

S Supporting Information

Heat, electricity, or transportation? The optimal use of residual and waste biomass in Europe from an environmental perspective

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S.1 Bioenergy technologies data

Table S-1: Bioenergy technology data

Bioenergy technology description	Energy service output per MJ biomass input			LCIA results									
	Heat	Electricity	Transportation	IPCC GWP 100a	Recipe single score	Ozone depletion	Human toxicity	Photochemical oxidant formation	Particulate matter formation	Terrestrial acidification	Freshwater eutrophication	Terrestrial ecotoxicity	CED, non-renewable, fossil
	MJ	MJ	pkm	kg CO2 eq	Pt	kg CFC-11 eq	kg 1,4-DB eq	kg NMVOC	kg PM10 eq	kg SO2 eq	kg P eq	kg 1,4-DB eq	MJ eq
Forest energy wood													
Heat, at wood heater 6kW	0.75	-	-	4.92E-03	3.30E-03	2.43E-10	3.84E-02	3.03E-04	1.61E-04	1.10E-04	3.42E-06	3.73E-04	3.32E-02
Heat, at furnace 15kW	0.82	-	-	1.26E-02	2.42E-03	8.45E-10	2.69E-02	1.24E-04	6.25E-05	9.71E-05	1.01E-05	1.62E-04	1.44E-01
Heat, at furnace 30kW	0.68	-	-	4.21E-03	2.85E-03	2.86E-10	3.90E-02	1.72E-04	7.49E-05	8.74E-05	3.88E-06	3.73E-04	3.70E-02
Heat, at furnace 30kW	0.68	-	-	4.30E-03	2.64E-03	3.00E-10	3.90E-02	1.72E-04	7.53E-05	8.82E-05	3.88E-06	3.73E-04	3.87E-02
Heat, at furnace 50kW	0.85	-	-	1.19E-02	2.33E-03	8.11E-10	2.65E-02	1.24E-04	5.58E-05	9.75E-05	9.82E-06	1.62E-04	1.38E-01
Heat, at furnace 50kW	0.80	-	-	4.74E-03	2.74E-03	3.83E-10	3.51E-02	1.47E-04	6.80E-05	8.63E-05	3.58E-06	3.25E-04	4.42E-02
Heat, at furnace 300kW, DH	0.73	-	-	3.62E-03	2.52E-03	3.29E-10	2.49E-02	1.38E-04	7.83E-05	8.23E-05	2.29E-06	1.64E-04	3.80E-02
Heat, at furnace 300kW	0.82	-	-	3.62E-03	2.52E-03	3.29E-10	2.49E-02	1.38E-04	7.83E-05	8.23E-05	2.29E-06	1.64E-04	3.80E-02
Heat, at furnace 1000kW, DH	0.76	-	-	3.46E-03	2.59E-03	3.40E-10	2.49E-02	1.35E-04	9.28E-05	8.10E-05	2.28E-06	1.64E-04	3.88E-02
Heat, at furnace 1000kW	0.85	-	-	3.46E-03	2.59E-03	3.40E-10	2.49E-02	1.35E-04	9.28E-05	8.10E-05	2.28E-06	1.64E-04	3.88E-02
Heat and electricity, CHP plant, ORC, 1400 kWth, DH	0.69	0.03	-	4.85E-03	4.46E-03	5.16E-10	2.57E-02	1.64E-04	1.48E-04	9.45E-05	2.05E-06	1.75E-04	6.24E-02
Heat and electricity, CHP plant, ORC, 1400 kWth	0.77	0.03	-	4.85E-03	4.46E-03	5.16E-10	2.57E-02	1.64E-04	1.48E-04	9.45E-05	2.05E-06	1.75E-04	6.24E-02
Heat and electricity, CHP plant, ORC, 6400 kWth, DH	0.68	0.08	-	4.80E-03	4.10E-03	5.12E-10	2.58E-02	1.40E-04	7.78E-05	8.13E-05	2.04E-06	1.76E-04	6.16E-02
Heat and electricity, CHP plant, ORC, 6400 kWth	0.77	0.08	-	4.80E-03	4.10E-03	5.12E-10	2.58E-02	1.40E-04	7.78E-05	8.13E-05	2.04E-06	1.76E-04	6.16E-02
Heat and electricity, CHP plant, ORC, emission control, 6400 kWth, DH	0.68	0.08	-	1.08E-02	4.16E-03	5.28E-10	2.61E-02	9.76E-05	3.39E-05	9.52E-05	2.08E-06	1.78E-04	6.36E-02
Heat and electricity, CHP plant, ORC, emission control, 6400 kWth	0.77	0.08	-	1.08E-02	4.16E-03	5.28E-10	2.61E-02	9.76E-05	3.39E-05	9.52E-05	2.08E-06	1.78E-04	6.36E-02
Heat and electricity, CHP plant, ORC, emission control, high el. eff., 6400 kWth, DH	0.49	0.30	-	1.08E-02	4.15E-03	5.27E-10	2.60E-02	9.74E-05	3.38E-05	9.50E-05	2.07E-06	1.77E-04	6.35E-02
Heat and electricity, CHP plant, ORC, emission control, high el. eff., 6400 kWth	0.55	0.30	-	1.08E-02	4.15E-03	5.27E-10	2.60E-02	9.74E-05	3.38E-05	9.50E-05	2.07E-06	1.77E-04	6.35E-02
Heat, SNG, at boiler atmospheric non-modulating <100kW	0.53	-	-	7.64E-03	2.44E-03	7.91E-10	1.16E-02	9.89E-05	2.66E-05	6.56E-05	3.42E-06	5.21E-05	8.76E-02
Heat, SNG, at industrial furnace >100kW	0.53	-	-	7.18E-03	2.40E-03	7.69E-10	1.10E-02	9.92E-05	2.62E-05	6.47E-05	2.97E-06	5.20E-05	8.26E-02
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn, DH	0.22	0.21	-	1.53E-02	4.82E-03	1.52E-09	2.15E-02	2.15E-04	5.41E-05	1.33E-04	5.29E-06	1.04E-04	1.60E-01
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn	0.25	0.21	-	1.53E-02	4.82E-03	1.52E-09	2.15E-02	2.15E-04	5.41E-05	1.33E-04	5.29E-06	1.04E-04	1.60E-01
Electricity, from SNG, at combined cycle power plant	-	0.32	-	7.01E-03	2.38E-03	7.57E-10	1.08E-02	1.03E-04	2.70E-05	6.60E-05	2.64E-06	5.20E-05	7.90E-02
Transport, passenger car, SNG, EURO3	-	-	0.29	1.72E-02	3.60E-03	1.87E-09	1.82E-02	1.46E-04	5.16E-05	1.25E-04	9.25E-06	5.60E-05	2.43E-01
Transport, passenger car, SNG, EURO5	-	-	0.35	1.85E-02	3.78E-03	2.02E-09	1.93E-02	1.55E-04	5.65E-05	1.37E-04	1.02E-05	5.67E-05	2.69E-01
Transport, passenger car, ethanol (99.7%)	-	-	0.28	1.68E-02	3.57E-03	1.87E-09	1.78E-02	1.69E-04	5.05E-05	1.13E-04	8.86E-06	5.59E-05	2.43E-01

Industrial wood residues

Heat, at wood heater 6kW	0.75	-	-	4.40E-03	1.99E-03	1.45E-10	3.86E-02	2.89E-04	1.58E-04	1.05E-04	3.83E-06	3.73E-04	2.41E-02
Heat, at furnace 15kW	0.82	-	-	4.97E-03	1.40E-03	4.11E-10	2.21E-02	1.01E-04	5.11E-05	6.38E-05	3.13E-06	1.60E-04	5.00E-02
Heat, at furnace 30kW	0.68	-	-	3.69E-03	1.53E-03	1.88E-10	3.92E-02	1.57E-04	7.18E-05	8.26E-05	4.30E-06	3.73E-04	2.79E-02
Heat, at furnace 50kW	0.85	-	-	4.25E-03	1.31E-03	3.78E-10	2.17E-02	1.01E-04	4.44E-05	6.42E-05	2.84E-06	1.60E-04	4.40E-02
Heat, at furnace 50kW	0.80	-	-	4.13E-03	1.63E-03	2.71E-10	3.53E-02	1.32E-04	6.45E-05	8.06E-05	4.00E-06	3.25E-04	3.35E-02
Heat, at furnace 300kW, DH	0.73	-	-	3.01E-03	1.41E-03	2.17E-10	2.51E-02	1.23E-04	7.48E-05	7.67E-05	2.70E-06	1.64E-04	2.73E-02
Heat, at furnace 300kW	0.82	-	-	3.01E-03	1.41E-03	2.17E-10	2.51E-02	1.23E-04	7.48E-05	7.67E-05	2.70E-06	1.64E-04	2.73E-02
Heat, at furnace 1000kW, DH	0.76	-	-	2.85E-03	1.48E-03	2.28E-10	2.51E-02	1.20E-04	8.93E-05	7.54E-05	2.69E-06	1.64E-04	2.80E-02
Heat, at furnace 1000kW	0.85	-	-	2.85E-03	1.48E-03	2.28E-10	2.51E-02	1.20E-04	8.93E-05	7.54E-05	2.69E-06	1.64E-04	2.80E-02
Heat and electricity, CHP plant, ORC, 1400 kWth, DH	0.69	0.03	-	3.63E-03	2.25E-03	2.92E-10	2.61E-02	1.34E-04	1.41E-04	8.32E-05	2.88E-06	1.75E-04	4.10E-02
Heat and electricity, CHP plant, ORC, 1400 kWth	0.77	0.03	-	3.63E-03	2.25E-03	2.92E-10	2.61E-02	1.34E-04	1.41E-04	8.32E-05	2.88E-06	1.75E-04	4.10E-02
Heat and electricity, CHP plant, ORC, 6400 kWth, DH	0.68	0.08	-	3.59E-03	1.88E-03	2.88E-10	2.61E-02	1.11E-04	7.08E-05	7.01E-05	2.87E-06	1.76E-04	4.01E-02
Heat and electricity, CHP plant, ORC, 6400 kWth	0.77	0.08	-	3.59E-03	1.88E-03	2.88E-10	2.61E-02	1.11E-04	7.08E-05	7.01E-05	2.87E-06	1.76E-04	4.01E-02
Heat and electricity, CHP plant, ORC, emission control, 6400 kWth, DH	0.68	0.08	-	9.59E-03	1.95E-03	3.04E-10	2.64E-02	6.79E-05	2.68E-05	8.40E-05	2.91E-06	1.78E-04	4.21E-02
Heat and electricity, CHP plant, ORC, emission control, 6400 kWth	0.77	0.08	-	9.59E-03	1.95E-03	3.04E-10	2.64E-02	6.79E-05	2.68E-05	8.40E-05	2.91E-06	1.78E-04	4.21E-02
Heat and electricity, CHP plant, ORC, emission control, high el. eff., 6400 kWth, DH	0.49	0.30	-	9.57E-03	1.94E-03	3.03E-10	2.63E-02	6.77E-05	2.67E-05	8.37E-05	2.91E-06	1.77E-04	4.20E-02
Heat and electricity, CHP plant, ORC, emission control, high el. eff., 6400 kWth	0.55	0.30	-	9.57E-03	1.94E-03	3.03E-10	2.63E-02	6.77E-05	2.67E-05	8.37E-05	2.91E-06	1.77E-04	4.20E-02
Heat, SNG, at boiler atmospheric non-modulating <100kW	0.53	-	-	7.03E-03	1.34E-03	6.79E-10	1.17E-02	8.40E-05	2.30E-05	6.00E-05	3.84E-06	5.20E-05	7.68E-02
Heat, SNG, at industrial furnace >100kW	0.53	-	-	6.57E-03	1.29E-03	6.57E-10	1.12E-02	8.43E-05	2.26E-05	5.91E-05	3.39E-06	5.20E-05	7.18E-02
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn, DH	0.22	0.21	-	1.41E-02	2.61E-03	1.30E-09	2.19E-02	1.86E-04	4.70E-05	1.22E-04	6.12E-06	1.04E-04	1.38E-01
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn	0.25	0.21	-	1.41E-02	2.61E-03	1.30E-09	2.19E-02	1.86E-04	4.70E-05	1.22E-04	6.12E-06	1.04E-04	1.38E-01
Electricity, from SNG, at combined cycle power plant	-	0.32	-	6.40E-03	1.28E-03	6.45E-10	1.10E-02	8.86E-05	2.35E-05	6.04E-05	3.05E-06	5.19E-05	6.83E-02
Transport, passenger car, SNG, EURO3	-	-	0.29	1.66E-02	2.50E-03	1.76E-09	1.84E-02	1.31E-04	4.81E-05	1.20E-04	9.66E-06	5.59E-05	2.32E-01
Transport, passenger car, SNG, EURO5	-	-	0.35	1.79E-02	2.68E-03	1.91E-09	1.95E-02	1.40E-04	5.30E-05	1.31E-04	1.06E-05	5.66E-05	2.58E-01
Transport, passenger car, ethanol, EURO5	-	-	0.28	1.62E-02	2.46E-03	1.76E-09	1.80E-02	1.54E-04	4.70E-05	1.07E-04	9.27E-06	5.58E-05	2.32E-01

Waste wood

Heat, at furnace 300kW, DH	0.73	-	-	3.40E-03	1.04E-03	2.99E-10	2.51E-02	1.26E-04	7.58E-05	7.90E-05	2.62E-06	1.64E-04	3.39E-02
Heat, at furnace 300kW	0.82	-	-	3.40E-03	1.04E-03	2.99E-10	2.51E-02	1.26E-04	7.58E-05	7.90E-05	2.62E-06	1.64E-04	3.39E-02
Heat, at furnace 1000kW, DH	0.76	-	-	3.24E-03	1.10E-03	3.09E-10	2.51E-02	1.23E-04	9.04E-05	7.77E-05	2.61E-06	1.64E-04	3.47E-02
Heat, at furnace 1000kW	0.85	-	-	3.24E-03	1.10E-03	3.09E-10	2.51E-02	1.23E-04	9.04E-05	7.77E-05	2.61E-06	1.64E-04	3.47E-02
Heat and electricity, CHP plant, ORC, 1400 kWth, DH	0.69	0.03	-	4.42E-03	1.50E-03	4.56E-10	2.60E-02	1.40E-04	1.43E-04	8.78E-05	2.72E-06	1.75E-04	5.42E-02
Heat and electricity, CHP plant, ORC, 1400 kWth	0.77	0.03	-	4.42E-03	1.50E-03	4.56E-10	2.60E-02	1.40E-04	1.43E-04	8.78E-05	2.72E-06	1.75E-04	5.42E-02
Heat and electricity, CHP plant, ORC, 6400 kWth, DH	0.68	0.08	-	4.37E-03	1.13E-03	4.51E-10	2.61E-02	1.16E-04	7.29E-05	7.46E-05	2.71E-06	1.76E-04	5.34E-02
Heat and electricity, CHP plant, ORC, 6400 kWth	0.77	0.08	-	4.37E-03	1.13E-03	4.51E-10	2.61E-02	1.16E-04	7.29E-05	7.46E-05	2.71E-06	1.76E-04	5.34E-02
Heat and electricity, CHP plant, ORC, emission control, 6400 kWth, DH	0.68	0.08	-	1.04E-02	1.19E-03	4.68E-10	2.64E-02	7.35E-05	2.89E-05	8.85E-05	2.75E-06	1.78E-04	5.54E-02
Heat and electricity, CHP plant, ORC, emission control, 6400 kWth	0.77	0.08	-	1.04E-02	1.19E-03	4.68E-10	2.64E-02	7.35E-05	2.89E-05	8.85E-05	2.75E-06	1.78E-04	5.54E-02
Heat and electricity, CHP plant, ORC, emission control, high el. eff., 6400 kWth, DH	0.49	0.30	-	1.04E-02	1.19E-03	4.67E-10	2.63E-02	7.33E-05	2.88E-05	8.83E-05	2.74E-06	1.77E-04	5.53E-02
Heat and electricity, CHP plant, ORC, emission control, high el. eff., 6400 kWth	0.55	0.30	-	1.04E-02	1.19E-03	4.67E-10	2.63E-02	7.33E-05	2.88E-05	8.83E-05	2.74E-06	1.77E-04	5.53E-02
Heat, SNG, at boiler atmospheric non-modulating <100kW	0.53	-	-	7.43E-03	9.59E-04	7.61E-10	1.17E-02	8.68E-05	2.41E-05	6.23E-05	3.76E-06	5.21E-05	8.35E-02
Heat, SNG, at industrial furnace >100kW	0.53	-	-	6.96E-03	9.15E-04	7.38E-10	1.11E-02	8.71E-05	2.37E-05	6.14E-05	3.31E-06	5.20E-05	7.85E-02
Heat and electricity, from SNG, at CHP plant, 1MWle lean burn, DH	0.22	0.21	-	1.49E-02	1.86E-03	1.46E-09	2.18E-02	1.91E-04	4.91E-05	1.27E-04	5.95E-06	1.04E-04	1.51E-01
Heat and electricity, from SNG, at CHP plant, 1MWle lean burn	0.25	0.21	-	1.49E-02	1.86E-03	1.46E-09	2.18E-02	1.91E-04	4.91E-05	1.27E-04	5.95E-06	1.04E-04	1.51E-01
Electricity, from SNG, at combined cycle power plant	-	0.32	-	6.79E-03	9.00E-04	7.27E-10	1.09E-02	9.14E-05	2.45E-05	6.26E-05	2.97E-06	5.19E-05	7.49E-02
Transport, passenger car, SNG, EURO3	-	-	0.29	1.70E-02	2.12E-03	1.84E-09	1.83E-02	1.34E-04	4.91E-05	1.22E-04	9.58E-06	5.59E-05	2.39E-01
Transport, passenger car, SNG, EURO5	-	-	0.35	1.83E-02	2.30E-03	1.99E-09	1.95E-02	1.43E-04	5.40E-05	1.33E-04	1.05E-05	5.67E-05	2.65E-01
Heat and electricity, disposal in MSW incineration, DH	0.17	0.09	-	8.37E-04	1.49E-04	8.77E-11	3.32E-03	3.23E-05	7.08E-06	1.72E-05	4.41E-07	9.10E-08	1.09E-02
Heat and electricity, disposal in MSW incineration	0.20	0.09	-	8.37E-04	1.49E-04	8.77E-11	3.32E-03	3.23E-05	7.08E-06	1.72E-05	4.41E-07	9.10E-08	1.09E-02
Heat and electricity, disposal in MSW incineration, future, DH	0.17	0.09	-	5.36E-04	9.56E-05	5.61E-11	2.12E-03	2.07E-05	4.53E-06	1.10E-05	2.82E-07	5.83E-08	6.95E-03
Heat and electricity, disposal in MSW incineration, future	0.20	0.09	-	5.36E-04	9.56E-05	5.61E-11	2.12E-03	2.07E-05	4.53E-06	1.10E-05	2.82E-07	5.83E-08	6.95E-03
Heat, disposal in cement factory	0.07	-	-	2.76E-03	6.39E-04	6.66E-10	4.21E-03	2.04E-04	5.03E-05	1.15E-04	1.36E-06	1.41E-06	7.28E-02
Transport, passenger car, ethanol, EURO5	-	-	0.28	1.66E-02	2.08E-03	1.84E-09	1.80E-02	1.57E-04	4.80E-05	1.09E-04	9.19E-06	5.59E-05	2.38E-01

Agricultural residues

Heat, from SNG, at furnace < 100 kW	0.41	-	-	3.19E-02	3.60E-03	1.01E-09	4.36E-03	7.47E-05	6.99E-05	4.10E-04	5.76E-06	1.14E-03	1.20E-01
Heat, from SNG, at industrial furnace > 100 kW	0.41	-	-	3.15E-02	3.57E-03	9.94E-10	3.93E-03	7.49E-05	6.96E-05	4.10E-04	5.41E-06	1.14E-03	1.17E-01
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn	0.21	0.18	-	6.40E-02	7.17E-03	1.98E-09	7.49E-03	1.66E-04	1.41E-04	8.23E-04	1.03E-05	2.28E-03	2.29E-01
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn, DH	0.19	-	-	6.40E-02	7.17E-03	1.98E-09	7.49E-03	1.66E-04	1.41E-04	8.23E-04	1.03E-05	2.28E-03	2.29E-01
Transport, passenger car, SNG, EURO5	-	-	0.27	4.02E-02	4.64E-03	1.96E-09	1.04E-02	1.18E-04	9.30E-05	4.65E-04	1.10E-05	1.15E-03	2.60E-01
Heat, from SNG, BCM, at furnace < 100 kW	0.35	-	-	3.48E-02	1.71E+00	1.17E-03	3.66E-03	3.98E-04	7.01E-05	2.50E-03	8.33E-06	1.14E-03	1.10E-01
Heat, from SNG, BCM, at industrial furnace > 100 kW	0.35	-	-	3.45E-02	1.71E+00	1.17E-03	3.29E-03	3.99E-04	6.98E-05	2.50E-03	8.03E-06	1.14E-03	1.07E-01
Heat and electricity, from SNG, BCM, at CHP plant, 1 MWe lean burn	0.18	0.16	-	6.97E-02	3.43E+00	2.33E-03	6.26E-03	8.11E-04	1.41E-04	5.00E-03	1.56E-05	2.29E-03	2.11E-01
Heat and electricity, from SNG, BCM, at CHP plant, 1 MWe lean burn, DH	0.18	0.16	-	6.97E-02	3.43E+00	2.33E-03	6.26E-03	8.11E-04	1.41E-04	5.00E-03	1.56E-05	2.29E-03	2.11E-01
Transport, passenger car, SNG, BCM, EURO5	-	-	0.23	4.19E-02	1.72E+00	1.17E-03	8.80E-03	4.36E-04	8.99E-05	2.55E-03	1.28E-05	1.15E-03	2.30E-01
Heat and electricity, from biogas, w ith biogas engine, 160 kWe	0.26	0.15	-	4.77E-02	6.40E-03	1.77E-09	6.44E-03	1.32E-04	1.34E-04	8.04E-04	9.00E-06	2.28E-03	2.10E-01
Heat and electricity, from biogas, w ith biogas engine, 160 kWe, DH	0.26	0.15	-	4.77E-02	6.40E-03	1.77E-09	6.44E-03	1.32E-04	1.34E-04	8.04E-04	9.00E-06	2.28E-03	2.10E-01
Heat and electricity, from biogas, w ith ignition gas engine, 50 kWe	0.28	0.17	-	5.35E-02	6.89E-03	2.41E-09	6.50E-03	1.99E-04	1.49E-04	8.45E-04	9.07E-06	2.28E-03	2.71E-01
Heat and electricity, from biogas, w ith ignition gas engine, 50 kWe, DH	0.28	0.17	-	5.35E-02	6.89E-03	2.41E-09	6.50E-03	1.99E-04	1.49E-04	8.45E-04	9.07E-06	2.28E-03	2.71E-01
Transport, passenger car, ethanol, EURO5	-	-	0.41	3.80E-02	4.93E-03	2.50E-09	1.35E-02	1.80E-04	1.04E-04	4.74E-04	1.35E-05	1.15E-03	3.42E-01
Electricity, from SNG, at combined cycle power plant	-	0.27	-	2.36E-02	3.19E-03	8.74E-10	3.17E-03	7.43E-05	6.79E-05	4.01E-04	4.44E-06	1.14E-03	1.04E-01
Electricity, from SNG, BCM, at combined cycle power plant	-	0.23	-	2.36E-02	3.18E-03	8.74E-10	3.16E-03	7.23E-05	6.75E-05	4.00E-04	4.44E-06	1.14E-03	1.04E-01
Animal manure													
Heat, from SNG, at furnace < 100 kW	0.41	-	-	2.58E-02	1.49E-03	3.16E-10	1.89E-03	3.58E-05	5.45E-05	3.68E-04	1.84E-06	4.13E-07	3.74E-02
Heat, from SNG, at industrial furnace > 100 kW	0.41	-	-	2.54E-02	1.45E-03	2.99E-10	1.46E-03	3.60E-05	5.42E-05	3.67E-04	1.49E-06	3.49E-07	3.36E-02
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn, DH	0.19	0.18	-	5.18E-02	2.94E-03	5.89E-10	2.55E-03	8.88E-05	1.10E-04	7.39E-04	2.48E-06	6.57E-07	6.32E-02
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn	0.21	0.18	-	5.18E-02	2.94E-03	5.89E-10	2.55E-03	8.88E-05	1.10E-04	7.39E-04	2.48E-06	6.57E-07	6.32E-02
Electricity, from SNG, at combined cycle power plant	-	0.28	-	2.53E-02	1.45E-03	2.91E-10	1.31E-03	4.09E-05	5.52E-05	3.69E-04	1.24E-06	3.29E-07	3.09E-02
Transport, passenger car, SNG, EURO3	-	-	0.22	3.32E-02	2.38E-03	1.15E-09	7.00E-03	7.19E-05	7.38E-05	4.14E-04	6.33E-06	3.39E-06	1.57E-01
Transport, passenger car, SNG, EURO5	-	-	0.27	3.41E-02	2.58E-03	1.32E-09	8.18E-03	8.11E-05	7.83E-05	4.24E-04	7.38E-06	4.02E-06	1.83E-01
Heat, from SNG, BCM, at furnace < 100 kW	0.35	-	-	2.57E-02	1.48E-03	3.12E-10	1.80E-03	3.46E-05	5.41E-05	3.67E-04	1.74E-06	3.99E-07	3.64E-02
Heat, from SNG, BCM, at industrial furnace > 100 kW	0.35	-	-	2.54E-02	1.45E-03	2.97E-10	1.43E-03	3.47E-05	5.39E-05	3.66E-04	1.45E-06	3.43E-07	3.30E-02
Heat and electricity, from SNG, BCM, at CHP plant, 1 MWe lean burn, DH	0.16	0.16	-	5.15E-02	2.93E-03	5.86E-10	2.54E-03	8.39E-05	1.09E-04	7.37E-04	2.47E-06	6.52E-07	6.27E-02
Heat and electricity, from SNG, BCM, at CHP plant, 1 MWe lean burn	0.18	0.16	-	5.15E-02	2.93E-03	5.86E-10	2.54E-03	8.39E-05	1.09E-04	7.37E-04	2.47E-06	6.52E-07	6.27E-02
Electricity, from SNG, BCM, at combined cycle power plant	-	0.24	-	1.87E-02	1.26E-03	6.28E-10	1.02E-03	3.68E-05	5.32E-05	3.61E-04	8.88E-07	3.13E-07	6.85E-02
Transport, passenger car, SNG, BCM, EURO3	-	-	0.19	3.20E-02	2.25E-03	1.03E-09	6.18E-03	6.55E-05	7.07E-05	4.06E-04	5.60E-06	2.95E-06	1.39E-01
Transport, passenger car, SNG, BCM, EURO5	-	-	0.23	2.62E-02	2.23E-03	1.52E-09	6.92E-03	7.13E-05	7.30E-05	4.09E-04	6.16E-06	3.48E-06	1.99E-01
Heat and electricity, from biogas, w ith biogas engine, 160 kWe, DH	0.24	0.16	-	3.55E-02	2.17E-03	3.78E-10	1.51E-03	5.47E-05	1.03E-04	7.20E-04	1.16E-06	4.56E-07	4.45E-02
Heat and electricity, from biogas, w ith biogas engine, 160 kWe	0.27	0.16	-	3.55E-02	2.17E-03	3.78E-10	1.51E-03	5.47E-05	1.03E-04	7.20E-04	1.16E-06	4.56E-07	4.45E-02
Heat and electricity, from biogas, w ith ignition gas engine, 50 kWe, DH	0.26	0.18	-	4.14E-02	2.68E-03	1.03E-09	1.57E-03	1.22E-04	1.19E-04	7.61E-04	1.23E-06	7.16E-07	1.07E-01

Biowaste

Heat, from SNG, at furnace < 100 kW	0.44	-	-	2.05E-02	1.09E-03	4.74E-10	1.94E-03	2.60E-05	1.05E-05	4.34E-05	3.19E-02	3.82E-07	5.55E-02
Heat, from SNG, at industrial furnace > 100 kW	0.45	-	-	2.01E-02	1.05E-03	4.55E-10	1.46E-03	2.62E-05	1.02E-05	4.26E-05	3.15E-02	3.12E-07	5.13E-02
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn, DH	0.19	0.18	-	4.11E-02	2.13E-03	8.98E-10	2.51E-03	6.67E-05	2.18E-05	8.84E-05	6.40E-02	5.74E-07	9.78E-02
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn	0.21	0.18	-	4.11E-02	2.13E-03	8.98E-10	2.51E-03	6.67E-05	2.18E-05	8.84E-05	6.40E-02	5.74E-07	9.78E-02
Electricity, from SNG, at combined cycle power plant	-	0.27	-	2.00E-02	1.04E-03	4.45E-10	1.29E-03	2.99E-05	1.09E-05	4.37E-05	1.18E-06	2.88E-07	4.82E-02
Transport, passenger car, SNG, EURO3	-	-	0.24	2.86E-02	2.07E-03	1.39E-09	7.54E-03	6.56E-05	3.17E-05	9.38E-05	4.02E-02	3.65E-06	1.87E-01
Transport, passenger car, SNG, EURO5	-	-	0.29	2.97E-02	2.29E-03	1.58E-09	8.83E-03	7.57E-05	3.66E-05	1.06E-04	7.92E-06	4.34E-06	2.16E-01
Heat, from SNG, BCM, at furnace < 100 kW	0.38	-	-	1.31E-02	8.75E-04	8.40E-10	1.53E-03	2.23E-05	8.43E-06	3.48E-05	3.48E-02	3.51E-07	9.57E-02
Heat, from SNG, BCM, at industrial furnace > 100 kW	0.38	-	-	1.28E-02	8.43E-04	8.23E-10	1.12E-03	2.24E-05	8.17E-06	3.41E-05	3.45E-02	2.91E-07	9.21E-02
Heat and electricity, from SNG, BCM, at CHP plant, 1 MWe lean burn, DH	0.16	0.16	-	2.63E-02	1.71E-03	1.64E-09	1.89E-03	5.72E-05	1.76E-05	7.10E-05	6.97E-02	5.40E-07	1.80E-01
Heat and electricity, from SNG, BCM, at CHP plant, 1 MWe lean burn	0.18	0.16	-	2.63E-02	1.71E-03	1.64E-09	1.89E-03	5.72E-05	1.76E-05	7.10E-05	6.97E-02	5.40E-07	1.80E-01
Electricity, from SNG, BCM, at combined cycle power plant	-	0.23	-	1.27E-02	8.32E-04	8.15E-10	9.76E-04	2.56E-05	8.76E-06	3.50E-05	7.94E-07	2.70E-07	8.95E-02
Transport, passenger car, SNG, BCM, EURO3	-	-	0.21	2.01E-02	1.72E-03	1.62E-09	6.34E-03	5.62E-05	2.66E-05	7.80E-05	4.19E-02	3.15E-06	2.09E-01
Transport, passenger car, SNG, BCM, EURO5	-	-	0.25	2.10E-02	1.90E-03	1.79E-09	7.44E-03	6.49E-05	3.08E-05	8.81E-05	6.58E-06	3.75E-06	2.33E-01
Heat and electricity, from biogas, with biogas engine, 160 kWe, DH	0.23	0.15	-	2.33E-02	1.29E-03	6.64E-10	1.35E-03	3.20E-05	1.42E-05	6.75E-05	4.77E-02	3.50E-07	7.72E-02
Heat and electricity, from biogas, with biogas engine, 160 kWe	0.26	0.15	-	2.33E-02	1.29E-03	6.64E-10	1.35E-03	3.20E-05	1.42E-05	6.75E-05	4.77E-02	3.50E-07	7.72E-02
Heat and electricity, from biogas, with ignition gas engine, 50 kWe, DH	0.25	0.17	-	2.91E-02	1.78E-03	1.30E-09	1.41E-03	9.85E-05	2.92E-05	1.08E-04	5.35E-02	6.05E-07	1.38E-01
Heat and electricity, from biogas, with ignition gas engine, 50 kWe	0.28	0.17	-	2.91E-02	1.78E-03	1.30E-09	1.41E-03	9.85E-05	2.92E-05	1.08E-04	5.35E-02	6.05E-07	1.38E-01
Heat and electricity, disposal in MSW incineration, DH	0.07	0.02	-	6.85E-03	8.15E-04	7.13E-10	1.12E-02	1.15E-04	2.68E-05	6.53E-05	8.23E-06	1.67E-06	7.97E-02
Heat and electricity, disposal in MSW incineration	0.07	0.02	-	6.85E-03	8.15E-04	7.13E-10	1.12E-02	1.15E-04	2.68E-05	6.53E-05	8.23E-06	1.67E-06	7.97E-02
Heat and electricity, disposal in MSW incineration, future, DH	0.39	0.08	-	6.85E-03	8.16E-04	7.13E-10	1.12E-02	1.15E-04	2.68E-05	6.53E-05	8.24E-06	1.67E-06	7.98E-02
Heat and electricity, disposal in MSW incineration, future	0.44	0.08	-	6.85E-03	8.16E-04	7.13E-10	1.12E-02	1.15E-04	2.68E-05	6.53E-05	8.24E-06	1.67E-06	7.98E-02
Sewage sludge													
Heat and electricity, from biogas, with biogas engine 160 kWe / heat and electricity, from digested sludge, MSW incineration, DH	0.13	0.09	-	1.60E-02	1.71E-03	2.26E-09	2.70E-02	9.53E-05	2.61E-05	7.19E-05	3.80E-05	3.38E-06	1.84E-01
Heat and electricity, from biogas, with biogas engine 160 kWe / heat and electricity, from digested sludge, MSW incineration	0.15	0.09	-	1.60E-02	1.71E-03	2.26E-09	2.70E-02	9.53E-05	2.61E-05	7.19E-05	3.80E-05	3.38E-06	1.84E-01
Heat and electricity, from biogas, with biogas engine 160 kWe / heat and electricity, from digested sludge, MSW incineration, future, DH	0.24	0.09	-	1.59E-02	1.71E-03	2.25E-09	2.68E-02	9.46E-05	2.60E-05	7.15E-05	3.77E-05	3.36E-06	1.83E-01
Heat and electricity, from biogas, with biogas engine 160 kWe / heat and electricity, from digested sludge, MSW incineration, future	0.27	0.09	-	1.59E-02	1.71E-03	2.25E-09	2.68E-02	9.46E-05	2.60E-05	7.15E-05	3.77E-05	3.36E-06	1.83E-01
Heat and electricity, from biogas, with ignition gas engine 160 kWe / heat and electricity, from digested sludge, MSW incineration, DH	0.14	0.10	-	1.92E-02	1.99E-03	2.62E-09	2.71E-02	1.32E-04	3.45E-05	9.44E-05	3.81E-05	3.52E-06	2.18E-01
Heat and electricity, from biogas, with ignition gas engine 160 kWe / heat and electricity, from digested sludge, MSW incineration	0.16	0.10	-	1.92E-02	1.99E-03	2.62E-09	2.71E-02	1.32E-04	3.45E-05	9.44E-05	3.81E-05	3.52E-06	2.18E-01
Heat and electricity, from biogas, with ignition gas engine 160 kWe / heat and electricity, from digested sludge, MSW incineration, future, DH	0.25	0.10	-	1.91E-02	1.98E-03	2.61E-09	2.69E-02	1.32E-04	3.43E-05	9.39E-05	3.78E-05	3.50E-06	2.17E-01
Heat and electricity, from biogas, with ignition gas engine 160 kWe / heat and electricity, from digested sludge, MSW incineration, future	0.28	0.10	-	1.91E-02	1.98E-03	2.61E-09	2.69E-02	1.32E-04	3.43E-05	9.39E-05	3.78E-05	3.50E-06	2.17E-01
Heat and electricity, from SNG, at furnace < 100 kW / heat and electricity, from digested sludge, MSW incineration	0.25	-	-	1.63E-02	1.58E-03	1.85E-09	2.71E-02	9.35E-05	2.53E-05	6.83E-05	3.82E-05	3.32E-06	1.35E-01
Heat and electricity, from SNG, at furnace < 100 kW / heat and electricity, from digested sludge, MSW incineration, future, DH	0.37	0.00	-	1.62E-02	1.57E-03	1.83E-09	2.69E-02	9.28E-05	2.51E-05	6.78E-05	3.79E-05	3.30E-06	1.34E-01
Heat and electricity, from SNG, at industrial furnace > 100 kW / heat and electricity, from digested sludge, MSW incineration	0.25	-	-	1.61E-02	1.56E-03	1.83E-09	2.69E-02	9.36E-05	2.51E-05	6.79E-05	3.80E-05	3.28E-06	1.32E-01
Heat and electricity, from SNG, at industrial furnace > 100 kW / heat and electricity, from digested sludge, MSW incineration, future	0.37	0.00	-	1.60E-02	1.55E-03	1.82E-09	2.67E-02	9.29E-05	2.49E-05	6.74E-05	3.77E-05	3.26E-06	1.32E-01

Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn / heat and electricity, from digested sludge, MSW incineration, DH	0.10	0.10	-	2.59E-02	2.19E-03	2.39E-09	2.77E-02	1.15E-04	3.04E-05	8.36E-05	3.88E-05	3.51E-06	1.95E-01
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn / heat and electricity, from digested sludge, MSW incineration	0.12	0.10	-	2.59E-02	2.19E-03	2.39E-09	2.77E-02	1.15E-04	3.04E-05	8.36E-05	3.88E-05	3.51E-06	1.95E-01
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn / heat and electricity, from digested sludge, MSW incineration, future, DH	0.21	0.10	-	2.58E-02	2.18E-03	2.38E-09	2.75E-02	1.14E-04	3.02E-05	8.32E-05	3.85E-05	3.48E-06	1.95E-01
Heat and electricity, from SNG, at CHP plant, 1 MWe lean burn / heat and electricity, from digested sludge, MSW incineration, future	0.24	0.10	-	2.58E-02	2.18E-03	2.38E-09	2.75E-02	1.14E-04	3.02E-05	8.32E-05	3.85E-05	3.48E-06	1.95E-01
Transport, passenger car, SNG, EURO3 / heat and electricity, from digested sludge, MSW incineration	-	-	0.14	2.08E-02	2.13E-03	2.36E-09	3.03E-02	1.16E-04	3.71E-05	9.65E-05	4.10E-05	5.15E-06	2.08E-01
Transport, passenger car, SNG, EURO3 / heat and electricity, from digested sludge, MSW incineration, future	0.12	0.00	0.14	2.08E-02	2.12E-03	2.34E-09	3.00E-02	1.15E-04	3.69E-05	9.60E-05	4.07E-05	5.12E-06	2.08E-01
Heat and electricity, from SNG, BCM, at furnace < 100 kW / heat and electricity, from digested sludge, MSW incineration	0.21	-	-	1.22E-02	1.46E-03	2.05E-09	2.69E-02	9.14E-05	2.41E-05	6.35E-05	3.80E-05	3.31E-06	1.57E-01
Heat and electricity, from SNG, BCM, at furnace < 100 kW / heat and electricity, from digested sludge, MSW incineration, future, DH	0.34	0.00	-	1.21E-02	1.45E-03	2.04E-09	2.67E-02	9.07E-05	2.39E-05	6.30E-05	3.77E-05	3.28E-06	1.56E-01
Heat and electricity, from SNG, BCM, at industrial furnace > 100 kW / heat and electricity, from digested sludge, MSW incineration	0.22	-	-	1.20E-02	1.44E-03	2.04E-09	2.67E-02	9.15E-05	2.40E-05	6.31E-05	3.78E-05	3.27E-06	1.55E-01
Heat and electricity, from SNG, BCM, at industrial furnace > 100 kW / heat and electricity, from digested sludge, MSW incineration, future	0.34	0.00	-	1.19E-02	1.44E-03	2.03E-09	2.65E-02	9.08E-05	2.38E-05	6.27E-05	3.75E-05	3.25E-06	1.54E-01
Heat and electricity, from SNG, BCM, at CHP plant, 1 MWe lean burn / heat and electricity, from digested sludge, MSW incineration, DH	0.09	0.09	-	1.77E-02	1.95E-03	2.81E-09	2.73E-02	1.09E-04	2.80E-05	7.39E-05	3.84E-05	3.49E-06	2.41E-01
Heat and electricity, from SNG, BCM, at CHP plant, 1 MWe lean burn / heat and electricity, from digested sludge, MSW incineration	0.10	0.09	-	1.77E-02	1.95E-03	2.81E-09	2.73E-02	1.09E-04	2.80E-05	7.39E-05	3.84E-05	3.49E-06	2.41E-01
Heat and electricity, from SNG, BCM, at CHP plant, 1 MWe lean burn / heat and electricity, from digested sludge, MSW incineration, future, DH	0.20	0.09	-	1.76E-02	1.94E-03	2.79E-09	2.71E-02	1.09E-04	2.78E-05	7.34E-05	3.81E-05	3.46E-06	2.41E-01
Heat and electricity, from SNG, BCM, at CHP plant, 1 MWe lean burn / heat and electricity, from digested sludge, MSW incineration, future	0.22	0.09	-	1.76E-02	1.94E-03	2.79E-09	2.71E-02	1.09E-04	2.78E-05	7.34E-05	3.81E-05	3.46E-06	2.41E-01
Transport, passenger car, SNG, BCM, EURO3 / heat and electricity, from digested sludge, MSW incineration	-	-	0.12	1.61E-02	1.93E-03	2.49E-09	2.96E-02	1.10E-04	3.43E-05	8.77E-05	4.03E-05	4.87E-06	2.20E-01
Transport, passenger car, SNG, BCM, EURO3 / heat and electricity, from digested sludge, MSW incineration, future	0.12	0.00	0.12	1.60E-02	1.93E-03	2.48E-09	2.94E-02	1.10E-04	3.41E-05	8.72E-05	4.00E-05	4.85E-06	2.20E-01
Heat and electricity, from sew age sludge, MSW incineration, DH	-	-	-	1.09E-02	1.33E-03	1.96E-09	2.69E-02	1.41E-04	3.53E-05	9.13E-05	3.90E-05	3.50E-06	1.05E-01
Heat and electricity, from sew age sludge, MSW incineration	-	-	-	1.09E-02	1.33E-03	1.96E-09	2.69E-02	1.41E-04	3.53E-05	9.13E-05	3.90E-05	3.50E-06	1.05E-01
Heat and electricity, from sew age sludge, MSW incineration, future, DH	0.22	0.01	-	1.09E-02	1.33E-03	1.96E-09	2.69E-02	1.41E-04	3.53E-05	9.13E-05	3.90E-05	3.50E-06	1.05E-01
Heat and electricity, from sew age sludge, MSW incineration, future	0.25	0.01	-	1.09E-02	1.33E-03	1.96E-09	2.69E-02	1.41E-04	3.53E-05	9.13E-05	3.90E-05	3.50E-06	1.05E-01
Electricity, from SNG, at combined cycle plant / heat and electricity, from digested sludge, MSW incineration	-	0.15	-	1.60E-02	1.55E-03	1.83E-09	2.68E-02	9.56E-05	2.55E-05	6.85E-05	3.79E-05	3.27E-06	1.30E-01
Electricity, from SNG, at combined cycle plant / heat and electricity, from digested sludge, MSW incineration, future	0.12	0.16	-	1.59E-02	1.55E-03	1.82E-09	2.66E-02	9.50E-05	2.53E-05	6.80E-05	3.76E-05	3.25E-06	1.30E-01
Electricity, from SNG, BCM, at combined cycle plant / heat and electricity, from digested sludge, MSW incineration	-	0.13	-	1.19E-02	1.44E-03	2.04E-09	2.66E-02	9.33E-05	2.43E-05	6.36E-05	3.77E-05	3.26E-06	1.54E-01
Electricity, from SNG, BCM, at combined cycle plant / heat and electricity, from digested sludge, MSW incineration, future	0.12	0.13	-	1.19E-02	1.43E-03	2.03E-09	2.64E-02	9.26E-05	2.41E-05	6.32E-05	3.74E-05	3.24E-06	1.53E-01
Transport, passenger car, SNG, EURO5 / heat and electricity, from digested sludge, MSW incineration	-	-	0.16	2.14E-02	2.25E-03	2.46E-09	3.10E-02	1.21E-04	3.99E-05	1.03E-04	4.16E-05	5.54E-06	2.24E-01
Transport, passenger car, SNG, EURO5 / heat and electricity, from digested sludge, MSW incineration, future	0.12	0.00	0.16	2.14E-02	2.24E-03	2.45E-09	3.08E-02	1.21E-04	3.97E-05	1.03E-04	4.13E-05	5.51E-06	2.23E-01
Transport, passenger car, SNG, BCM, EURO5 / heat and electricity, from digested sludge, MSW incineration	-	-	0.14	1.66E-02	2.04E-03	2.58E-09	3.02E-02	1.15E-04	3.66E-05	9.33E-05	4.09E-05	5.20E-06	2.34E-01
Transport, passenger car, SNG, BCM, EURO5 / heat and electricity, from digested sludge, MSW incineration, future	0.12	0.00	0.14	1.65E-02	2.03E-03	2.57E-09	3.00E-02	1.15E-04	3.65E-05	9.28E-05	4.06E-05	5.18E-06	2.33E-01

S.2 Fossil energy technology data

Table S-2: Fossil energy technology data

Fossil technology description	Energy service output			LCIA results										
	Electricity	Transportation	IPCC GWP 100a	Ecoindicator '99	Recipe single score	Human toxicity	Photochemical oxidant formation	Particulate matter formation	Ionising radiation	Freshwater eutrophication	Marine eutrophication	Freshwater ecotoxicity	CED, non-renewable, fossil	
	MJ	MJ	pkm	kg CO2 eq	Pt	kg CFC-11 eq	kg 1,4-DB eq	kg NMVOC	kg PM10 eq	kg SO2 eq	kg P eq	kg 1,4-DB eq	MJ eq	
Heat, light fuel oil, at boiler 10kW condensing, non-modulating	1.00	-	-	8.93E-02	7.77E-03	1.30E-08	5.40E-03	1.44E-04	5.15E-05	1.74E-04	3.66E-06	5.76E-06	1.2835685	
Heat, natural gas, at boiler atmospheric non-modulating <100kW	1.00	-	-	7.72E-02	6.95E-03	1.19E-08	2.30E-03	8.11E-05	1.95E-05	6.06E-05	2.04E-06	1.38E-06	1.2916557	
Heat, anthracite, at stove 5-15kW	1.00	-	-	1.36E-01	1.09E-02	4.65E-10	3.77E-02	7.29E-04	1.62E-04	6.14E-04	4.24E-05	3.75E-06	1.2567773	
Heat, light fuel oil, at industrial furnace 1MW	1.00	-	-	9.26E-02	8.06E-03	1.36E-08	3.74E-03	1.71E-04	5.58E-05	1.92E-04	2.37E-06	3.26E-05	1.333575	
Heat, natural gas, at industrial furnace >100kW	1.00	-	-	7.16E-02	6.55E-03	1.03E-08	1.02E-03	6.95E-05	1.68E-05	5.12E-05	1.07E-06	1.25E-06	1.2452503	
Heat, at hard coal industrial furnace 1-10MW	1.00	-	-	1.31E-01	1.11E-02	5.55E-10	3.87E-02	3.86E-04	2.56E-04	8.46E-04	4.41E-05	3.08E-06	1.2567129	
Electricity, nuclear, at power plant	-	1.00	-	2.16E-03	5.07E-04	5.27E-09	1.01E-02	1.13E-05	1.59E-05	1.42E-05	1.13E-06	1.29E-06	0.02762338	
Electricity, natural gas, at combined cycle plant	-	1.00	-	1.18E-01	1.08E-02	1.70E-08	1.05E-03	1.28E-04	3.03E-05	8.86E-05	7.28E-07	1.98E-06	2.05100558	
Electricity, hard coal, at power plant	-	1.00	-	3.00E-01	2.58E-02	1.55E-09	8.92E-02	7.18E-04	3.83E-04	1.27E-03	1.36E-04	3.43E-06	3.38833944	
Electricity, oil, at power plant	-	1.00	-	2.46E-01	2.36E-02	2.93E-08	2.37E-02	1.01E-03	5.92E-04	2.26E-03	6.71E-06	4.83E-05	3.40258806	
Transport, passenger car, petrol, EURO5	-	-	1.00	1.66E-01	1.55E-02	2.22E-08	2.92E-02	4.43E-04	1.56E-04	4.25E-04	2.53E-05	1.67E-05	2.465682	
Transport, passenger car, diesel, EURO5	-	-	1.00	1.59E-01	1.49E-02	2.26E-08	2.81E-02	5.27E-04	1.60E-04	3.84E-04	2.44E-05	1.56E-05	2.3487619	
Transport, passenger car, natural gas, EURO5	-	-	1.00	1.50E-01	1.50E-02	2.35E-08	2.64E-02	2.88E-04	1.19E-04	3.07E-04	2.34E-05	1.56E-05	2.6747931	

S.3 Energy demand per technology before and after removal of biomass

Table S-3: Use of fossil technologies as in the original scenarios and with removal of biomass and adjustment for fossil energy technology use

Sector	Energy carrier	Technology	unit	Today, original data	Today 2010, biomass excluded	Additional fossil energy use	2030 Reference , original data	Reference 2030, biomass excluded	Additional fossil energy use	2030 energy [r]evolution scenario, original data	Revolution 2030, biomass excluded	Additional fossil energy use
Heat: households & services			<i>PJ</i>	10664	12043	13%	9923	11398	15%	7011	10326	47%
	Light fuel oil	Boiler 10kW condensing, non-modulating	<i>PJ</i>	2880	3253	13%	2266	2605	15%	1635	2408	47%
	Gas	Boiler atmospheric non-modulating <100kW	<i>PJ</i>	7171	8098	13%	7337	8422	15%	5319	7834	47%
	Coal	Anthracite stove 5-15kW	<i>PJ</i>	613	692	13%	321	371	16%	57	84	47%
Heat: industry			<i>PJ</i>	7665	8183	7%	7899	8746	11%	4460	6597	48%
	Light fuel oil	Industrial furnace 1MW	<i>PJ</i>	1769	1888	7%	1693	1874	11%	588	870	48%
	Gas	Industrial furnace >100kW	<i>PJ</i>	4085	4361	7%	4514	4997	11%	3326	4920	48%
	Coal	Industrial furnace 1-10MW	<i>PJ</i>	1811	1933	7%	1693	1874	11%	546	808	48%
Electricity			<i>PJ</i>	8494	8780	3%	9377	10406	11%	4849	6343	31%
	Nuclear	Nuclear power plant	<i>PJ</i>	3374	3487	3%	3537	3925	11%	569	744	31%
	Gas	Natural gas combined cycle plant	<i>PJ</i>	2789	2883	3%	2608	2894	11%	3474	4544	31%
	Coal	Hard coal power plant	<i>PJ</i>	1955	2021	3%	3087	3426	11%	745	975	31%
	Oil	Oil power plant	<i>PJ</i>	376	389	3%	145	161	11%	61	80	31%
Transport			<i>10E9 pkm</i>	4611	4779	4%	4860	5479	13%	3857	4162	8%
	Petrol	Passenger car, Euro 5	<i>10E9 pkm</i>	2969	3078	4%	2527	2849	13%	1995	2149	8%
	Diesel	Passenger car, Euro 5	<i>10E9 pkm</i>	1596	1654	4%	2299	2592	13%	1815	1955	8%
	Gas	Passenger car, Euro 5	<i>10E9 pkm</i>	46	48	4%	34	39	13%	47	59	25%

S.4 Optimal use of individual biomass feedstocks

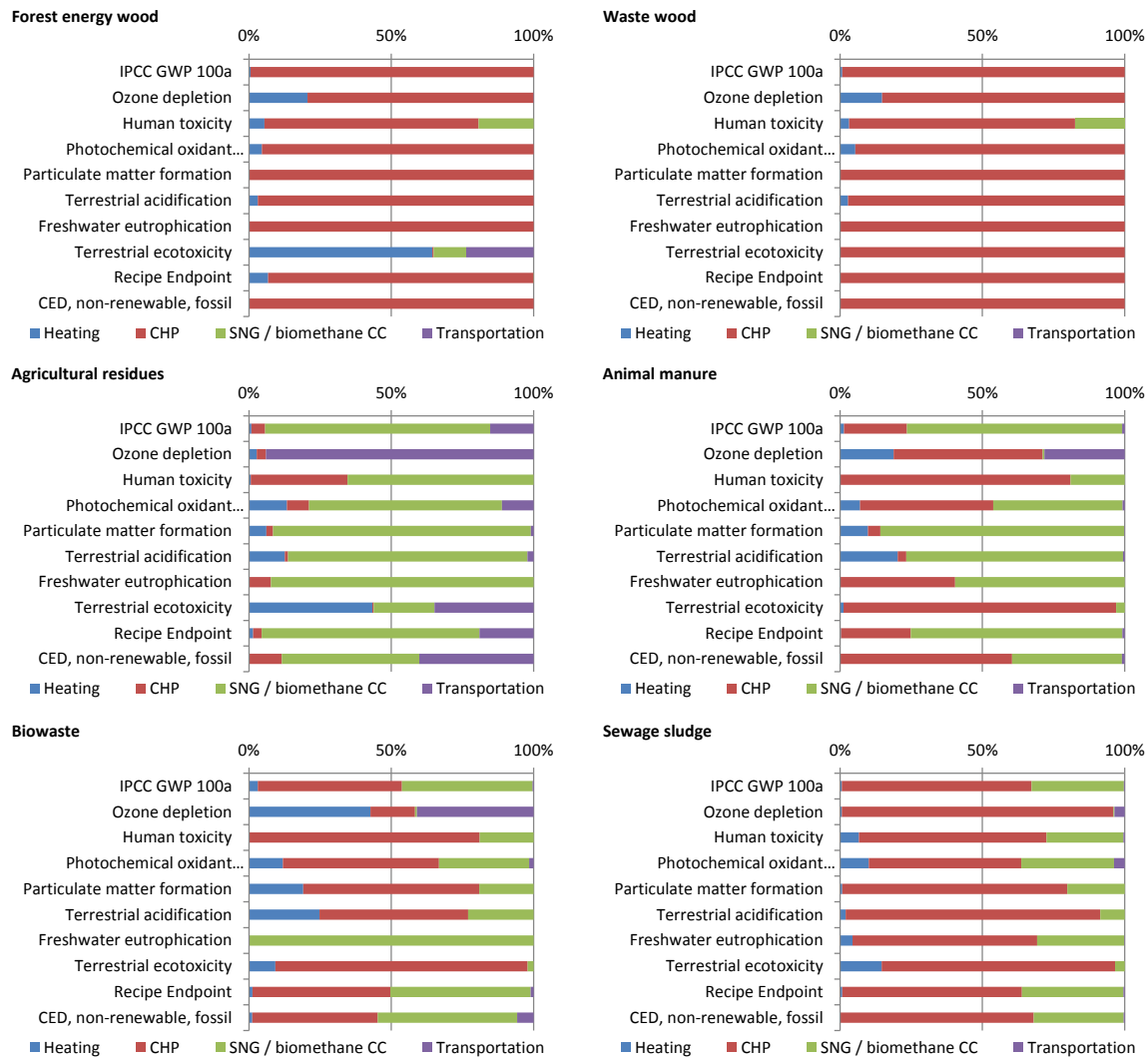


Fig. S-1: Optimal biomass use by feedstock in the scenario Today 2010

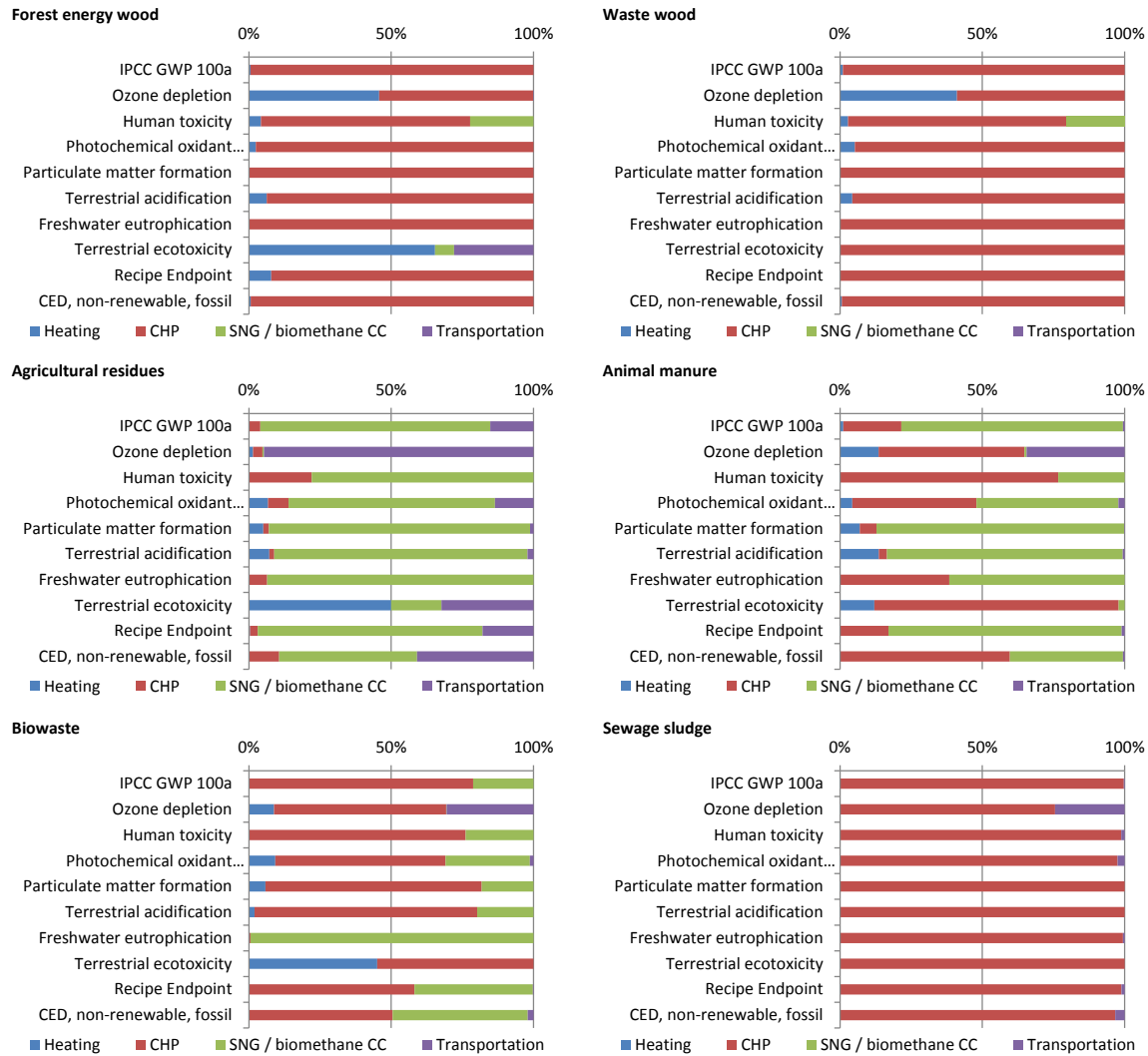


Fig. S-2: Optimal biomass use by feedstock in the scenario Reference 2030

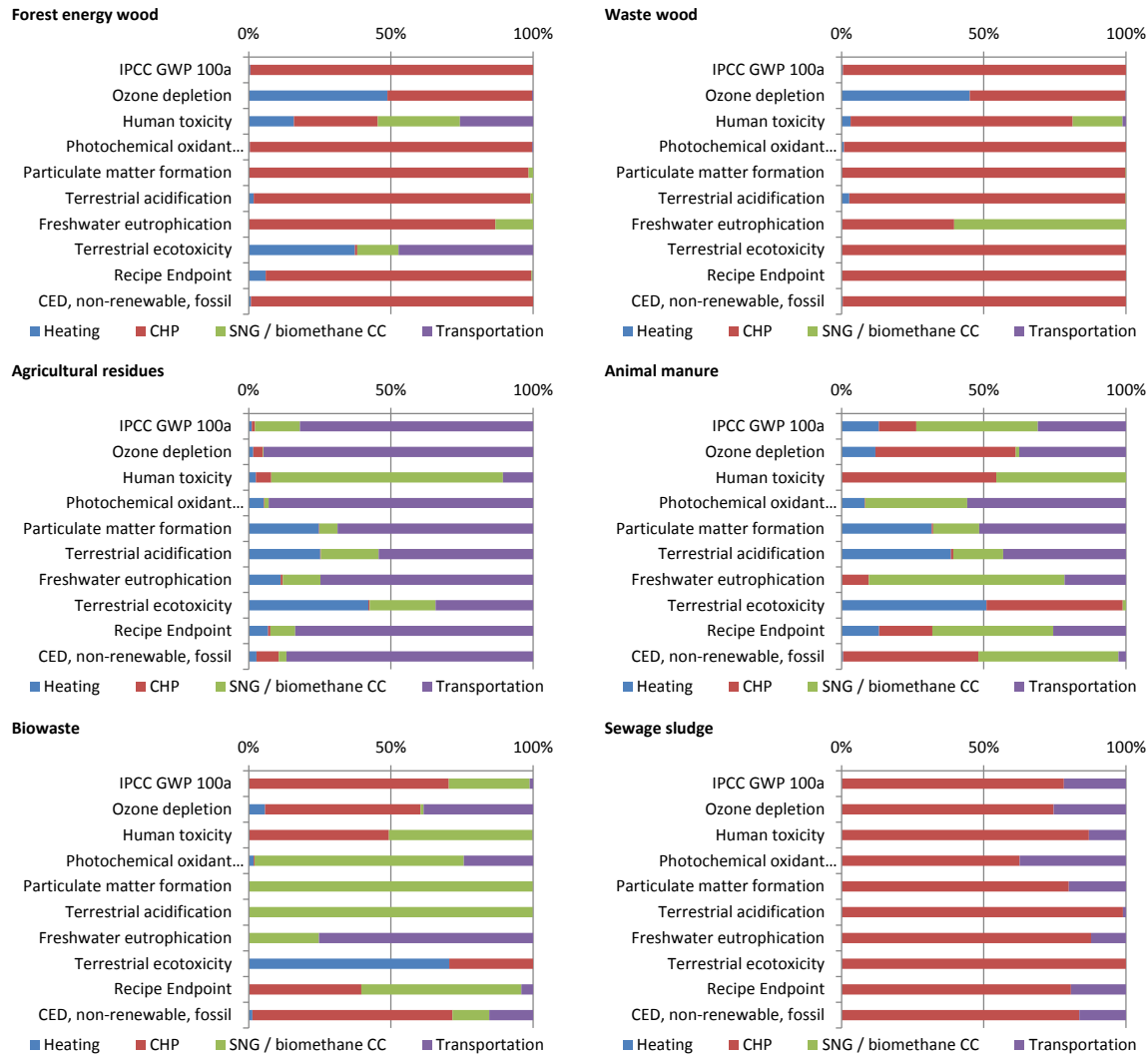


Fig. S-3: Optimal biomass use by feedstock in the scenario Revolution 2030

S.5 Sensitivity analyses

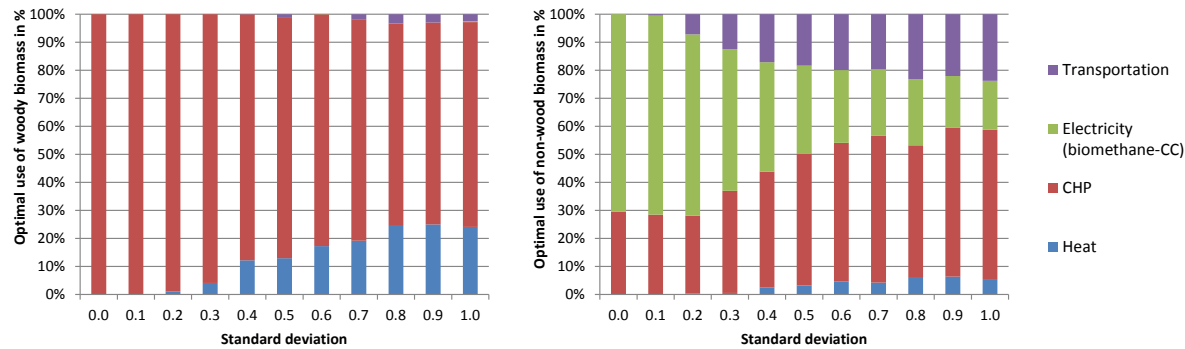
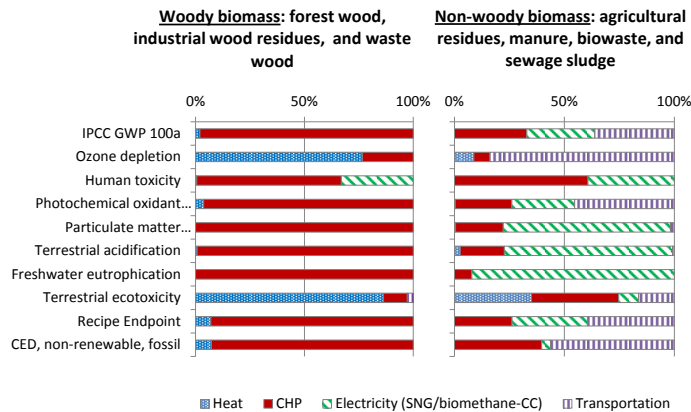


Fig. S-4: Optimal use of woody (left) and non-woody (right) biomass for GWP IPCC 100a for heating, CHP, electricity generation, and transportation as a function of the assumed standard deviation

a) optimal use of biomass



b) optimal substitution of fossil energy services

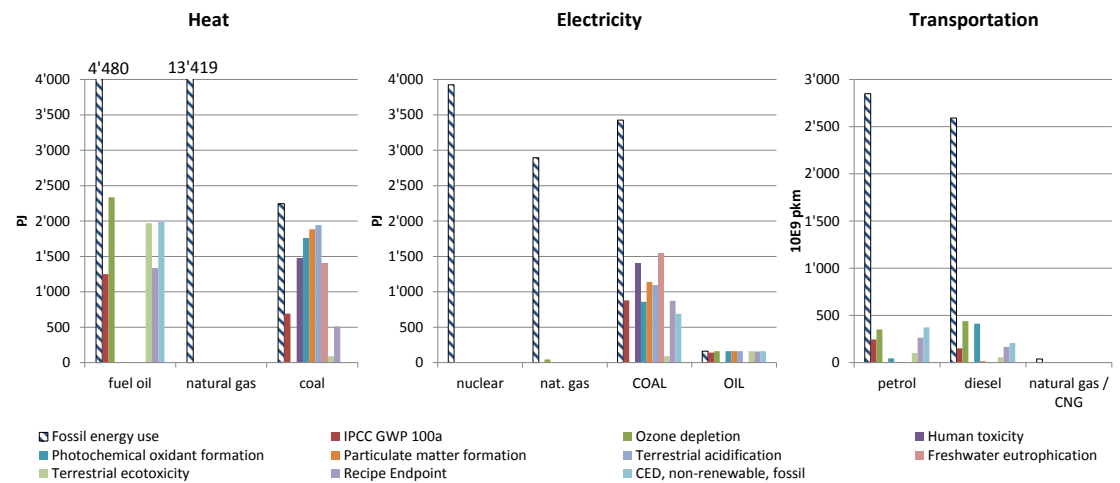
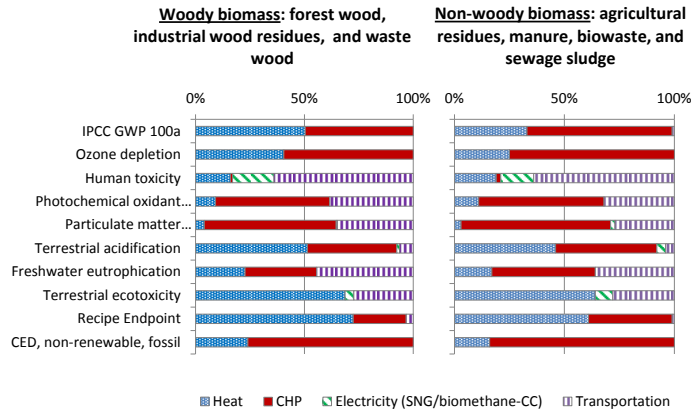


Fig. S-5: If the environmental impacts of oil based technologies were to increase by 50% (Reference Scenario)

a) optimal use of biomass



b) optimal substitution of fossil energy services

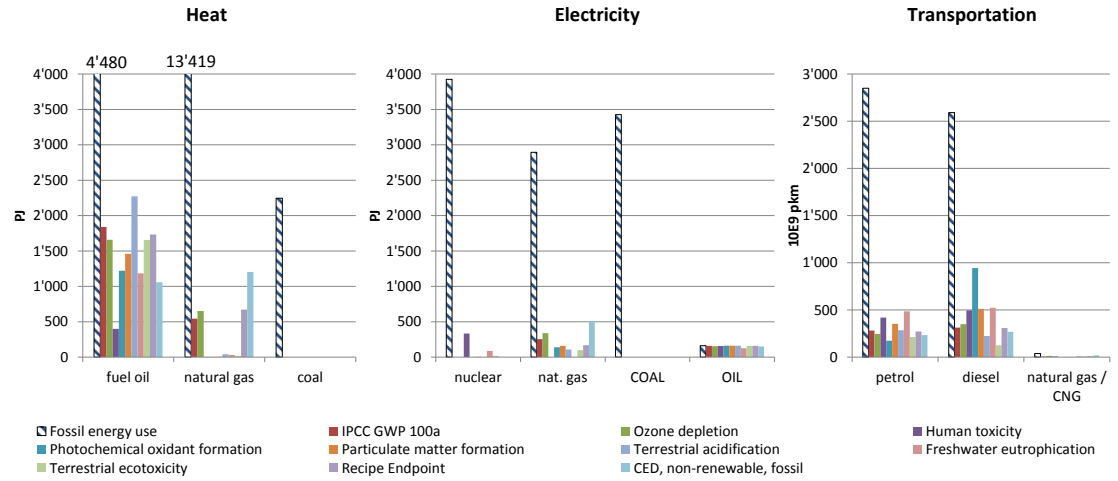
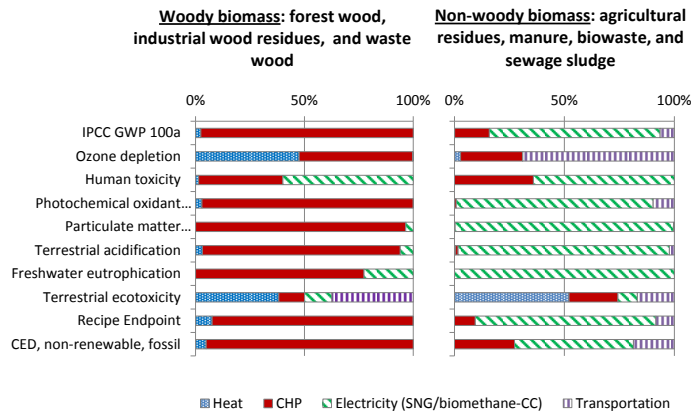


Fig. S-6: If coal could not be substituted (Reference Scenario)

a) optimal use of biomass



b) optimal substitution of fossil energy services

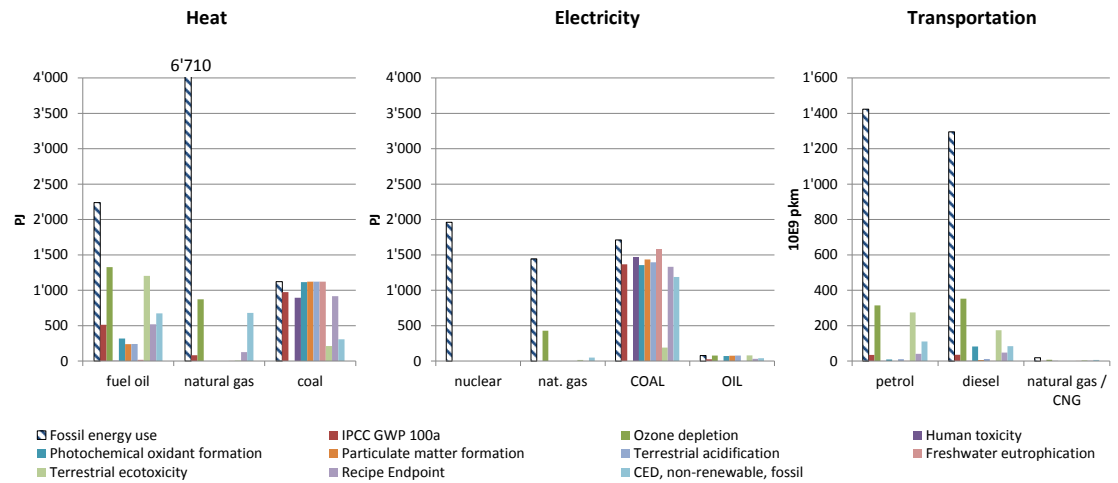
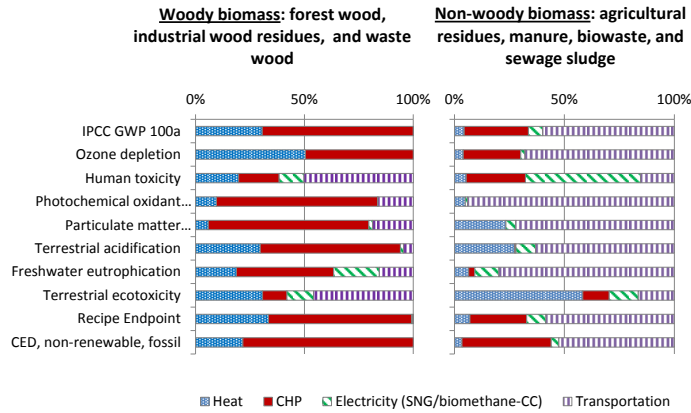


Fig. S-7: If fossil energy technologies could only be replaced to a maximal degree of 50% (Reference Scenario)

a) optimal use of biomass



b) optimal substitution of fossil energy services

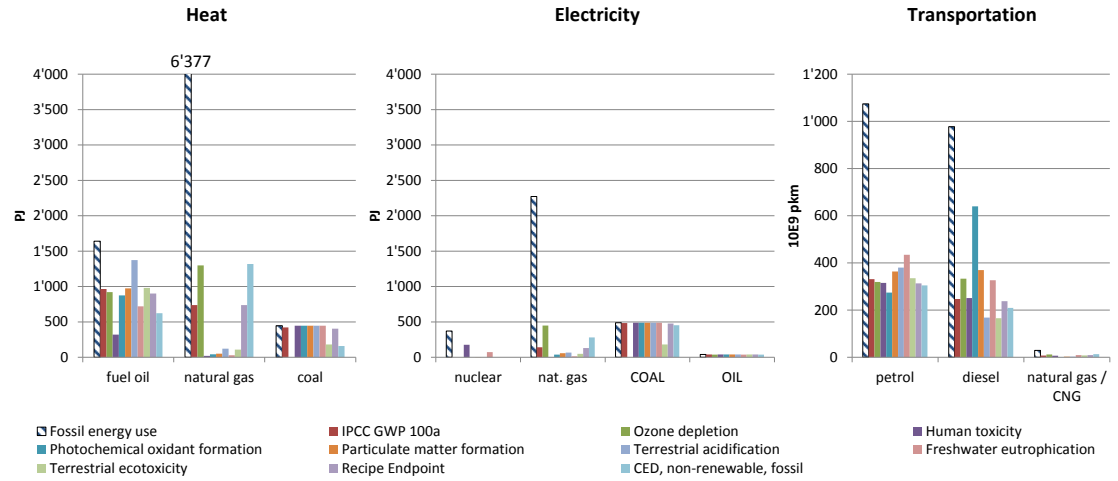
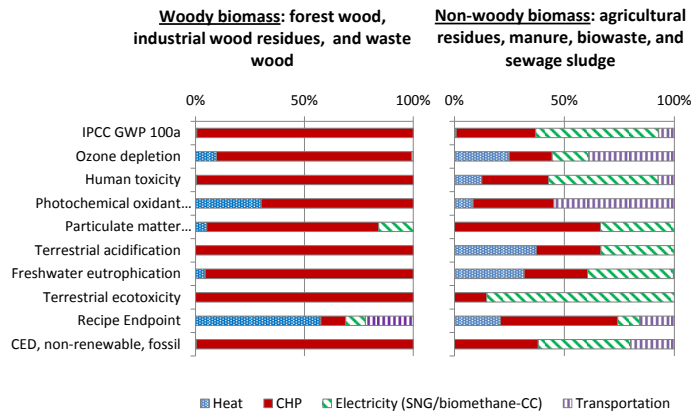


Fig. S-8: If fossil energy technologies could only be replaced to a maximal degree of 50% (Revolution Scenario)

a) optimal use of biomass



b) optimal substitution of fossil energy services

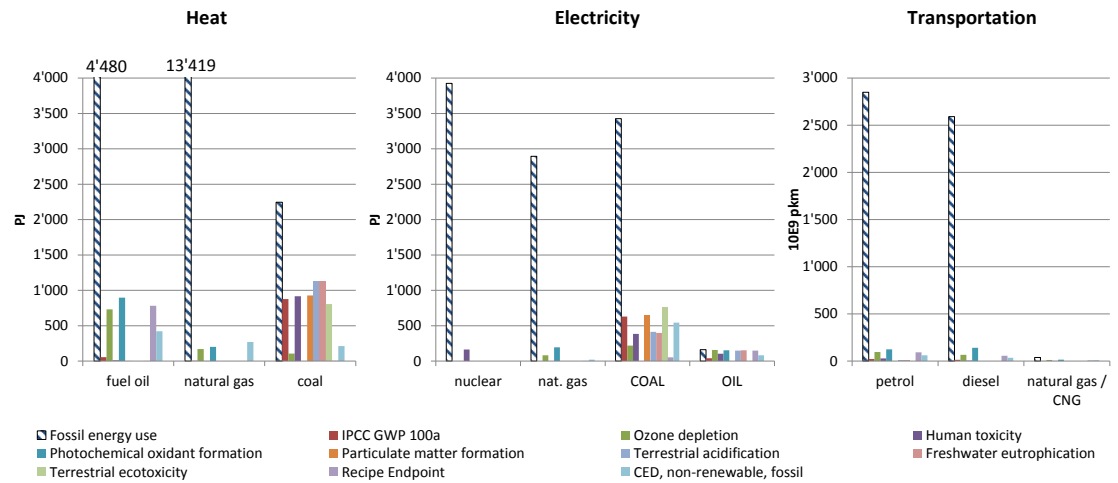
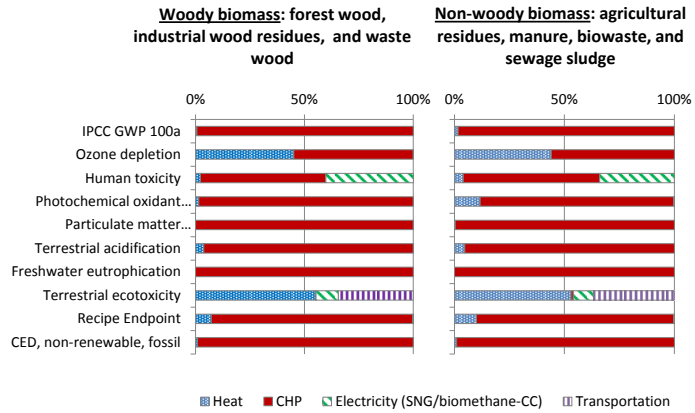


Fig. S-9: 50% decrease in biomass availability (Reference Scenario)

a) optimal use of biomass



b) optimal substitution of fossil energy services

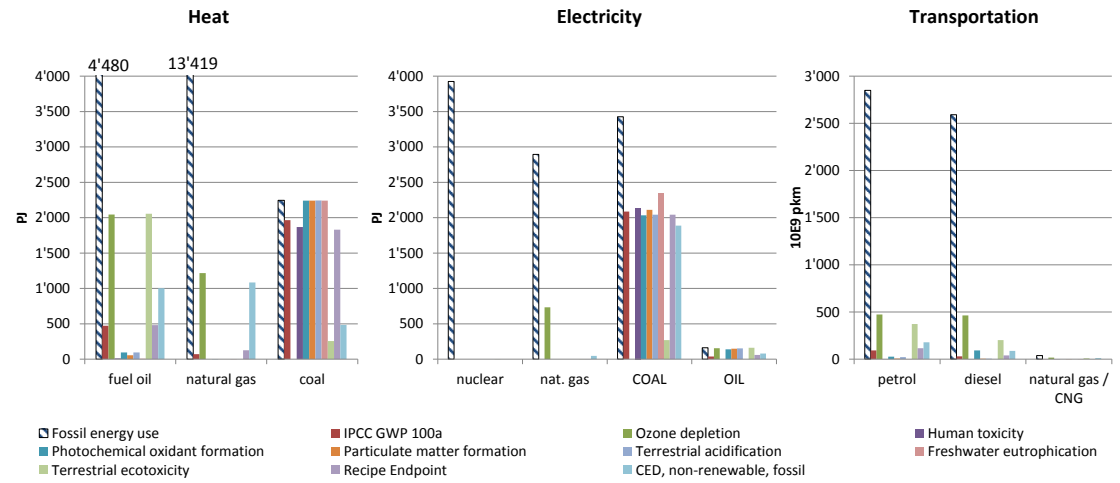
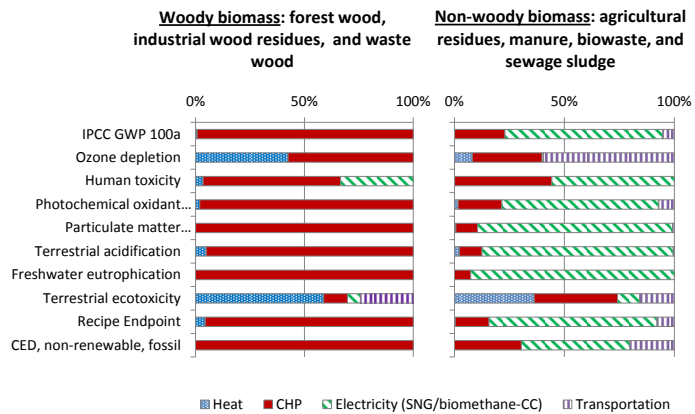


Fig. S-10: 50% increase in biomass availability (Reference Scenario)

a) optimal use of biomass



b) optimal substitution of fossil energy services

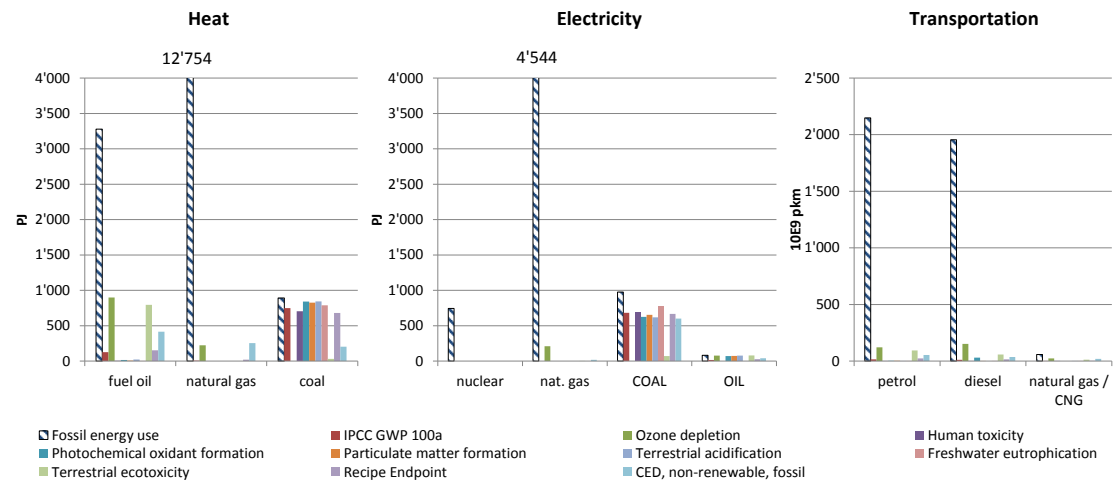
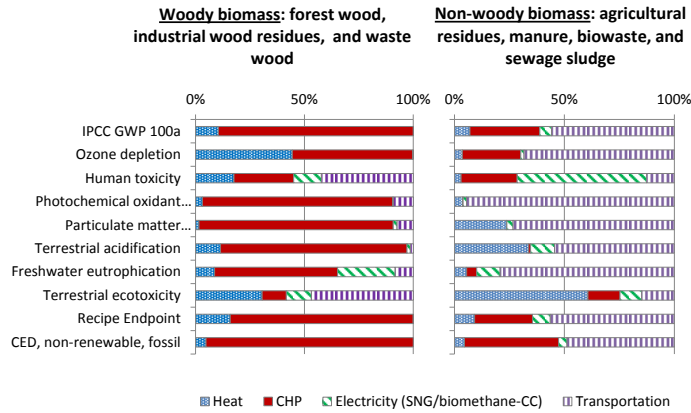


Fig. S-11: 50% decrease in biomass availability (Revolution Scenario)

a) optimal use of biomass



b) optimal substitution of fossil energy services

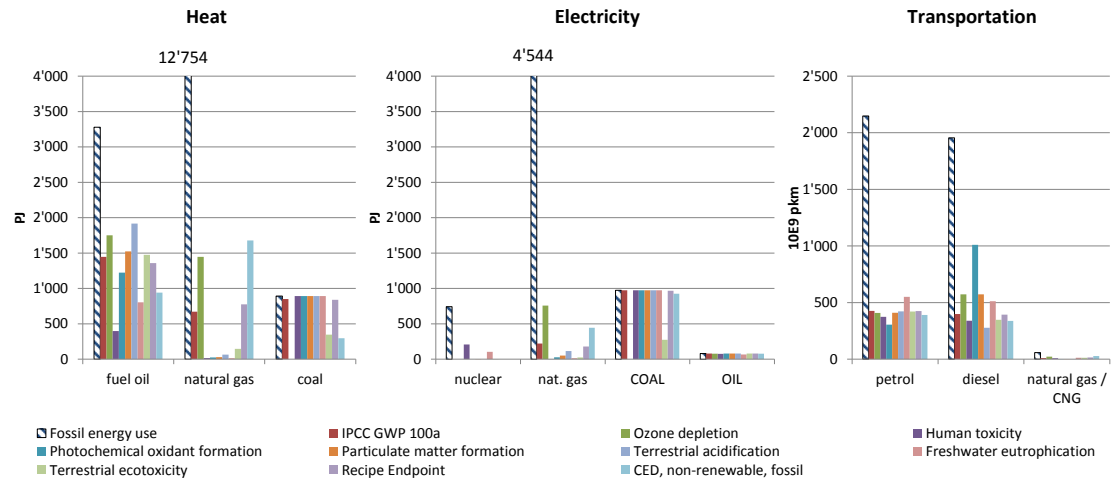
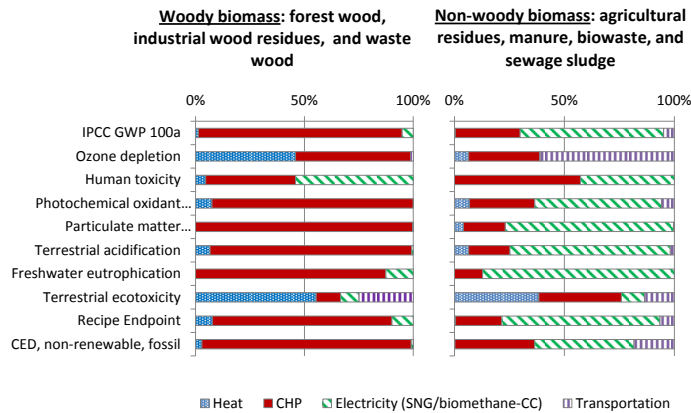


Fig. S-12: 50% increase in biomass availability (Revolution Scenario)

a) optimal use of biomass



b) optimal substitution of fossil energy services

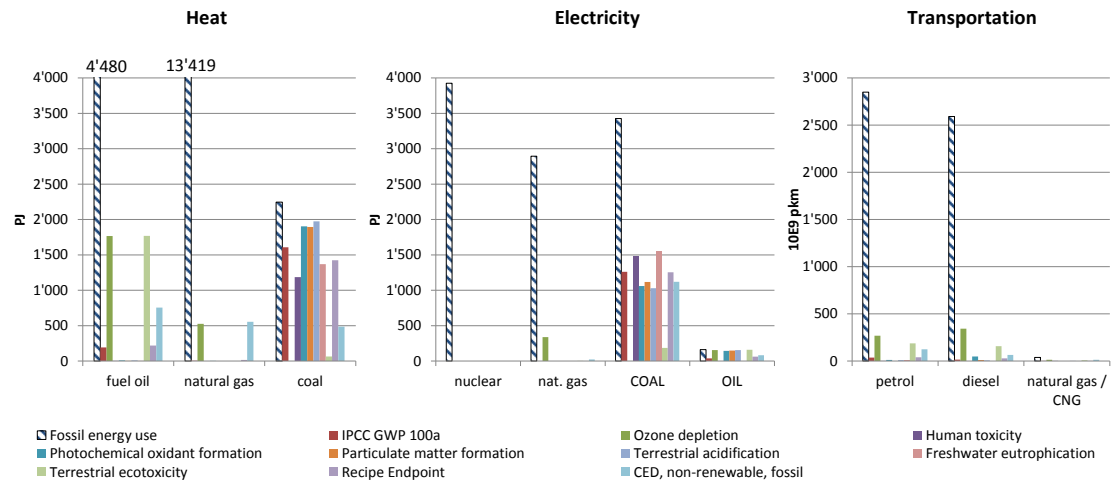


Fig. S-13: Conversion efficiency of wood to SNG increased to 70% (Reference Scenario)

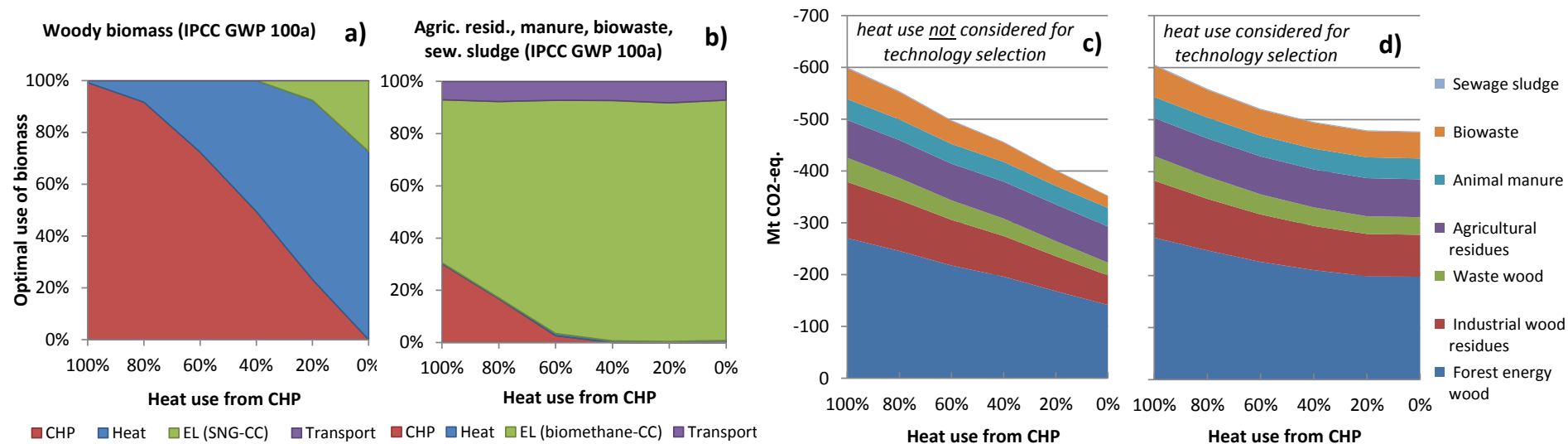


Fig. S-14: Sensitivity of heat use from CHP. (a) and (b) show the optimal use of biomass depending on the fraction of heat used from CHP. Part (c) shows the avoided GHG emissions if the heat use from CHP *is not considered* (i.e. assuming always 100% heat use, but not actually using it) and part (d) if it *is considered* in the selection of bioenergy technologies during optimization (Reference Scenario)