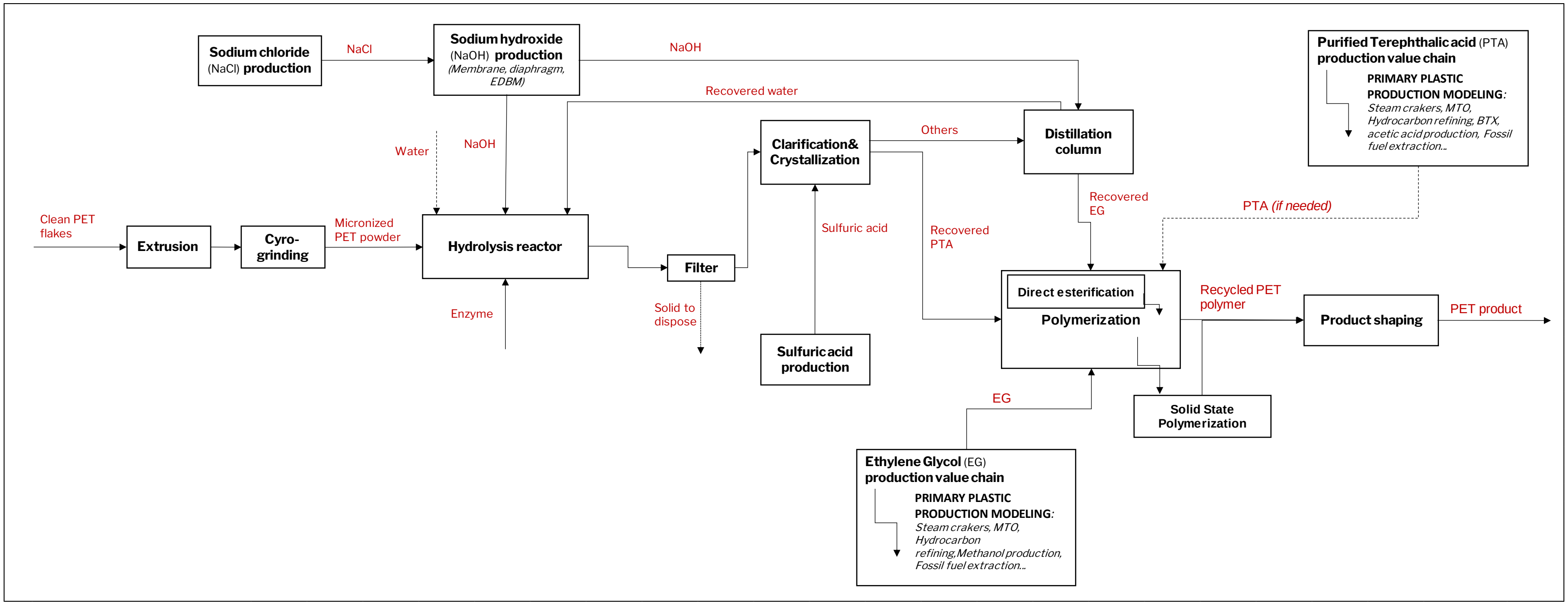
Supplementary Fig. S12. Plastic Waste Collection and Pretreatment Process Flow for Mixed and Single-Stream Collections

Note: This study assumes that mixed plastic collections undergo initial sorting processes before proceeding to chemical recycling technologies.



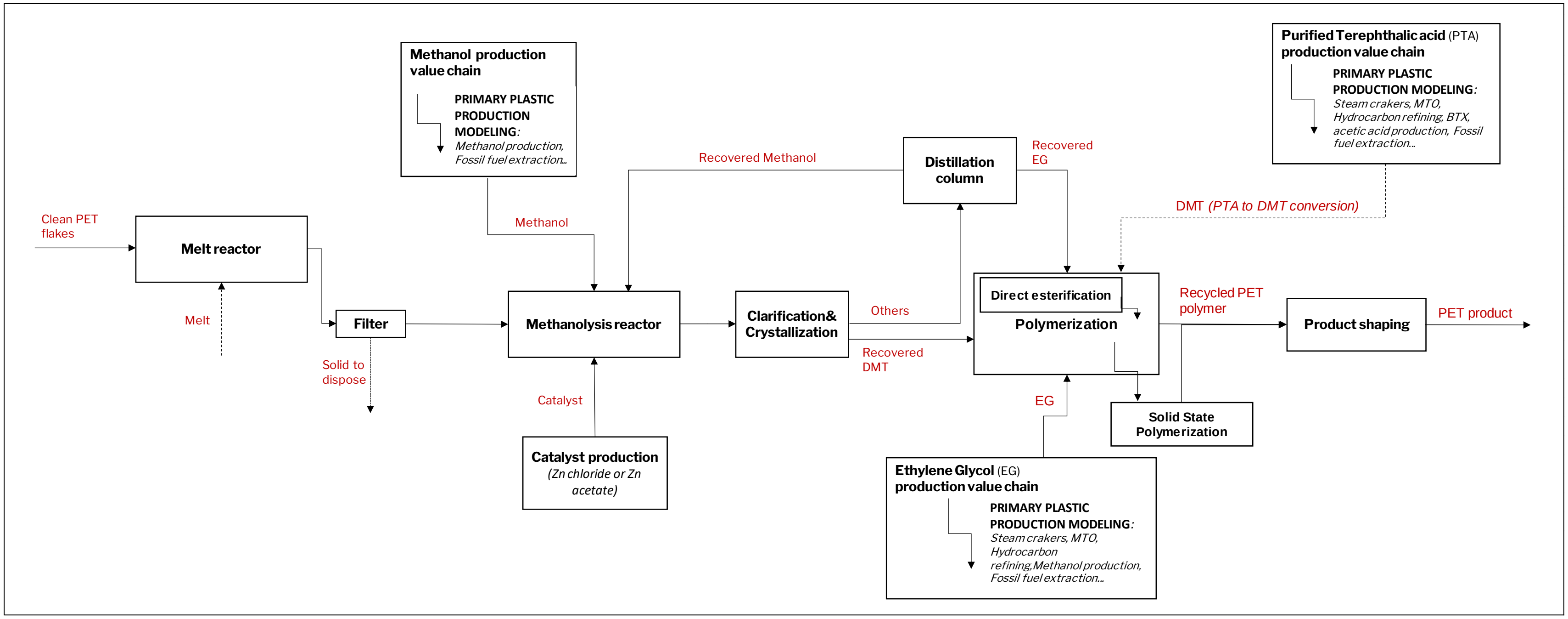
Supplementary Fig. S13. Solvent-Based Chemical Recycling: Production Value Chain and Material Flow Chart

Note: Process conditions for solvent-based recycling, including specific solvents and antisolvents used, energy requirements, direct process emissions, and detailed production parameters for solvent and antisolvent manufacturing for each polymer type, are provided in Materials and Methods sections b and c. For polymer-specific product shaping stage details, refer to the primary plastic production modeling in Karali et al. (1).



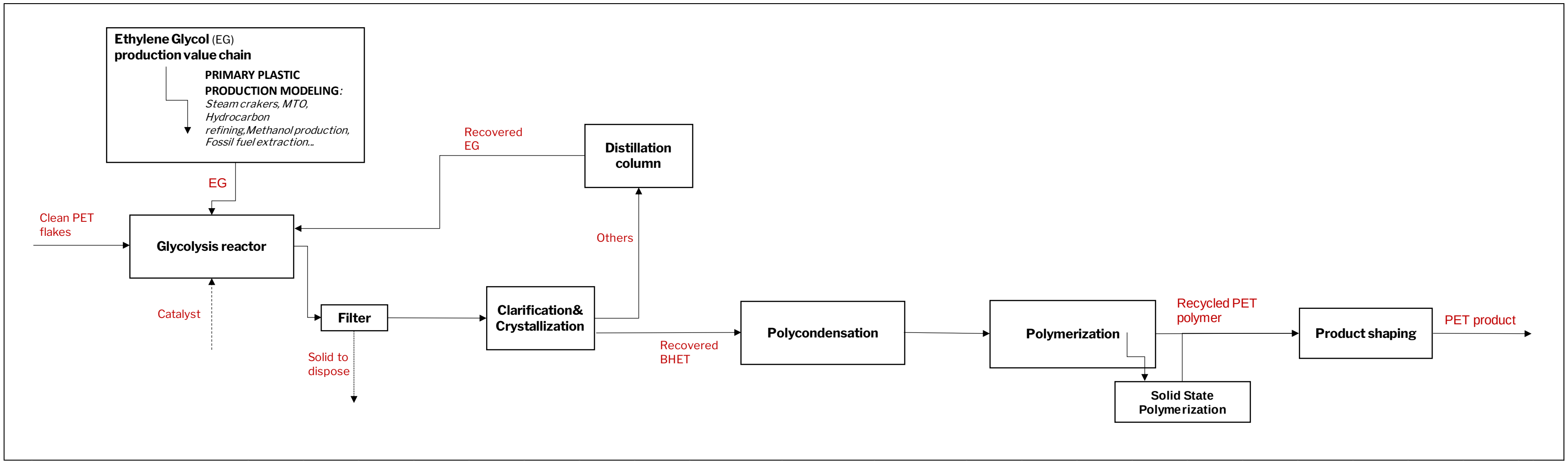
Supplementary Fig. S14. Polyethylene Terephthalate (PET) Enzymatic Hydrolysis Depolymerization: Production Value Chain and Material Flow Chart

Note: Detailed process conditions for polyethylene terephthalate (PET) enzymatic hydrolysis, including chemical reagents (NaOH, NaCl, and sulfuric acid), energy inputs, direct process emissions, and chemical production parameters are outlined in Materials and Methods sections b and c. Under optimal experimental conditions with minimal contamination, recovered purified terephthalic acid (PTA) is sufficient for producing one tonne of PET. However, real-world conditions may involve material losses throughout the recycling process, including collection and pretreatment stages, and contamination, resulting in lower recovery rates. Primary plastic production modeling details for ethylene glycol (EG), PTA production, PET polymerization, and product shaping are available in Karali et al. (1).



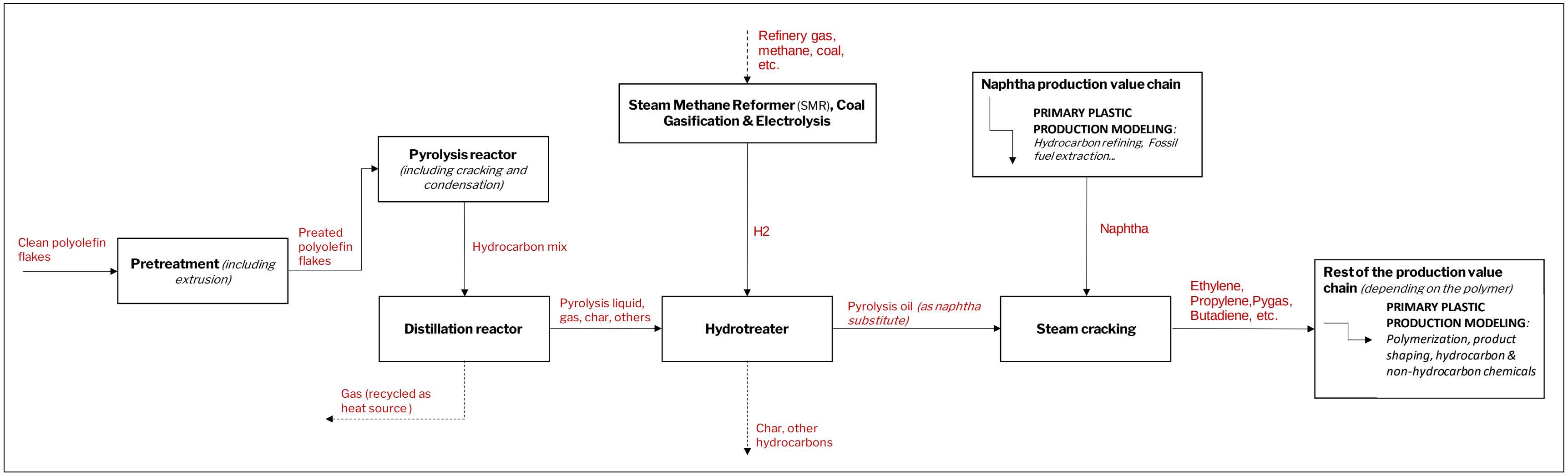
Supplementary Fig. S15. PET Methanolysis Depolymerization: Production Value Chain and Material Flow Chart

Note: Methanolysis process conditions, including chemical agents, energy requirements, direct process emissions, and catalyst production details (zinc (Zn) chloride and Zn acetate) are detailed in Materials and Methods sections b and c. Under ideal experimental conditions with minimal contamination, recovered dimethyl terephthalate (DMT) is adequate for producing one tonne of PET. However, real-world applications may experience material losses at each recycling stage, including preprocessing steps, and contamination, leading to reduced recovery rates. When recovery rates are insufficient, additional DMT is sourced from primary plastic production pathways. For comprehensive details on EG, PTA, and methanol production parameters, as well as PET polymerization and product shaping processes, refer to Karali et al. (1).



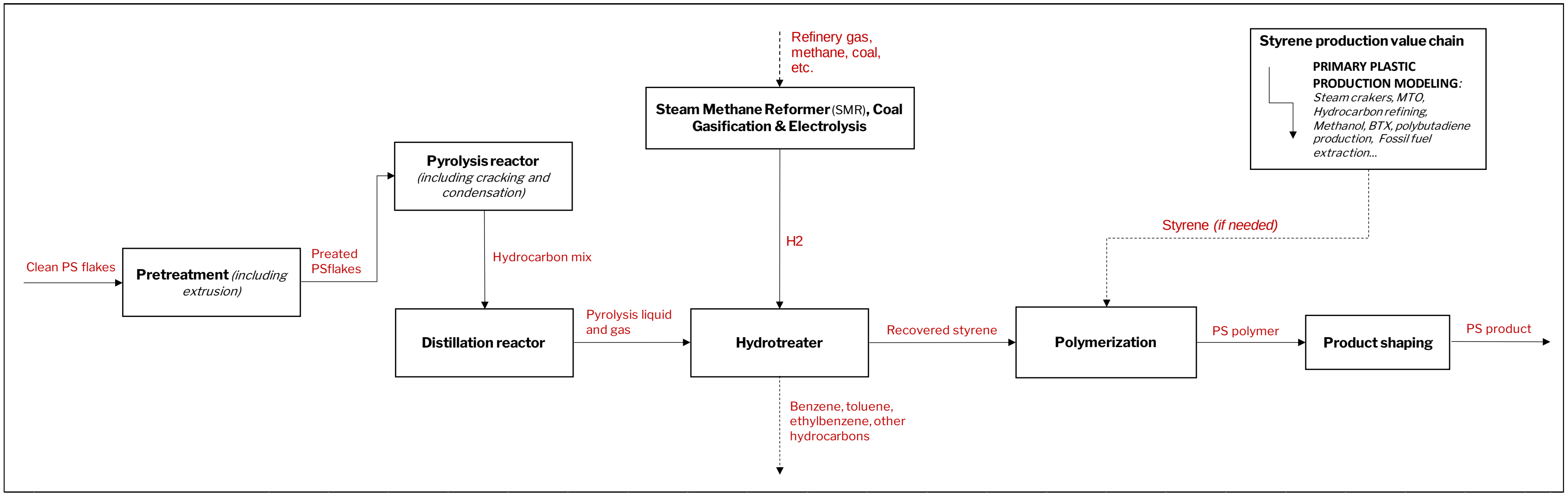
Supplementary Fig. S16. PET Glycolysis Depolymerization: Production Value Chain and Material Flow Chart

Note: Glycolysis process conditions are detailed in Materials and Methods sections b and c. Under controlled experimental conditions with minimal contamination, recovered bis(2-hydroxyethyl) terephthalate (BHET) is sufficient for producing one tonne of PET. However, practical applications may involve material losses throughout the recycling chain, including collection and pretreatment operations, and contamination, resulting in reduced recovery efficiencies. When recovery rates are inadequate, supplementary BHET is obtained through primary plastic production routes. Detailed parameters for EG and methanol production, PET polymerization, and product shaping are available in Karali et al. (1).



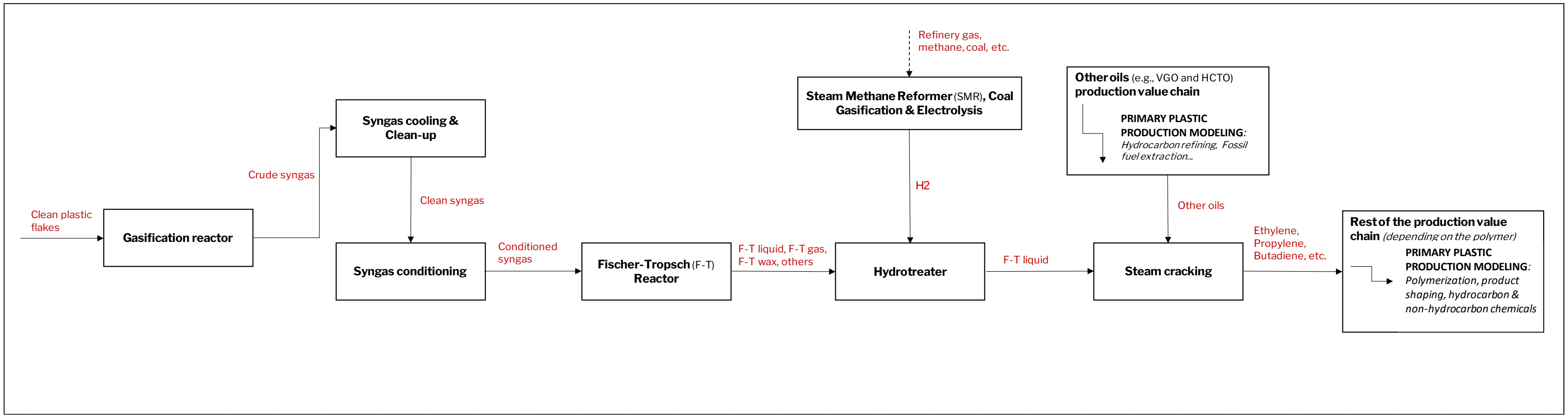
Supplementary Fig. S17. Polyolefin Pyrolysis: Production Value Chain and Material Flow Chart

Note: Pyrolysis process conditions, including energy inputs and direct process emissions, are specified in Materials and Methods sections b and c. For detailed parameters of subsequent production stages and hydrogen (H_2) production processes, refer to the primary plastic production modeling framework in Karali et al. (1).



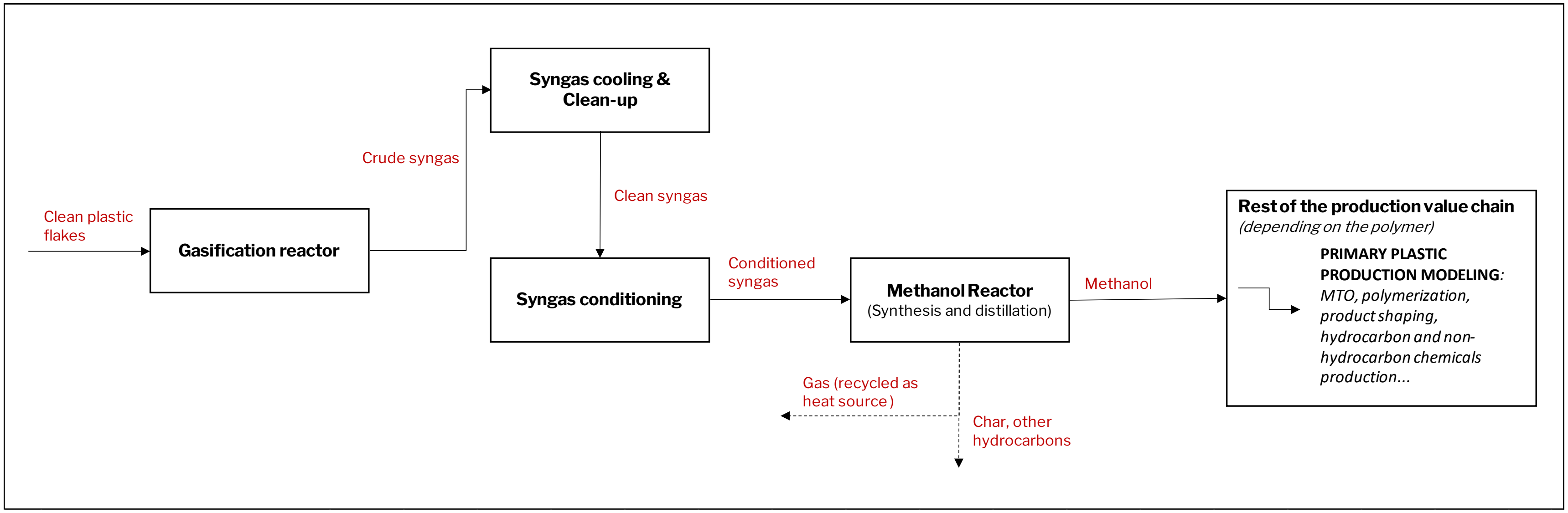
Supplementary Fig. S18. Polystyrene (PS) Pyrolysis: Production Value Chain and Material Flow Chart

Note: PS pyrolysis process conditions, including energy requirements and direct process emissions, are outlined in Materials and Methods section b. Under optimal experimental conditions with minimal contamination, recovered styrene monomer is sufficient for producing one tonne of PS. However, real-world operations may experience material losses throughout the recycling process, including preprocessing stages, and contamination, leading to reduced recovery yields. When recovery rates are insufficient, additional styrene is sourced from primary plastic production pathways. Comprehensive details on styrene and hydrogen production parameters, polymerization processes, and product shaping are available in Karali et al. (1).



Supplementary Fig. S19. Gasification with Fischer-Tropsch (F-T) Synthesis: Production Value Chain and Material Flow Chart

Note: Gasification F-T synthesis process conditions, including energy demands and direct process emissions, are detailed in Materials and Methods section b. For comprehensive information on hydrogen production parameters and subsequent production value chain stages, refer to the primary plastic production modeling in Karali et al. (1).



Supplementary Fig. S20. Gasification with Methanol Synthesis: Production Value Chain and Material Flow Chart

Note: Gasification methanol synthesis process conditions, including energy requirements and direct process emissions, are specified in Materials and Methods section b. Detailed parameters for subsequent production value chain stages are available in the primary plastic production modeling framework presented in Karali et al. (1).

b. Chemical recycling technologies parameter set and assumptions used in the modeling

The modeling and chemical scenario results are based on assumptions summarized in this section.

For solvent-based recycling, we employ the most commonly applied solvent and antisolvent pairs identified in the literature. Most studies on solvent-based recycling of polyethylene (PE), polypropylene (PP), and polyethylene terephthalate (PET) report a polymer concentration of 5% w/v from experimental investigations *(2)*, indicating 1 gram of polymer dissolved in 20 ml of solvent. However, some studies report higher concentrations of 10% w/v or 15% w/v *(3)*. This study applies a 10% w/v concentration with a ±30% sensitivity range for uncertainty analysis. For polyvinyl chloride (PVC), polystyrene (PS), and acrylonitrile butadiene styrene (ABS), polymer concentrations are directly adopted from the references listed in the corresponding tables, with the same ±30% sensitivity range applied. Detailed production information for solvents and antisolvents used in solvent-based recycling is provided in subsection c.

In this paper, "loss" is defined as the difference between the initial weight of the plastic feedstock and the weight of the recovered products after processing.

Supplementary Table S21. Modeling Parameters and Assumptions Applied in Solvent-Based LDPE/LLDPE Recycling

Polymer	LDPE/LLDPE		
		Sensitivity range	
Contamination level	<12%		*(3)*
MRF loss rate	5%	3-25%	
Recycling polymer recovery rate	98.9%	92-100%	*(2,3)*
Recycling solvent/non-solvent	Xylene/Hexane		
Recycling solvent/non-solvent amount (ml per gr waste polymer flake)	10ml/30ml	±30%	
Recycling solvent/non-solvent loss rate	3%	0-25%	
Material quality loss each recycling cycle	10%		*(3)*
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(4–6)*
MRF (incl., shredding, sorting, washing, drying) (GJ/tonne plastic bale)	3.84		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Dissolution/precipitation process (GJ/tonne recycled polymer)	0.6	±20%	*(5,6)*
Electricity (%)	90.0%		
Natural gas (%)	10.0%		
Solvent recovery (GJ/tonne recycled polymer)	1.0	±20%	
Electricity (%)	2.5%		
Natural gas (%)	8.5%		
Steam (%)	89.0%		
Non-solvent recovery (GJ/tonne recycled polymer)	1.0	±20%	
Electricity (%)	2.5%		
Natural gas (%)	8.5%		
Steam (%)	89.0%		

Extrusion (GJ/tonne recycled polymer)	5.30 for LDPE/4.72 for LLDPE		*(1)*
Process emissions (% of used amount)			
Xylene	0.005%		*(3)*
Hexane	0.005%		

Note: LDPE = low-density polyethylene, LLDPE = linear low-density polyethylene

Supplementary Table S22. Modeling Parameters and Assumptions Applied in Solvent-Based HDPE Recycling

Polymer	HDPE		
		Sensitivity range	
Contamination level	<10%		*(3)*
MRF loss rate	10%	5-25%	
Recycling polymer recovery rate	97.7%	92-100%	*(2,3)*
Recycling solvent/non-solvent	Xylene/Hexane		
Recycling solvent/non-solvent amount (ml per gr waste polymer flake)	10ml/30ml	±30%	
Recycling solvent/non-solvent loss rate	3%	0-25%	
Material quality loss each recycling cycle	6%		*(3)*
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(4–6)*
MRF (incl., shredding, sorting, washing, drying) (GJ/tonne plastic bale)	3.84		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Dissolution/precipitation process (GJ/tonne recycled polymer)	0.6	±20%	*(5,6)*
Electricity (%)	90.0%		
Natural gas (%)	10.0%		
Solvent recovery (GJ/tonne recycled polymer)	1.0	±20%	
Electricity (%)	2.5%		
Natural gas (%)	8.5%		
Steam (%)	89.0%		
Non-solvent recovery (GJ/tonne recycled polymer)	1.0	±20%	
Electricity (%)	2.5%		
Natural gas (%)	8.5%		
Steam (%)	89.0%		
Extrusion (GJ/tonne recycled polymer)	4.12		*(1)*
Process emissions (% of used amount)			
Xylene	0.005%		*(3)*
Hexane	0.005%		

Supplementary Table S23. Modeling Parameters and Assumptions Applied in Solvent-Based PP Recycling

Polymer	PP		
		Sensitivity range	
Contamination level	<12%		*(3)*
MRF loss rate	15.00%	8-25%	
Recycling polymer recovery rate	98.6%	92-100%	*(2,3)*
Recycling solvent/non-solvent	Xylene/Hexane		*(2,3)*
Recycling solvent/non-solvent amount (ml per gr waste polymer flake)	10ml/30ml	±30%	
Recycling solvent/non-solvent loss rate	3%	0-25%	*(3)*
Material quality loss each recycling cycle	10%		

Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(4–6)*
MRF (incl., shredding, sorting, washing, drying) (GJ/tonne plastic bale)	3.84		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Dissolution/precipitation process (GJ/tonne recycled polymer)	0.6	±20%	*(5,6)*
Electricity (%)	90.0%		
Natural gas (%)	10.0%		
Solvent recovery (GJ/tonne recycled polymer)	1	±20%	
Electricity (%)	2.5%		
Natural gas (%)	8.5%		
Steam (%)	89.0%		
Non-solvent recovery (GJ/tonne recycled polymer)	1	±20%	
Electricity (%)	2.5%		
Natural gas (%)	8.5%		
Steam (%)	89.0%		
Extrusion (GJ/tonne recycled polymer)	5.51		*(1)*
Process emissions (% of used amount)			
Xylene	0.005%		*(3)*
Hexane	0.005%		

Supplementary Table S24. Modeling Parameters and Assumptions Applied in Solvent-Based PET Recycling

Polymer	PET		
		Sensitivity range	
Contamination level	<4%		*(3)*
MRF loss rate	19.00%	7-37%	*(7)*
Recycling polymer recovery rate	98.8%	92-100%	*(2–4)*
Recycling solvent/non-solvent	Benzyl alcohol/Methanol		
Recycling solvent/non-solvent amount (ml per gr waste polymer flake)	10ml/30ml	±30%	
Recycling solvent/non-solvent loss rate	2%	0-25%	
Material quality loss each recycling cycle	6%		*(3)*
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(4–6)*
MRF (incl., shredding, sorting, washing, drying) (GJ/tonne plastic bale)	3.84		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Dissolution/precipitation process (GJ/tonne recycled polymer)	0.6	±20%	*(5,6)*
Electricity (%)	90.0%		
Natural gas (%)	10.0%		
Solvent recovery (GJ/tonne recycled polymer)	1	±20%	
Electricity (%)	1.0%		
Natural gas (%)	3.0%		
Steam (%)	96.0%		
Non-solvent recovery (GJ/tonne recycled polymer)	1	±20%	
Electricity (%)	1.0%		
Natural gas (%)	3.0%		
Steam (%)	96.0%		
Extrusion (GJ/tonne recycled polymer)	5.28		*(1)*

Process emissions (% of used amount)			
Benzyl alcohol	0.005%		*(3)*
Methanol	0.005%		

Supplementary Table S25. Modeling Parameters and Assumptions Applied in Solvent-Based PS Recycling

Polymer	PS		
		Sensitivity range	
Contamination level	<12%		*Assumed as in LDPE and PP*
MRF loss rate	15%	8-40%	*(8,9)*
Recycling polymer recovery rate	94.7%	92-100%	*(2,5)*
Recycling solvent/non-solvent	DCM/Methanol*		
Recycling solvent/non-solvent amount (ml per gr waste polymer flake)	20ml/10ml	±30%	
Recycling solvent/non-solvent loss rate	3%	0-25%	
Material quality loss each recycling cycle	10%		*Assumed as in LDPE and PP*
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(4–6)*
MRF (incl., shredding, sorting, washing, drying) (GJ/tonne plastic bale)	3.84		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Dissolution/precipitation process (GJ/tonne recycled polymer)	0.6	±20%	*(5,6)*
Electricity (%)	90.0%		
Natural gas (%)	10.0%		
Solvent recovery (GJ/tonne recycled polymer)	1	±20%	
Electricity (%)	2.0%		
Natural gas (%)	7.0%		
Steam (%)	91.0%		
Non-solvent recovery (GJ/tonne recycled polymer)	1	±20%	
Electricity (%)	2.0%		
Natural gas (%)	7.0%		
Steam (%)	91.0%		
Extrusion (GJ/tonne recycled polymer)	6.4		*(1)*
Process emissions (% of used amount)			
DCM*	0.005%		*Assumed as in PEs and PP*
Methanol	0.005%		*Assumed as in PEs and PP*

Note: DCM - Dichloromethane

Supplementary Table S26. Modeling Parameters and Assumptions Applied in Solvent-Based ABS Recycling

Polymer	ABS		
		Sensitivity range	
Contamination level	<12%		*Assumed as in LDPE and PP*
MRF loss rate	17%	8-40%	*(6)*
Recycling polymer recovery rate	81.0%	72-90%	
Recycling solvent/non-solvent	Acetone/Water		

Recycling solvent/non-solvent amount (ml per gr waste polymer flake)	20ml/8.3ml	±30%	
Recycling solvent/non-solvent loss rate	3%	0-25%	
Material quality loss each recycling cycle	10%		*(10)*
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(4–6)*
MRF (incl., shredding, sorting, washing, drying) (GJ/tonne plastic bale)	3.84		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Dissolution/precipitation process (GJ/tonne recycled polymer)	0.6	±20%	*(5,6)*
Electricity (%)	90.0%		
Natural gas (%)	10.0%		
Solvent recovery (GJ/tonne recycled polymer)	1	±20%	
Electricity (%)	2.0%		
Natural gas (%)	7.0%		
Steam (%)	91.0%		
Non-solvent recovery (GJ/tonne recycled polymer)	1	±20%	
Electricity (%)	2.0%		
Natural gas (%)	7.0%		
Steam (%)	91.0%		
Extrusion (GJ/tonne recycled polymer)	6.4		*(1)*
Process emissions (% of used amount)			
Acetone	0.005%		*Assumed as in PEs and PP*

Supplementary Table S27. Modeling Parameters and Assumptions Applied in Solvent-Based PVC Recycling

Polymer	**PVC**		
		Sensitivity range	
Contamination level	<1%		*Assumption based on discussions in (11,12)*
MRF loss rate	13%	6-30%	
Recycling polymer recovery rate	97.0%	92-100%	*(13)*
Recycling solvent/non-solvent	Cyclohexanone/Hexane		
Recycling solvent/non-solvent amount (ml per gr waste polymer flake)	6.67ml/53.3ml	±30%	
Recycling solvent/non-solvent loss rate	5% | 9%	0-25% | 0-40%	*(13,14)*
Material quality loss each recycling cycle	5%		*(11,12)*
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(4–6)*
MRF (incl., shredding, sorting, washing, drying) (GJ/tonne plastic bale)	3.84		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Dissolution/precipitation process (GJ/tonne recycled polymer)	0.6	±20%	*(5,6)*
Electricity (%)	90.0%		
Natural gas (%)	10.0%		
Solvent recovery (GJ/tonne recycled polymer)	1	±20%	
Electricity (%)	2.0%		
Natural gas (%)	7.0%		
Steam (%)	91.0%		

Non-solvent recovery (GJ/tonne recycled polymer)	1	±20%	
Electricity (%)	2.0%		
Natural gas (%)	7.0%		
Steam (%)	91.0%		
Extrusion (GJ/tonne recycled polymer)	5.57		*(1)*
Process emissions (% of used amount)			
Cyclohexanone	0.005%		*Assumed as in PEs and PP*
Hexane	0.005%		*Assumed as in PEs and PP*

Supplementary Table S28. Modeling Parameters and Assumptions Applied in PET enzymatic hydrolysis

Polymer	PET		
		Sensitivity range	
Contamination level	0%>		*(3)*
MRF loss rate	19.00%	7-37%	*(7)*
PTA recovery rate (from flake)	82.0%	67-97%	*(3,15)*
EG recovery rate (from flake)	50.0%	35-65%	
Recycling solvent	Water and enzyme		
NaOH and Sulfuric acid demand (kg/kg rPET flake)	1 kgNaOH/kgPETflake; 0.43 kgsulfuric acid/kgPETflake		
Recovered PTA and EG purity rate	98%	90-100%	
Material quality loss each recycling cycle	7%		*(3)*
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(4–6)*
MRF (incl., shredding, sorting, washing, drying) (GJ/tonne plastic bale)	3.84		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Pretreatment (incl., extrusion and cyro-grinding) (GJ/tonne PET flake)	7.55	±20%	*(3,15)*
Electricity (%)	100.0%		
Enzymatic depolymerization and product recovery (incl., clarification, crystallization, TPA and EG recovery) (GJ/tonne PET flake)	13.2	±20%	*(3,15)*
Electricity (%)	17.0%		
Steam (%)	83.0%		
Extrusion (GJ/tonne recycled polymer)	5.28		*(1)*

Supplementary Table S29. Modeling Parameters and Assumptions Applied in PET methanolysis

Polymer	PET		
		Sensitivity range	
Contamination level	<30%		*(3)*
MRF loss rate	19.0%	7-37%	*(7)*
DMT recovery rate (from flake)	85.0%	70-100%	*(3,16)*
EG recovery rate (from flake)	80.0%	65-95%	
Recycling solvent	Methanol		
Methanol and catalyst demand (kg/kg rPET flake)*	3 kg/kgPETflake; 0.0018kg /kgPETflake		*(3,17)*
Recovered DMT and EG purity rate	94.5% for DMT; 92.6% for EG	90-99% for DMT; 88-97% for EG	
Methanol loss rate	3%	0-25%	

Material quality loss each recycling cycle	-		*(3)*
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±40%	*(4–6)*
MRF (incl., shredding, sorting, washing, drying) (GJ/tonne plastic bale)	6.6	±40%	
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Pretreatment (incl. melt reactor) (GJ/tonne PET flake)	2	±20%	*(3,15)*
Electricity (%)	100.0%		
Catalyst synthesis (GJ/tonne catalyst)	6.79	±10%	*(15)*
Electricity (%)	100.0%		
Depolymerization and product recovery (incl., pre-melting catalyst synthesis, clarification, crystallization, TPA and EG recovery, sodium sulfate recovery) (GJ/tonne PET flake)	35.9	±20%	*(3,15,17)*
Electricity (%)	17.0%		
Steam (%)	83.0%		
Solvent (methanol) recovery (GJ/tonne recycled polymer)	1	±20%	*(5,15)*
Electricity (%)	2.0%		
Natural gas (%)	7.0%		
Steam (%)	91.0%		
Extrusion (GJ/tonne recycled polymer)	5.28		*(1)*
Process emissions (% of used amount)			
Methanol	0.005%		*(3)*

Note: Catalyst - ZN acetate. There is a direct relationship between the amount of methanol or enzymes used and monomer recovery rates (18). While reducing methanol use can lower emissions, it also decreases DMT recovery, resulting in limited overall emissions impact.

Supplementary Table S30. Modeling Parameters and Assumptions Applied in PET glycolysis

Polymer	PET		
		Sensitivity range	
Contamination level	<30%		*(3)*
MRF loss rate	19.0%	7-37%	*(7)*
BHET recovery rate (from flake)	89.0%	75-100%	*(3,17)*
Recycling solvent	EG		
EG demand (kg/kg rPET flake)	0.23 kg/kgPETflake		*(3,17)*
Recovered BHET purity rate	98% (colored)	90-100%	
EG loss rate	18%	10-25%	
Material quality loss each recycling cycle	8%		*(3,19)*
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±40%	*(4–6)*
MRF (incl., shredding, sorting, washing, drying) (GJ/tonne plastic bale)	6.6	±40%	
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Glycolysis (incl., clarification, crystallization, and EG recovery) (GJ/tonne BHET recovered)	9.5	±20%	*(3,15,19)*
Electricity (%)	10.0%		
Steam (%)	90.0%		
Extrusion (GJ/tonne recycled polymer)	5.28		*(1)*

Supplementary Table S31. Modeling Parameters and Assumptions Applied in Pyrolysis of Polyolefins*

Polymer	**Polyolefins***		
		Sensitivity range	
Contamination level	0%>		*Assumption based on discussions in (5,20,21)*
Pretreatment loss rate	15.00%	8-25%	*(15,20,21)*
Pyrolysis process loss	25.0%	15-35%	*(15)*
Recycling pyrolysis oil recovery rate	50.0%	40-70%	*(22–24)*
Pyrolysis oil to virgin naphtha replacement ratio in steam craking unit (i.e., X% pyrolysis oil and 1-X% virgin naphtha)	5%	0.5-20%	*(3,25,26)*
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(4–6)*
Pretreatment (incl., shredding, extensive sorting, washing, drying, pelletizing) (GJ/tonne plastic bale)**	7.11		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Thermal Pyrolysis reactor (incl. cracking and condensation) (GJ/tonne plastic flake)	17.53	±20%	*(27)*
Electricity (%)	9.0%		
Pyrolysis oil (%)	63.0%		
Steam (%) (from pyrolysis gas)	28.0%		
Direct emissions to the air (kg/t recycled pyrolysis oil)			
CO_2	870		*(22)*
CO	1.7		
NO_x	0.47		
SO_x	0.00045		

*Note: * Polyolefins include LDPE, LLDPE, HDPE, and PP in this analysis. ** It is assumed that most waste that goes to plastic pyrolysis is collected as mixed waste. Thus, extensive sorting is required to avoid equipment damage.*

Supplementary Table S32. Modeling Parameters and Assumptions Applied in Pyrolysis of PS

Polymer	**PS**		
		Sensitivity range	
Contamination level	0%>		*Assumption based on discussions in (15,20,21)*
Pretreatment loss rate	15.0%	5-40%	*(15,20,21)*
Pyrolysis process loss	25.0%	15-35%	*(15)*
Recycling styrene recovery rate	59.0%	40-70%	*(28–30)*
Pyrolysis styrene to virgin styrene replacement ratio (i.e., X% pyrolysis styrene and 1-X% virgin styrene)	98.0%	80-100%	
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(4–6)*
Pretreatment (incl., shredding, extensive sorting, washing, drying) (GJ/tonne plastic bale)*	7.11		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Thermal Pyrolysis reactor (incl. cracking and condensation) (GJ/tonne plastic flake)	11.34	±20%	*(27,28)*
Electricity (%)	9.0%		
Pyrolysis oil (%)	63.0%		
Steam (%) (from pyrolysis gas)	28.0%		

Emissions to the air (kg/t recycled styrene)			
CO	2.0		*(3)*
NO_x	0.6		
SO_x	0.0005		

*Note: * It is assumed that most waste that goes to plastic pyrolysis is collected as mixed waste. Thus, extensive sorting is required to avoid equipment damage.*

Supplementary Table S33. Modeling Parameters and Assumptions Applied in Gasification and F-T synthesis of mixed plastics of (Polyolefins, PET, and PS)

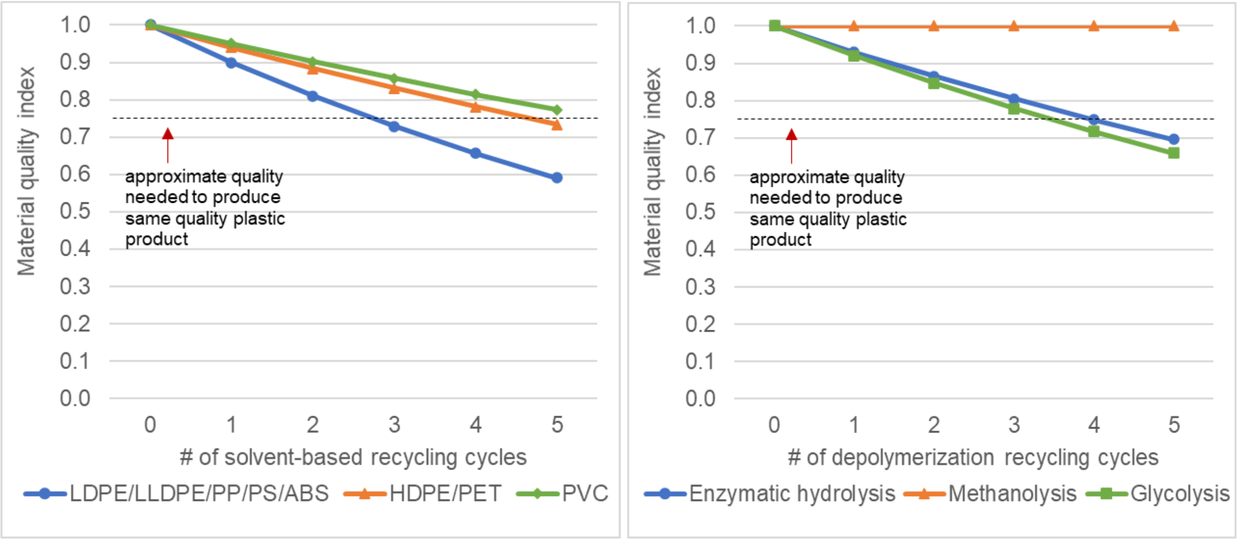
Polymer	Mixed plastic of L(L)DPE, HDPE, PP, PET, PS		
		Sensitivity range	
Contamination level	0%>		*Assumption based on discussions in (15,20,21)*
Pretreatment loss rate	25.0%	10-40%	*(15,20,21)*
Recycling syngas recovery rate	187.0%	175-200%	*(31,32)*
F-T liquids/plastic flake (kg/kg plastic flake)	0.25		*(33)*
F-T liquids to virgin naphtha replacement ratio in steam cracking unit (i.e., X% F-T liquids and 1-X% virgin naphtha)	95.0%	85-100%	*(3)*
Oxygen/plastic waste (no PS in the mix) (kg/kg plastic waste)	0.87		*(31,32,34)*
Oxygen/plastic waste (PS in the mix) (kg/kg plastic waste)	0.84		
Catalytic powder/plastic waste (kg/kg plastic waste)	0.05		
Nitrogen/plastic waste (kg/kg plastic waste)	0.40		
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(27)*
Pretreatment (incl., sorting, washing, drying, extrusion, pelletizing, milling) (GJ/tonne plastic bale)*	7.25		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Gasification reactor (incl. including cooling and clean up, light hydrocarbon treatment) (GJ/tonne plastic bale)**	4.75	±20%	*(31,32)*
Electricity (%)	42.5%		
Process tars (%)	0.0%		
Process char (%)	0.0%		
Steam (%) (from process gas)	57.5%		
Syngas conditioning (incl. compression and water gas shift) (GJ/tonne plastic bale)	3.14	±20%	*(31)*
Electricity (%)	73.0%		
Steam (%) (from process gas)	27.0%		
Fischer-Tropsch synthesis (GJ/tonne liquids recovered)	144.5	±20%	*(35)*
Steam (%) (from process gas)	100.0%		
Emissions to the air (kg CO2/t plastic waste)			
Flue gas CO_2	0.84		*(31,32,34)*
Syngas conditioning CO_2 (no PS)	0.79		
Syngas conditioning CO_2 (with PS)	0.95		

*Note: * The pretreatment process for gasifying plastic waste shares some similarities with a Materials Recovery Facility (MRF) process, but also has distinct differences. Both involve initial sorting and processing of materials, but gasification pretreatment focuses on preparing plastic for a thermal process, while MRFs prioritize material recovery. The pretreatment* *for gasification involves additional steps such as pelletizing, rinsing, milling, and drying plastics to ensure they are suitable for efficient gasification, which converts them into synthesis gas (syngas) for use as fuel or chemical feedstock (36).* It is also assumed that most waste that goes to plastic gasification is collected as mixed waste. Metallic contaminants and other solids should be removed before the gasification chamber. Thus, extensive sorting is required to avoid equipment damage. ** *Pyrolysis of plastic generally consumes more energy than gasification because pyrolysis requires higher temperatures and is typically conducted in the absence of oxygen, leading to a more energy-intensive process for achieving the desired thermal cracking of polymers (37). Gasification, while also involving high temperatures, can be more self-sufficient as the partial oxidation process generates some energy from the feedstock, while pyrolysis relies more heavily on external energy sources to reach the necessary temperatures.*

Supplementary Table S34. Modeling Parameters and Assumptions Applied in Gasification and methanol synthesis of mixed plastics of (Polyolefins, PET, and PS)

Polymer	Mixed plastic of L(L)DPE, HDPE, PP, PET, PS		
		Sensitivity range	
Contamination level	0%>	0%>	*Assumption based on discussions in (15,20,21)*
MRF loss rate	25.0%	10-40%	*(15,20,21)*
Recycling syngas recovery rate	187.0%	175-200%	*(31,32)*
Methanol/ plastic flake (kg/kg plastic flake)	0.45		*(34)*
Methanol recovered to virgin methanol replacement ratio	100.0%		*(3)*
Oxygen/plastic waste (no PS in the mix) (kg/kg plastic waste)	0.87		*(31,32,34)*
Oxygen/plastic waste (PS in the mix) (kg/kg plastic waste)	0.84		
Catalytic powder/plastic waste (kg/kg plastic waste)	0.05		
Nitrogen/plastic waste (kg/kg plastic waste)	0.40		
Energy consumption (GJ/tonne)			
Collection (GJ/tonne plastic bale)	0.87	±20%	*(27)*
Pretreatment (incl., sorting, washing, drying, extrusion, pelletizing, milling) (GJ/tonne plastic bale)*	7.25		
Electricity (%)	98.5%		
Natural gas (%)	1.5%		
Gasification reactor (incl. including cooling and clean up, light hydrocarbon treatment) (GJ/tonne plastic bale)	4.75	±20%	*(31,32)*
Electricity (%)	42.5%		
Process tars (%)	0.0%		
Process char (%)	0.0%		
Steam (%) (from process gas)	57.5%		
Syngas conditioning (incl. compression and water gas shift) (GJ/tonne plastic bale)	3.14	±20%	*(31)*
Electricity (%)	73.0%		
Steam (%) (from process gas)	27.0%		
Methanol synthesis and distillation (GJ/tonne methanol recovered)	14.0	±20%	*(35)*
Electricity (%)	100.0%		
Emissions to the air (kg CO2/t plastic waste)			
Flue gas CO_2	0.84		*(31,32,34)*
Syngas conditioning CO_2 (no PS)	0.79		
Syngas conditioning CO_2 (with PS)	0.95		

*Note: * Same as Supplementary Table S33.*

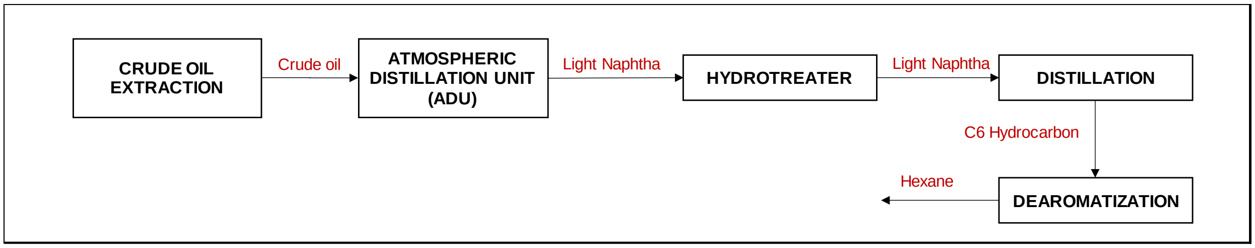


Supplementary Fig. S21. Material quality degradation of the solvent-based and depolymerization recycled polymers assumed in this analysis
Note: Material quality index 1.0 represents 100% quality.
Source: (3)

c. Chemical agents' production

Hexane

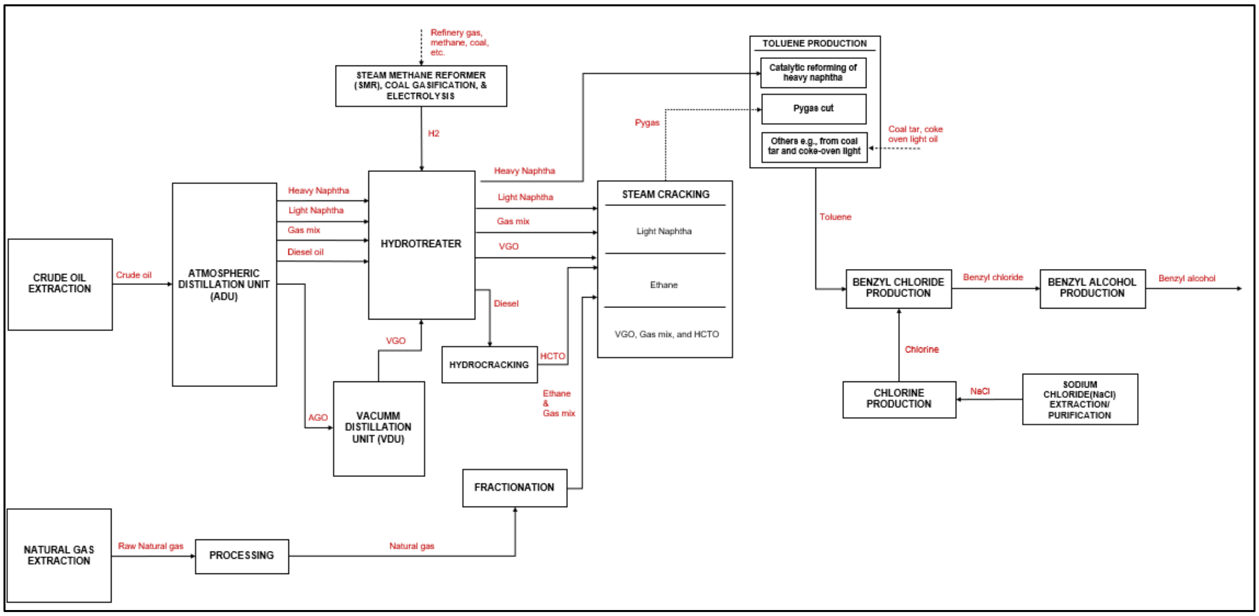
Hexane is an organic solvent that is classified as a straight-chain neutral aliphatic hydrocarbon *(38)*. It is a colorless, volatile petroleum distillate that is relatively insoluble in water and is present as a minor component of gasoline. Because of its low water solubility and volatility, it would have a propensity to migrate to the atmosphere following an environmental release. Hexane is generally produced from naphtha, one of the lightest fractions obtained directly from petroleum refining. In this study, we assume an average unit energy consumption of 0.94 GJ per tonne hexane.



Supplementary Fig. S22. Hexane production value chain and material flow chart
Note: A C6 hydrocarbon is an organic compound composed of six carbon atoms and associated hydrogen atoms. Examples include hexane, cyclohexane, and other isomers or derivatives with six carbon atoms.

Benzyl alcohol

Benzyl alcohol is an aromatic alcohol that consists of benzene. It is commonly used as a solvent in inks, paints, glues, and resins, in household cleaners and detergents *(39)*. Benzyl alcohol is produced industrially from toluene via benzyl chloride, which is hydrolyzed via alkaline hydrolysis (e.g., with sodium hydroxide). Another route is hydrogenation of benzaldehyde *(40)*. There is not any information in the literature regarding how much of benzyl alcohol is from hydrolysis of benzyl chloride vs hydrogenation of benzaldehyde. In this study, we assume that 100% of benzyl alcohol comes from hydrolysis of benzyl chloride as it is the most common one and the global average unit energy consumption for this process is 12.5 GJ per tonne benzyl alcohol *(41)*. We also assume a production ratio of 1.18 tonnes benzyl chloride per tonne benzyl alcohol, based on *(42)*.



Supplementary Fig. S23. Benzyl Alcohol production value chain and material flow chart

Benzyl chloride

Benzyl chloride is prepared industrially by the gas-phase photochemical reaction of toluene with chlorine. When producing benzyl chloride from toluene, the typical input ratio is roughly 0.9 kg of toluene and 1.43 kg of chlorine per 1.0 kg of benzyl chloride produced *(43)*. The energy consumption for benzyl chloride production is typically around 10-15 MJ/kg depending on the specific manufacturing process, raw materials used, and efficiency of the production facility *(43)*. In this study, we assume an average unit energy consumption of 10GJ per tonne benzyl chloride.

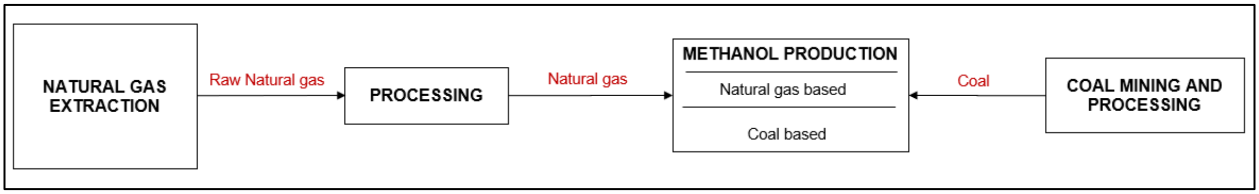
Methanol

Methanol is produced traditionally from natural gas in regions other than China, where its production is dominated by coal. Currently, about 55% of global methanol production is based on coal feedstock and about 35% on natural gas, with the rest using coke gas and other feedstocks *(1)*. In this study, it is assumed that the share of feedstocks other than natural gas, coal, and coke gas is negligible. Methanol production from coal has significantly higher energy consumption (~24 GJ/t methanol) compared to methanol from natural gas (~14 GJ/t methanol) *(1)*. In addition, methanol production has significantly low conversion efficiency, ranging from

67-75% for natural gas to methanol, and 48-61% for coal to methanol *(1)*. Please see Karali et al. *(1)* for more details of methanol production.

Supplementary Table S35. Methanol production conversion efficiency by feedstock assumed in this analysis

	Natural gas	Coal	Coke gas
Process conversion efficiency	71%	55%	55%



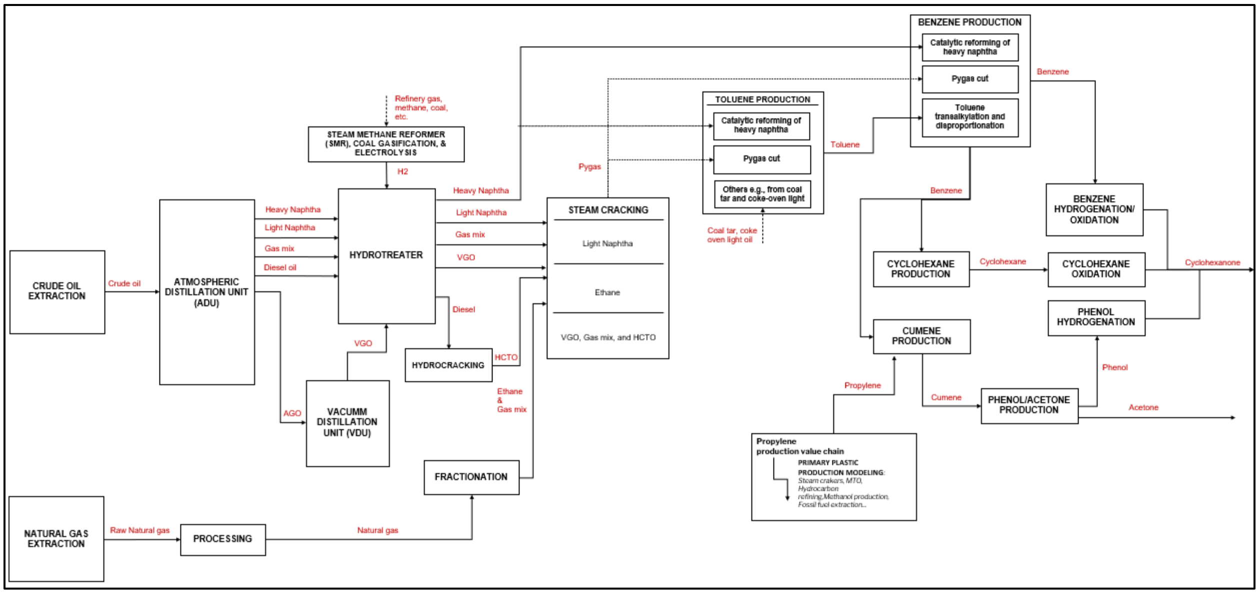
Supplementary Fig. S24. Methanol production value chain and material flow chart

Cyclohexanone

Cyclohexanone is a synthetic organic liquid used primarily as an intermediate in the production of nylon. Other minor applications are as an intermediate, additive and solvent in a variety of products. The industrial production is achieved by three routes: cyclohexane oxidation, phenol hydrogenation, and conversion of benzene into cyclohexanone *(44)*. Among the various these processes, cyclohexane oxidation technique is the most widely used in industry, because of its relatively low cost. The typical yield of cyclohexanone from cyclohexane oxidation is relatively low, usually around 8-10% conversion *(45)*. The oxidation of cyclohexane to cyclohexanone requires a significant amount of energy due to the harsh conditions typically needed for this reaction, including high temperatures and pressures. Energy consumption from this process is typically around 2-3 MJ/kg depending on the specific process used, with some studies indicating a net energy consumption closer to 0.7 MJ/kg produced cyclohexanone *(45)*. Production of cyclohexanone from phenol requires about 3.4 MJ per kg product *(46)*. A typical cyclohexanone yield can range from around 80% to over 95% depending on the specific catalyst, reaction conditions, and optimization techniques used.

Supplementary Table S36. Market share and energy demand of cyclohexanone production per process assumed in this analysis

	Cyclohexane oxidation	Phenol hydrogenation	Others
Global market share (%)	65%	30%	5%
Global average energy intensity (GJ/tonne)	1.6 GJ/tonne	3.4 GJ/tonne	0.7 GJ/tonne
Input demand (tonne/tonne)	11.1 tonne Cyclohexane/tonne Cyclohexanone	1.14 tonne Phenol/tonne Cyclohexanone	



Supplementary Fig. S25. Cyclohexanone production value chain and material flow chart

Cyclohexane

Cyclohexane has been primarily (about 80% to 85%) manufactured by the catalytic hydrogenation of benzene, which can be carried out in both liquid and gaseous phases, in the presence of different metal-based catalysts *(47)*. This process is considered relatively energy-intensive due to the need for high pressure and temperature conditions to overcome the stability of benzene's aromatic ring. Approximately 0.93 kg of benzene is needed per kg of cyclohexane produced theoretically *(47)*. In industrial practice, the actual ratio is typically higher (around 1.02-1.07 kg benzene/kg cyclohexane). We use a ratio of 0.93 kg of benzene per tonne cyclohexane in this study. Because other methods, e.g., fractionation of naphtha, have a very small share in cyclohexane production, we assume that cyclohexane is produced only from benzene in this study.

Phenol

The dominant process for production of phenol proceeds via cumene and cumene hydroperoxide. Benzene and propylene are alkylated to obtain cumene, which in turn is oxidized to form cumene hydroperoxide *(48)*. The hydroperoxide is cleaved using an acid catalyst to form phenol and acetone. Acetone is mostly produced as a byproduct of phenol production using the cumene process (~90%). One kilogram of phenol production results in about 0.6 kg of acetone or about about 0.40 to 0.45 kg of acetone per kilogram of cumene used *(49)*. Phenol from cumene average energy consumption used in this study is 13.62 GJ/tonne, which is based on IEA *(50)*.

Cumene

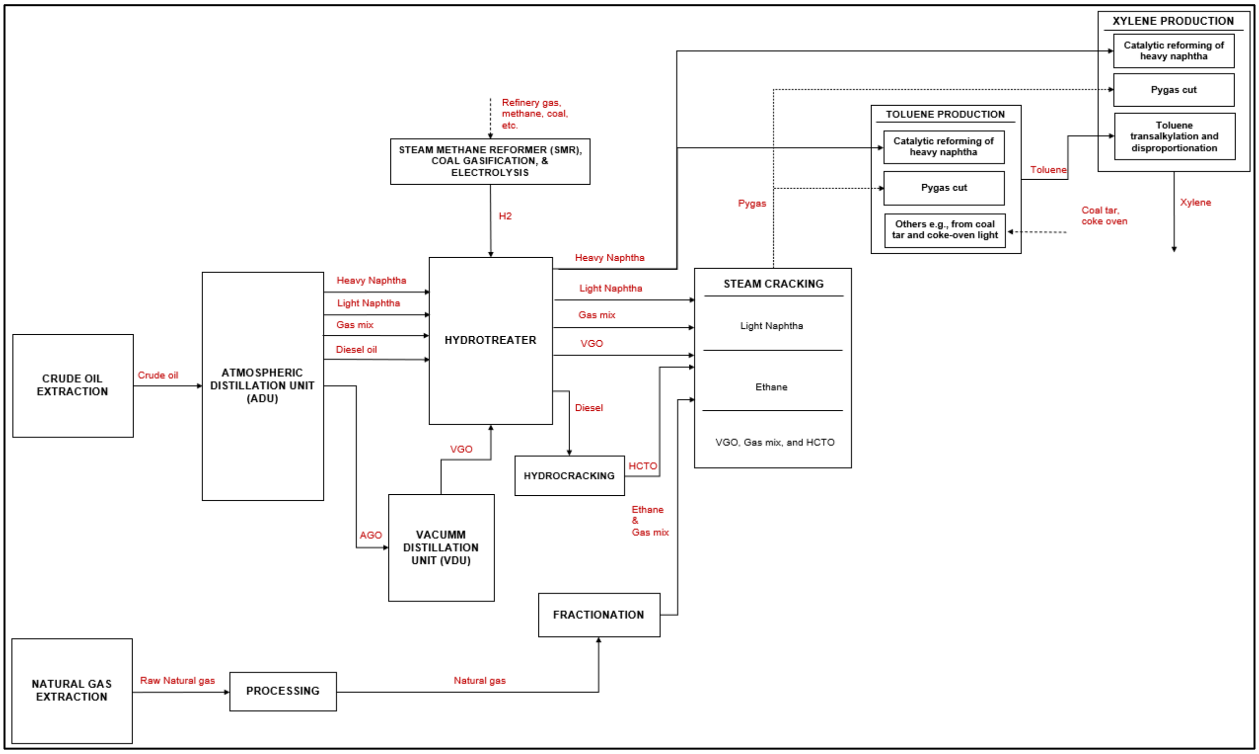
Cumene is produced commercially through the alkylation of benzene with propylene (7:1 molar ratio) over an acid catalyst. This catalytic alkylation of benzene using propylene currently accounts for 98% of all global production *(51)*. Over the years, many different catalysts have been proposed for this alkylation reaction, including boron trifluoride, hydrogen fluoride, aluminum chloride, and phosphoric acid. Cumene yield is limited to about 95% with average energy consumption of 3.8 GJ/tonne cumene *(52)*.

Benzene, Toluene, and Xylene (BTX)

Approximately 50% of the global benzene supply comes from the catalytic reforming of heavy naphtha, followed by toluene-based processes at 25%, and pygas cut at 25% *(1)*. Approximately 70% of the global toluene supply comes from the catalytic reforming of heavy naphtha, followed by pygas cut at 25%, and other materials at 5% *(1)*. Globally, most xylene (~79%) is produced by catalytic reforming of heavy naphtha. Approximately 17% is produced by toluene-based processes, followed by about 4% from pygas cut *(1)*. Pygas is a highly aromatic intermediate hydrocarbon produced by the steam cracking of light naphtha and VGO along with ethylene, propylene, and butadiene. It is often used as a highly aromatic hydrocarbon feedstock for the aromatic extraction of benzene, toluene, and xylene from a pyrolytic cracking process called "pygas cut." Supplementary Table S18 shows the process yields and unit energy consumptions of production technologies used to produce benzene, toluene, and xylene, along with the data assumed in this analysis. Please refer to Karali et al. *(1)* for more detailed description and data.

Supplementary Table S37. BTX yields and unit energy consumption from different production processes assumed in this analysis

	Yield (%)	Energy intensity (GJ/tonne product)
Benzene		
Catalytic reforming	5.7%	4.1 GJ/tonne benzene
Transalkylation and disproportionation of toluene	42%	4.5 GJ/tonne benzene
Pygas cut	33%	5.5 GJ/tonne benzene
Toluene		
Catalytic reforming	13-26%	2.2 GJ/tonne toluene
Pygas cut	19-20%	5.5 GJ/tonne toluene
Other materials e.g., coal tar and coke-oven light oil	18%	2.4 GJ/tonne toluene
Xylene		
Catalytic reforming	20%	14.7 GJ/tonne xylene
Transalkylation and disproportionation of toluene	97%	27.3 GJ/tonne p-xylene
Pygas cut	8%	14.1 GJ/tonne p-xylene

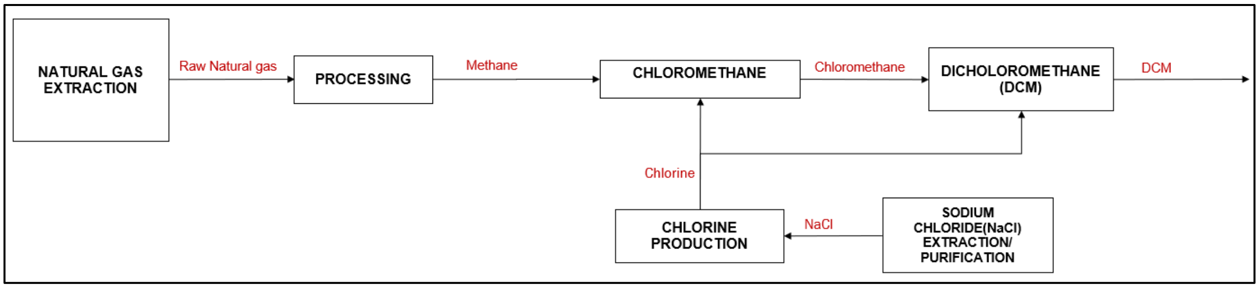


Supplementary Fig. S26. Xylene and Toluene production value chain and material flow chart

Dichloromethane (DCM)

DCM, commonly called methylene chloride, is a solvent that is widely used in chemical research and manufacturing. DCM is commonly produced by chlorination of methane with chlorine or by the chlorination of methanol with hydrogen chloride followed by chlorination of methyl chloride *(53)*. Although dichloromethane is the least toxic C1 chlorohydrocarbon, it does present hazards. Inhaling it can produce symptoms ranging from drowsiness to respiratory tract irritation and even death.

The energy demand for DCM production is significant, primarily due to the high temperature required for the chlorination reaction of methane or chloromethane, typically ranging between 400°C to 500°C, which necessitates a large amount of heat energy to initiate and sustain the chemical process; this is the main factor contributing to its energy-intensive production *(54)*. According to available data, the energy demand for dichloromethane (DCM) production is typically around 0.32 MJ/kg. Chlorine production is a very energy-intensive process, and the average energy intensity assumed in this analysis is 11.04 GJ/tonne chlorine, based on *(1)*. Supplementary Table S8 summarizes the input demand of the chloromethane production (i.e., chlorination of methane with chlorine) used in this analysis.



Supplementary Fig. S27. DCM production value chain and material flow chart

Supplementary Table S38. Input requirement of DCM production per process assumed in this analysis

	Input (kg/kg product)
Chloromethane/DCM	0.25
Chlorine/DCM	0.84
Chlorine/Chloromethane	2.0
Methane/Chloromethane	0.64

Sodium hydroxide (NaOH)

Sodium hydroxide is primarily produced through three electrolytic methods. Membrane cells use ion-exchange membranes to separate chlorine and sodium hydroxide streams, yielding high-purity NaOH (30% to 50%) with minimal salt contamination, making it ideal for sensitive industries *(55)*. Diaphragm cells, employing asbestos barriers, produce dilute NaOH requiring energy-intensive evaporation to reach 50% concentration *(56)*. Electrodialysis with bipolar membranes (EDBM) converts brine waste into HCl and NaOH. Membrane technology dominates modern production. Tables S35 and S36 summarizes the data used for NaOH production in this analysis.

Supplementary Table S39. Market share and energy demand of NaOH production per process assumed in this analysis

	Membrane	Diaphragm	EDBM
Global market share (%)	60%	20%	20%
Global average energy intensity (GJ/tonne)	8.9 GJ/tonne	8.2 GJ/tonne	10.3 GJ/tonne

Supplementary Table S40. Process output shares from electrolysis of NaCl assumed in this analysis

NaOH	50%
Chlorine (Cl_2)	47%
Others	3%

Source: (57)

Sulfuric acid

Sulfuric acid is produced mainly by the contact process, which begins with burning elemental sulfur or recovering sulfur dioxide (SO_2) from metallurgical off-gases or spent acid. The production is highly exothermic, allowing for energy recovery as high-pressure steam or electricity. Sulfuric acid is the world's most widely produced chemical, essential for fertilizers, explosives, dyes, petroleum refining, and many industrial processes. In this study, we assume an average unit energy consumption of 0.15 GJ per tonne sulfuric acid *(58)*.

Nitrogen and Oxygen

Nitrogen is produced industrially through methods such as cryogenic (fractional) distillation, pressure swing adsorption (PSA), and membrane separation. Overall, all three methods are energy intensive, especially for high-purity or large-volume applications. In this study, we assume an average unit energy consumption of 2 GJ per tonne nitrogen *(59)*.

Oxygen is produced industrially primarily through cryogenic air separation, a process that cools air to extremely low temperatures to liquefy it and then separates oxygen from nitrogen and other gases based on their different boiling points. This method is very energy intensive, typically requiring between 0.2 and 0.7 kilowatt-hours (0.72–2.5 MJ) of electricity per kilogram of oxygen produced *(59)*, mainly due to the energy needed for air compression, refrigeration, and distillation. In this study, we assume an average unit energy consumption of 1.3 GJ per tonne oxygen.

Supplementary Table S41. Shares of fuels used in production of chemicals, assumed in this analysis

	Electricity	Residual oil/VGO/heating oil	Natural gas	Refinery gas	Petroleum coke	Offsite steam
Hexane	4.5%	1.4%	26.0%	51.6%	12.7%	3.8%
Benzyl alcohol	4.5%	1.4%	26.0%	51.6%	12.7%	3.8%
Benzyl chloride	4.5%	1.4%	26.0%	51.6%	12.7%	3.8%
Cyclohexanone	14.0%		86.0%			
Phenol	6.0%		94.0%			
Acetone						
Cumene	2.0%					98.0%
Dichloromethane	45.0%		55.0%			
Sodium hydroxide	98.0%					2.0%
Sulfuric acid	100.0%					
Nitrogen	100.0%					
Oxygen	3.0%		97.0%			

Note: See Karali et al. (1) for methanol and BTX.

d. Collection modeling and assumptions

Supplementary Table S42. Production share and lifetime assumptions

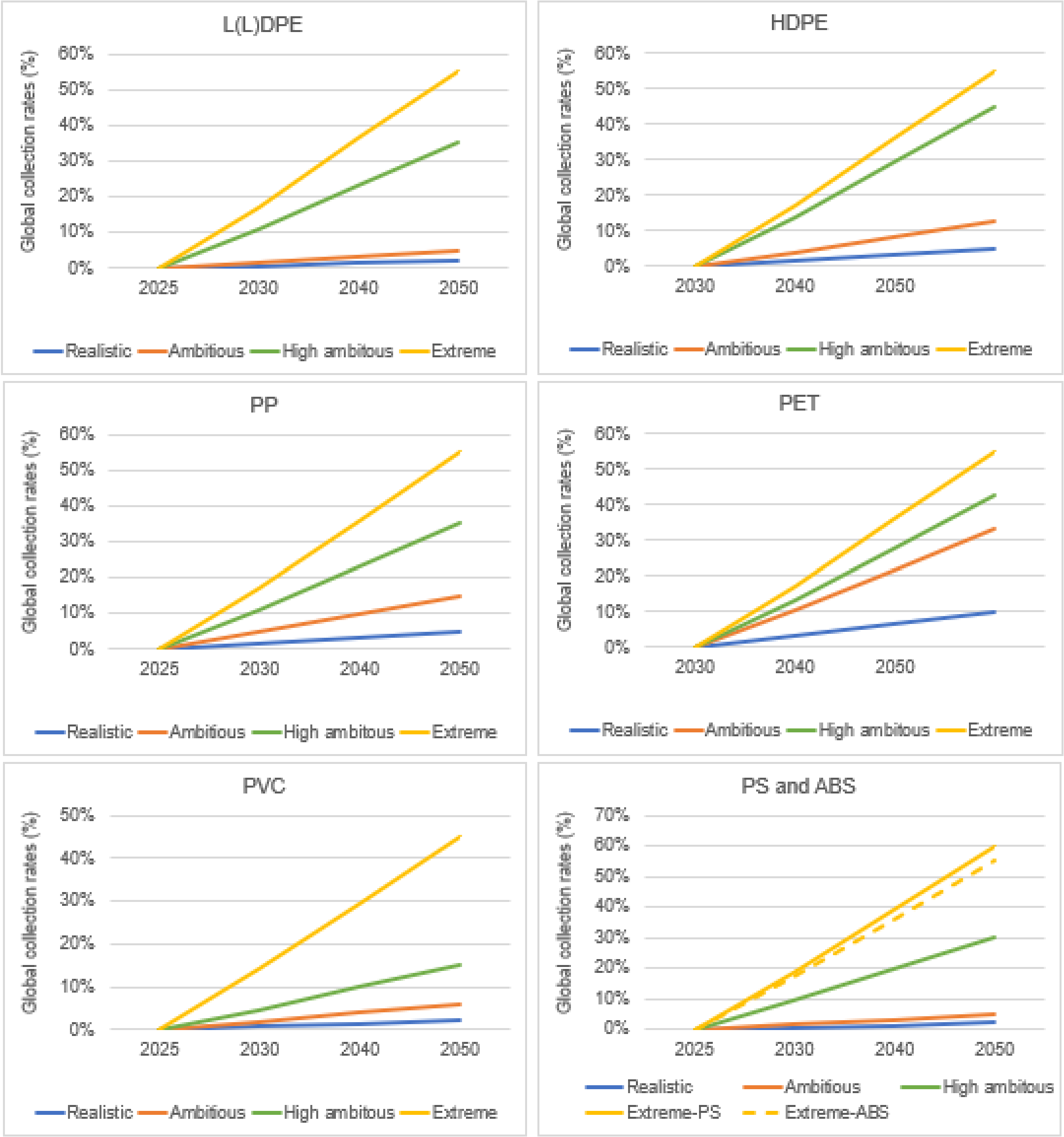
		Production share per application (%)	Lifetime assumption (years)
LDPE/ LLDPE	Construction	5%	10
	Consumer products	13%	2
	Electrical/electronic	3%	5
	Packaging	70%	0.25

	Vehicles	1%	15
	Others	8%	1.3
HDPE	Construction	19%	10
	Consumer products	11%	2
	Electrical/electronic	1%	5
	Packaging	56%	0.25
	Vehicles	5%	15
	Others	8%	3.3
PP	Construction	5%	10
	Consumer products	22%	2
	Electrical/electronic	5%	5
	Packaging	43%	0.25
	Vehicles	16%	15
	Fibers	8%	2.5
	Others	1%	3.9
PET	Packaging	66%	0.25
	Fiber	34%	2.5
PS	Construction	29%	10
	Consumer products	25%	2
	Electrical/electronic	8%	5
	Packaging	28%	0.25
	Others	10%	4.3
ABS	Construction	3%	10
	Consumer products	44%	2
	Electrical/electronic	27%	5
	Packaging	19%	0.25
	Others	7%	2.8
PVC	Construction	69%	10
	Consumer products	5%	2
	Electrical/electronic	3%	5
	Packaging	7%	0.25
	Vehicles	4%	15
	Others	12%	8.8

Note: Production share assumptions are based on (1).

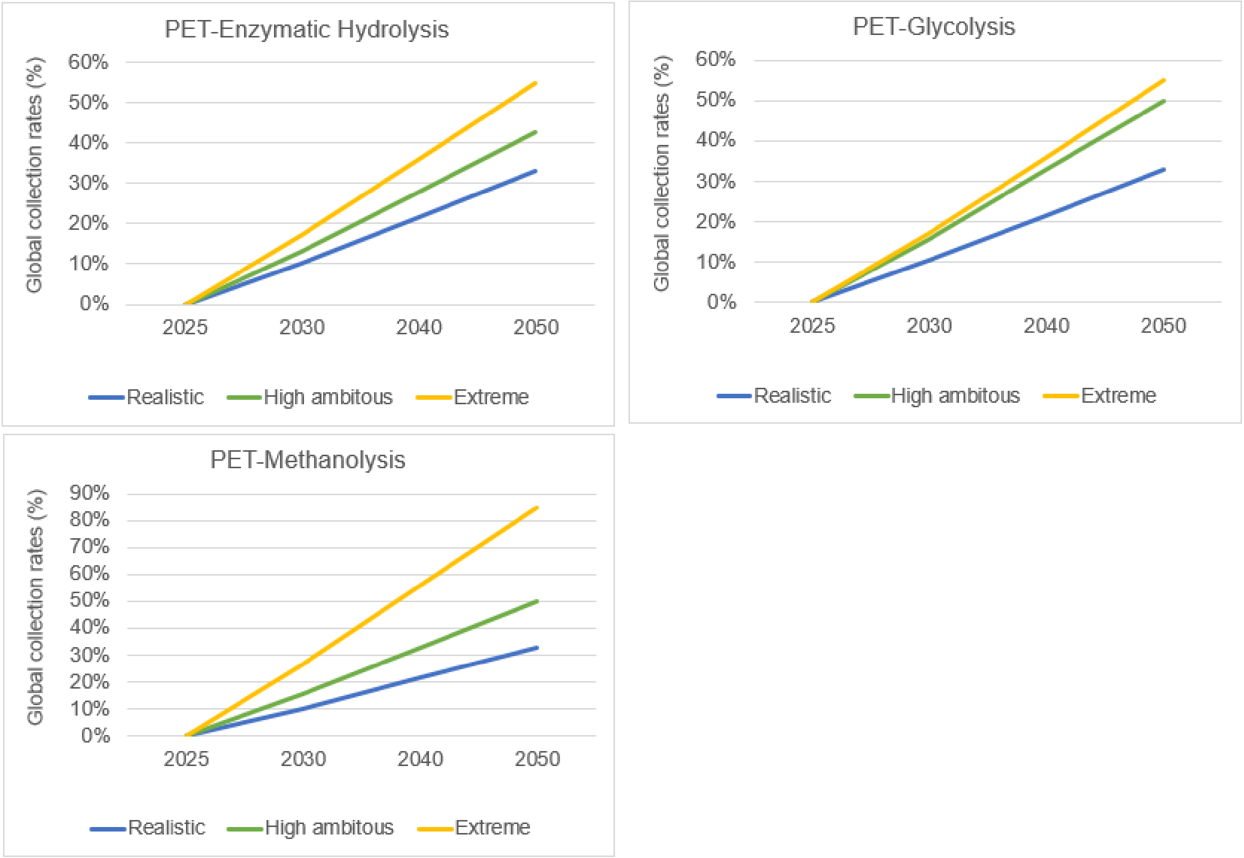
Collection scenarios through the modeling period

Collection scenarios are defined for the period 2025-2050, with all scenarios beginning at a collection rate of 0.1% in 2025.



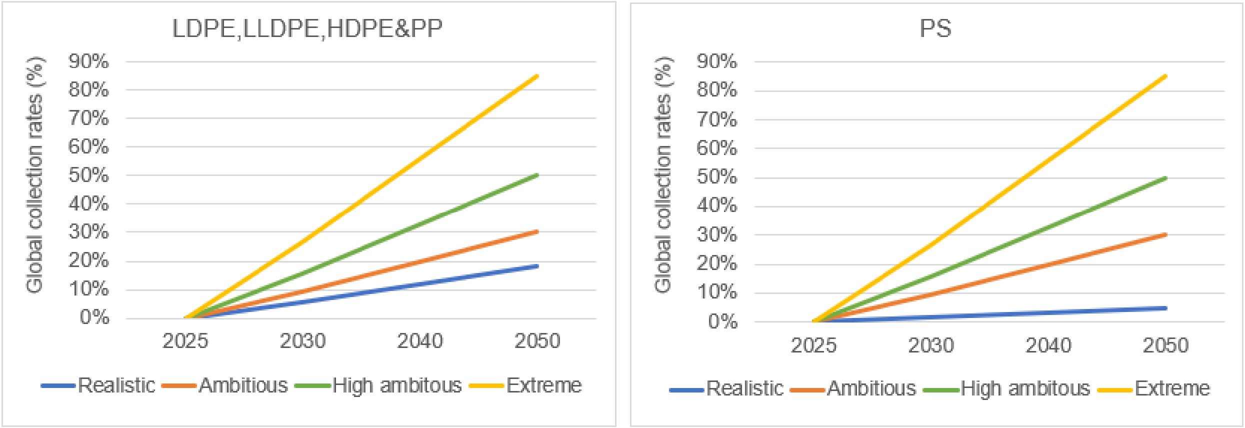
Supplementary Fig. S28. Collection rates assumed between 2025 and 2050 per polymer in the solvent-based recycling scenarios.

Note: y-scales are not uniform across charts.

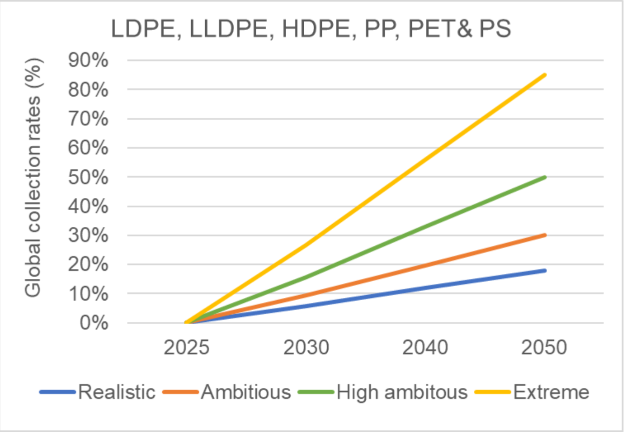


Supplementary Fig. S29. Collection rates assumed between 2025 and 2050 per polymer in the depolymerization scenarios

Note: y-scales are not uniform across charts.

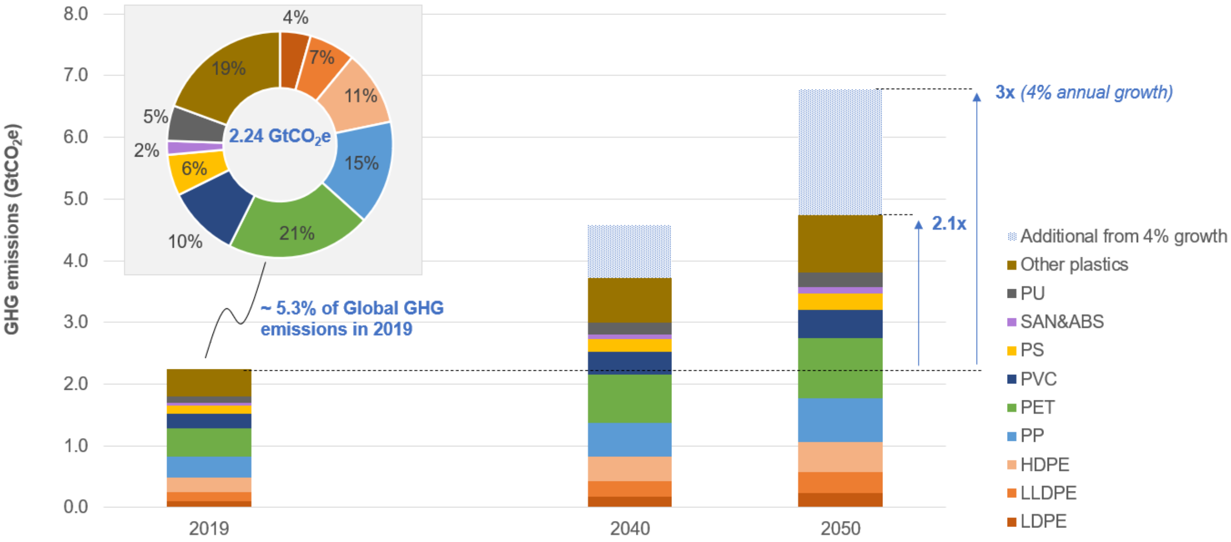


Supplementary Fig. S30. Collection rates assumed between 2025 and 2050 per polymer in the pyrolysis scenarios



Supplementary Fig. S31. Collection rates assumed between 2025 and 2050 in the gasification scenarios

e. Reference scenario GHG emissions



Supplementary Fig. S32. A. GHG emissions from primary plastic production by polymer type in 2019, 2040 and 2050

Notes: Projections are under the assumption that current production and consumption trends remain constant. SAN = Styrene Acrylonitrile.

Source: (1)

f. Other assumptions

Supplementary Table S43. Fuel combustion emission factors by fuel type assumed in this analysis

	Emission factor ($kgCO_2/GJ$)
Coal	94.6
Gas	56.1
Oil (gas, diesel, other)	73.3
Refinery gas	57.6

Petroleum coke	97.5
Coke oven gas	52.6
Residual fuel oil	77
Gasoline	69
Electricity	128
Offsite steam	56.1 (assumed as natural gas)

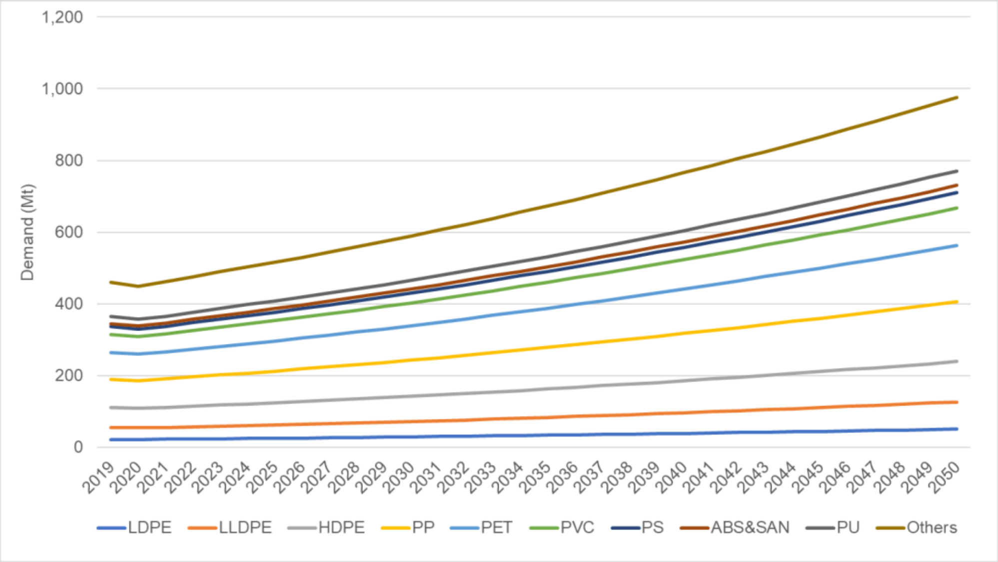
Source: (1)

Supplementary Table S44. Conversion factors to CO2 equivalents (CO_2e)

	Conversion factor to CO_2e
CH_4	29.8
CO	2.0
SO_2	0.44
NO_x	8.5
Xylene	16
Hexane	0.9
Benzyl Alcohol	0.9
Acetone	0.5
DCM	9.0
Cyclohexanone	0

In addition, fossil fuels (namely crude oil, natural gas, and coal) are used as feedstock and fuel energy sources of plastic production. The extraction of fossil fuels includes several activities: from exploration, through drilling, fracking, and mining, and then development, production and extraction, to surface processing and transport to refineries and/or processing facilities. Each of these activities causes emissions: direct emissions, like CH_4 leakage and flaring, along with emissions from fuel combustion. In this analysis, we assumed that

- 10.3 gCO_2e/MJ crude oil, (or 0.5 kg CO_2e/kg crude oil with an average heat value of 44.5 MJ/kg crude oil for unit GHG emissions of crude oil production),
- 13.3 gCO_2e/MJ natural gas, (or 0.7 kg CO_2e/kg natural gas with an average heat value of 50 MJ/kg natural gas for unit GHG emissions of natural gas production, and
- 0.2 kg CO_2e/kg coal for unit GHG emissions of coal production *(1)*.



Supplementary Fig. S33. Plastic demand between 2019 and 2050 per polymer type, assumed in the 2.5% annual growth scenario.

Note: 'Mt' refers to Million tonnes. Source: (1)

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