Supplementary Materials: Life Cycle Environmental Impact of Underground Plastic Recharge Chambers in Stormwater Management

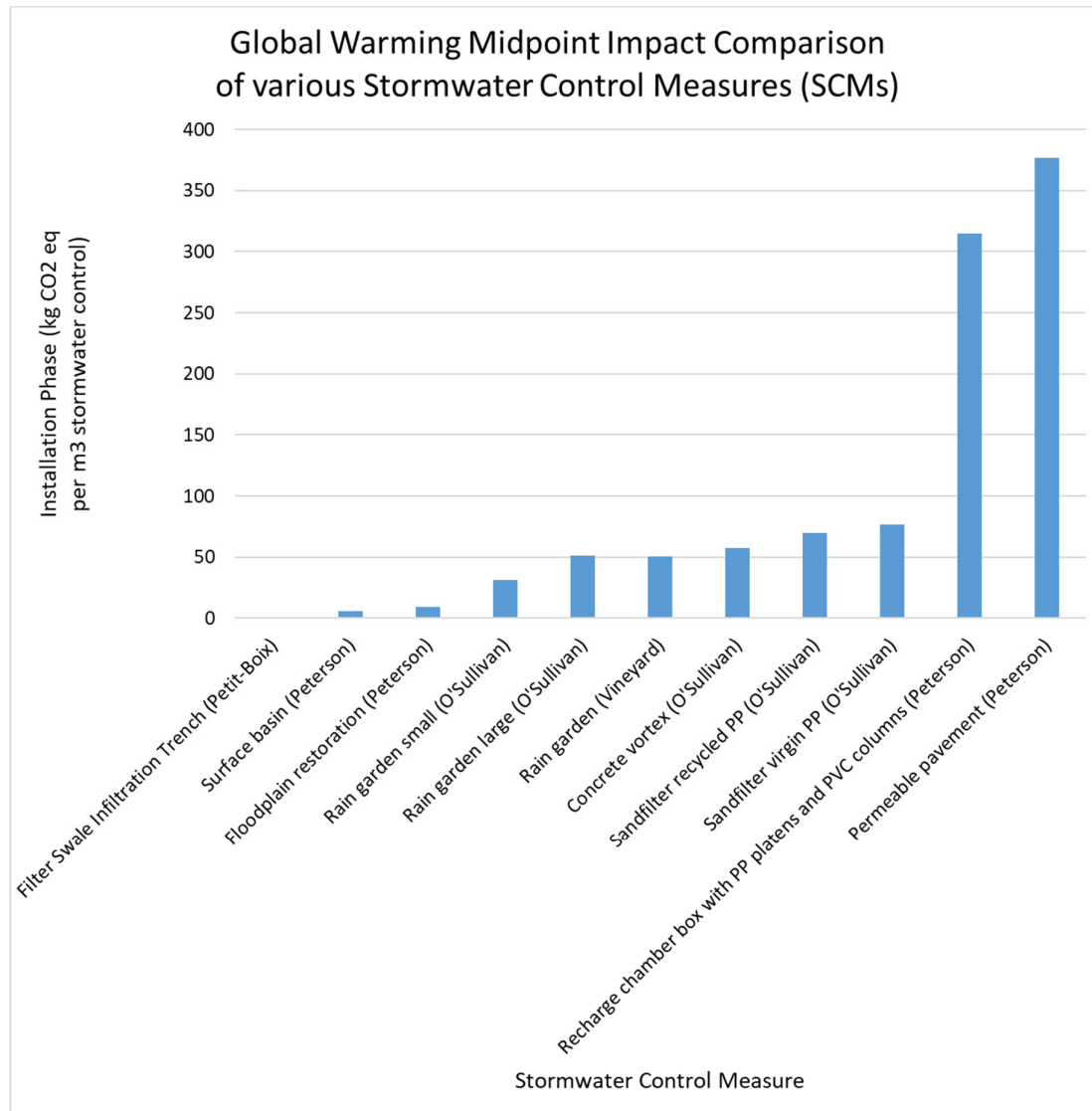Lisa A. Peterson, Patricia M. Gallagher and Sabrina Spatari

Figure S1. Comparison of stormwater management solutions showing a range of up to nearly 400 kg CO_2 eq per cubic meter of managed stormwater [1–4].
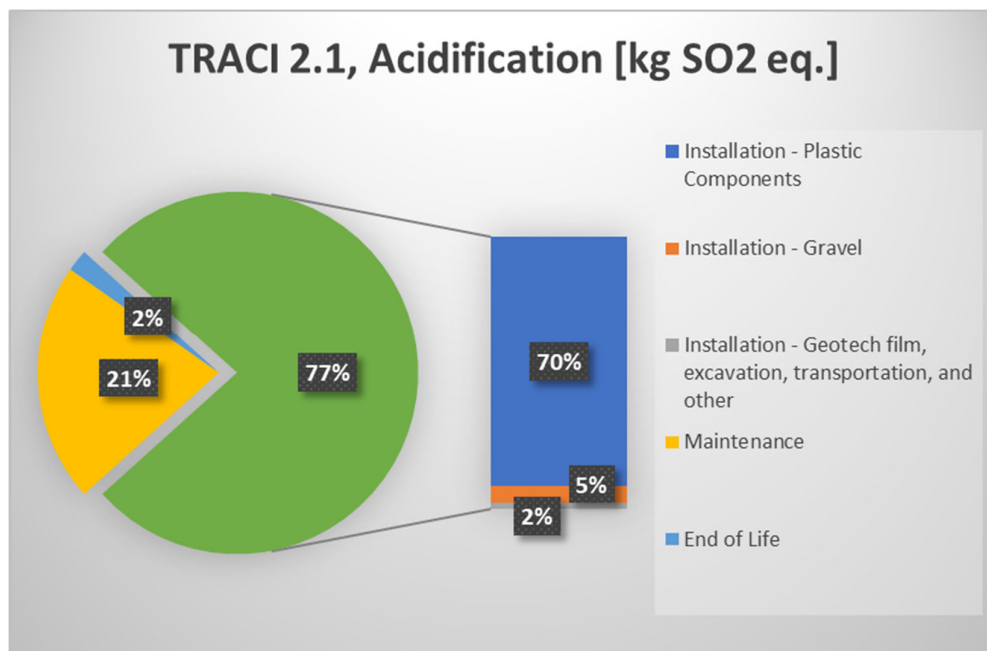
Figure S2. Cradle-to-grave LCA for plastic box recharge chamber reveals installation phase as 77% of the life cycle midpoint impact for acidification and the plastic components as 70% of the life cycle or 92% of the installation phase.
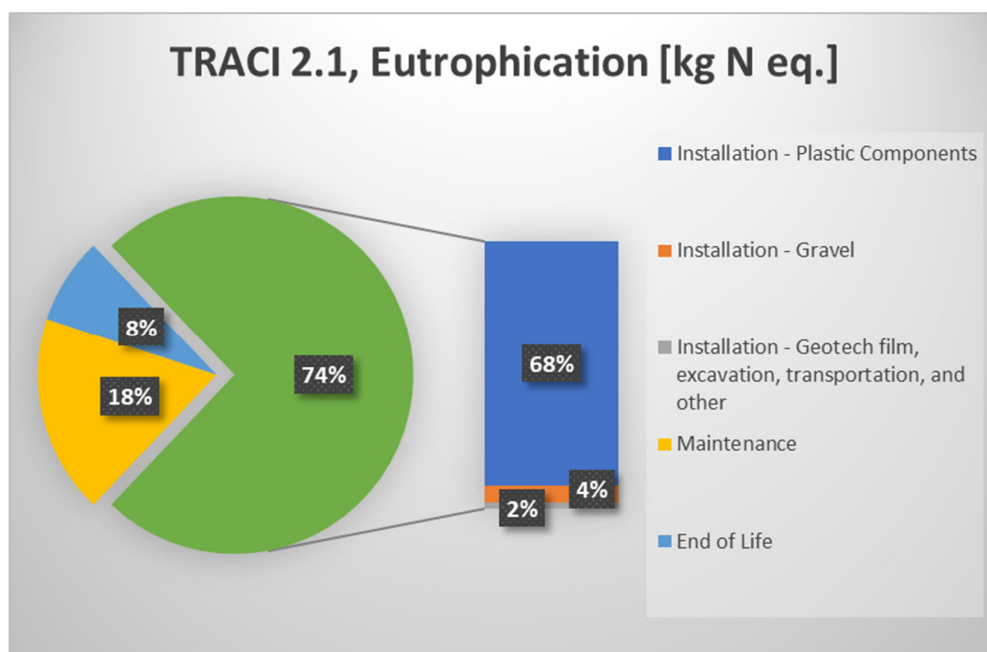

Figure S3. Cradle-to-grave LCA for plastic box recharge chamber reveals installation phase as 74% of the life cycle midpoint impact for eutrophication and the plastic components as 68% of the life cycle or 92% of the installation phase.
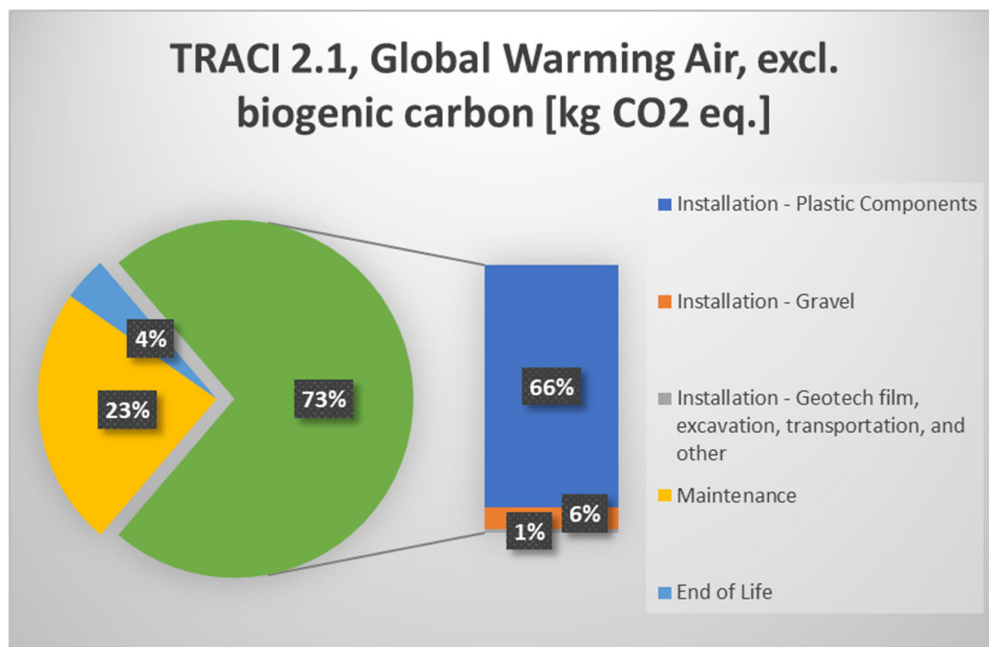
Figure S4. Cradle-to-grave LCA for plastic box recharge chamber reveals installation phase as 73% of the life cycle midpoint impact for global warming and the plastic components as 66% of the life cycle or 91% of the installation phase.
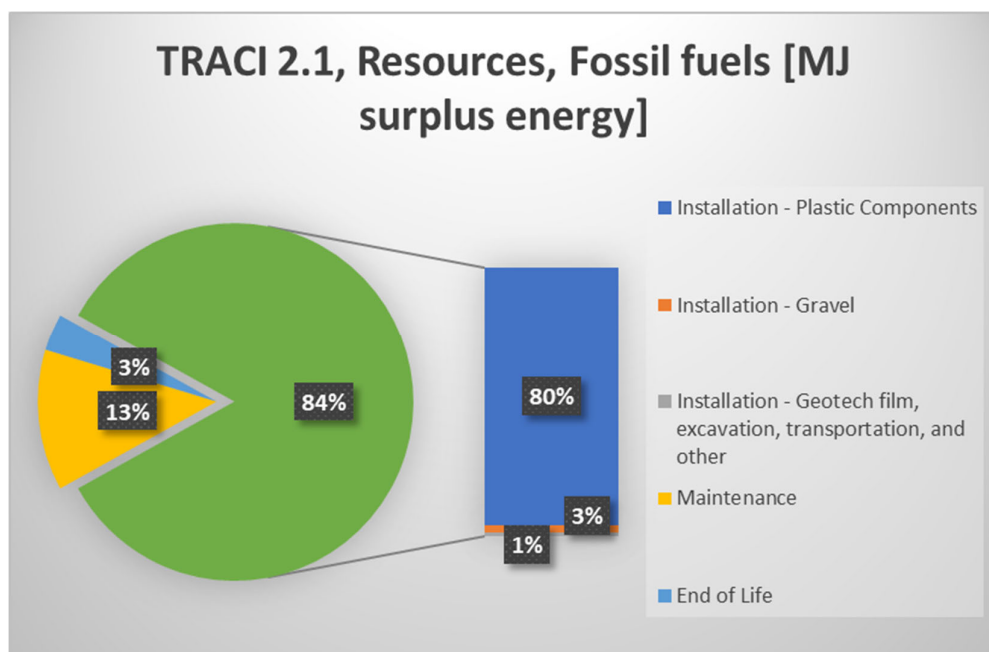

Figure S5. Cradle-to-grave LCA for plastic box recharge chamber reveals installation phase as 84% of the life cycle midpoint impact for fossil fuel resources and the plastic components as 80% of the life cycle or 95% of the installation phase.
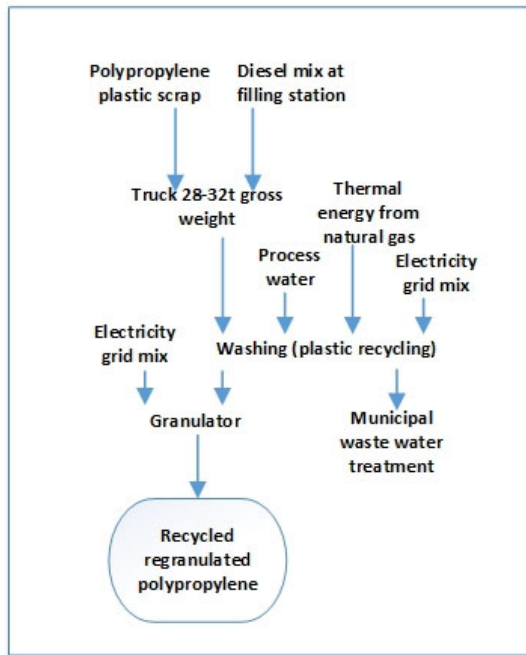
Figure S6. System diagram for recycled regranulated polypropylene.

Table S1. Recharge chamber plastic box SCMs evaluated (data sourced in 2018).

Supplier	Brand Name	Material	Manufac-turing Process	Backfill/ Covering	Mass (kg/m3 storage)	Source
ACF Environ-mental	R-Tank SD	Polypropylene (recycled)	Injection Molding	Gravel	63.43	[5]
ACO	StormBrixx	Polypropylene (recycled)	Injection Molding	Sand	47.28	[6]
Atlantis	Matrix D-Raintank Mini	Polypropylene (recycled)	Injection Molding	Gravel or Sand	60.55	[7]
Atlantis	Matrix D-Raintank 1	Polypropylene (recycled)	Injection Molding	Gravel or Sand	51.58	[7]
Atlantis	Matrix D-Raintank 2	Polypropylene (recycled)	Injection Molding	Gravel or Sand	48.69	[7]
Atlantis	Matrix D-Raintank 3	Polypropylene (recycled)	Injection Molding	Gravel or Sand	47.70	[7]
Atlantis	Matrix D-Raintank 4	Polypropylene (recycled)	Injection Molding	Gravel or Sand	49.34	[7]
Atlantis	Matrix D-Raintank 5	Polypropylene (recycled)	Injection Molding	Gravel or Sand	67.54	[7]
Brentwood StormTank	StormTank	Polypropylene & Polyvinylchloride	Injection Molding & Extrusion	Gravel	39.78	[8]
Brentwood StormTank	StormTank	Polypropylene & Polyvinylchloride	Injection Molding & Extrusion	Gravel	37.08	[8]
Brentwood StormTank	StormTank	Polypropylene & Polyvinylchloride	Injection Molding & Extrusion	Gravel	34.80	[8]
Brentwood StormTank	StormTank	Polypropylene & Polyvinylchloride	Injection Molding & Extrusion	Gravel	33.56	[8]
EcoRain	Eco-Rain Tank ET-1500	Polypropylene (recycled)	Injection Molding	Gravel	51.42	[9]
EcoRain	Eco-Rain Tank ET-1501	Polypropylene (recycled)	Injection Molding	Gravel	48.13	[9]
EcoRain	Eco-Rain Tank ET-1501.5	Polypropylene (recycled)	Injection Molding	Gravel	45.75	[9]
EcoRain	Eco-Rain Tank ET-1502	Polypropylene (recycled)	Injection Molding	Gravel	45.26	[9]
EcoRain	Eco-Rain Tank ET-1502.5	Polypropylene (recycled)	Injection Molding	Gravel	44.38	[9]
EcoRain	Eco-Rain Tank ET-1503	Polypropylene (recycled)	Injection Molding	Gravel	44.28	[9]
EcoRain	Eco-Rain Tank ET-1503.5	Polypropylene (recycled)	Injection Molding	Gravel	43.75	[9]
EcoRain	Eco-Rain Tank ET-1504	Polypropylene (recycled)	Injection Molding	Gravel	43.78	[9]
EcoRain	Eco-Rain Tank ET-1504.5	Polypropylene (recycled)	Injection Molding	Gravel	43.45	[9]
EcoRain	Eco-Rain Tank ET-1505	Polypropylene (recycled)	Injection Molding	Gravel	43.47	[9]

Greening Solution	GS-tanks M2014	Polypropylene (recycled)	Injection Molding	Sand	66.67	[10]
Greening Solution	GS-tanks M2015H	Polypropylene (recycled)	Injection Molding	Sand	76.53	[10]
Greening Solution	GS-tanks M2015F	Polypropylene (recycled)	Injection Molding	Sand	61.06	[10]
Greening Solution	GS-tanks M2016S	Polypropylene (recycled)	Injection Molding	Sand	63.29	[10]
Greening Solution	GS-tanks M2016B	Polypropylene (recycled)	Injection Molding	Sand	56.25	[10]
NidaPlast	AZbox	Polypropylene	Injection Molding	Gravel	84.85	[11]
NidaPlast	Nidaflow EP500	Polypropylene	Extrusion	Gravel	40.00	[11]
NidaPlast	Nidaflow EP600	Polypropylene	Extrusion	Gravel	44.00	[11]
Wavin	Q-Bic Plus	Polypropylene	Injection Molding	Sand	43.22	[12]

Table S2. Recharge chamber plastic arch SCMs evaluated. Note that the typical process is structural foam polypropylene or gas-assisted injection molding polypropylene. For LCA process modeling, the injection molding process is used as a proxy for these detailed variants of processing. (Data sourced in 2018.)

Supplier	Brand Name	Material	Manufac-turing Process	Backfill/ Covering	Mass (kg/m3 storage)	Source
ADS	StormTech SC-160LP	Polypropylene	Injection Molding	Gravel	25.95	[13]
ADS	StormTech SC-310	Polypropylene	Injection Molding	Gravel	19.09	[13]
ADS	StormTech SC-740	Polypropylene	Injection Molding	Gravel	15.85	[13]
Contech	ChamberMaxx	Polypropylene	Injection Molding	Gravel	15.54	[14]
Graf	EcoBloc Infil-tration Tunnel	Polypropylene	Injection Molding	Gravel	36.67	[15]
Prinsco	Hydro Stor HS180	Polypropylene	Injection Molding	Gravel	15.09	[16]
Prinsco	Hydro Stor HS180	Polypropylene	Injection Molding	Gravel	11.30	[16]
Stormkeeper	StormKeeper Chamber SK75	Polypropylene	Injection Molding	Gravel	15.09	[17]
Stormkeeper	StormKeeper Chamber SK180	Polypropylene	Injection Molding	Gravel	11.30	[17]

Table S3. Densities of inventory items for conversion from volume or area to mass.

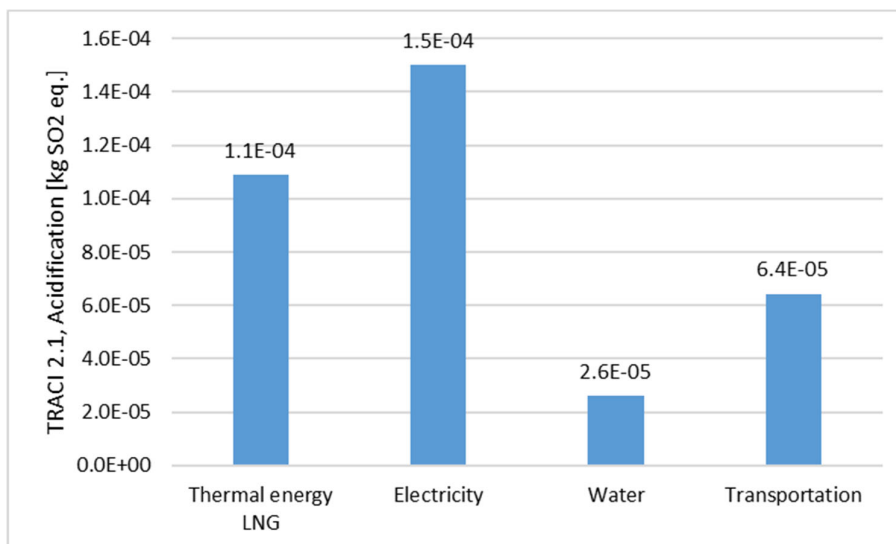| Inventory item	Density	Source
Moist excavated earth	1442 kg per m3	[18]
Geotextile fabric	0.15 kg per m2	[19]
Gravel	1602 kg per m3	[18]
Sand	1602 kg per m3	[18]

Figure S7. Acidification impact assessment shows the dominance of electricity and thermal energy from natural gas in the polypropylene recycling process, with an impact of 3.5E-4 kg SO_2 eq per 1kg recycled polypropylene granulate. Virgin polypropylene has an impact of 2.7E-3 kg SO_2 eq per 1kg.
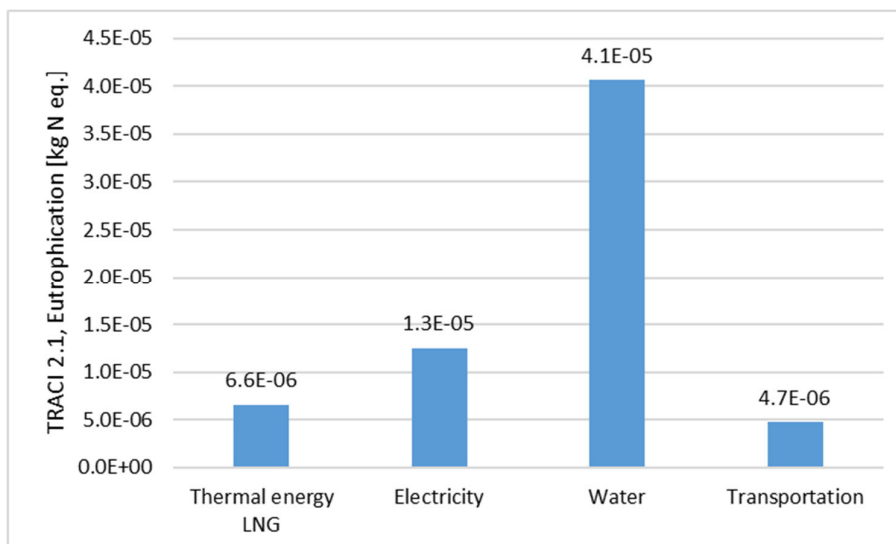

Figure S8. Eutrophication impact assessment shows the dominance of water in the polypropylene recycling process, with an impact of 6.5E-5 kg N eq per 1kg recycled polypropylene granulate. Virgin polypropylene has an impact of 2E-4 kg N eq per 1kg.
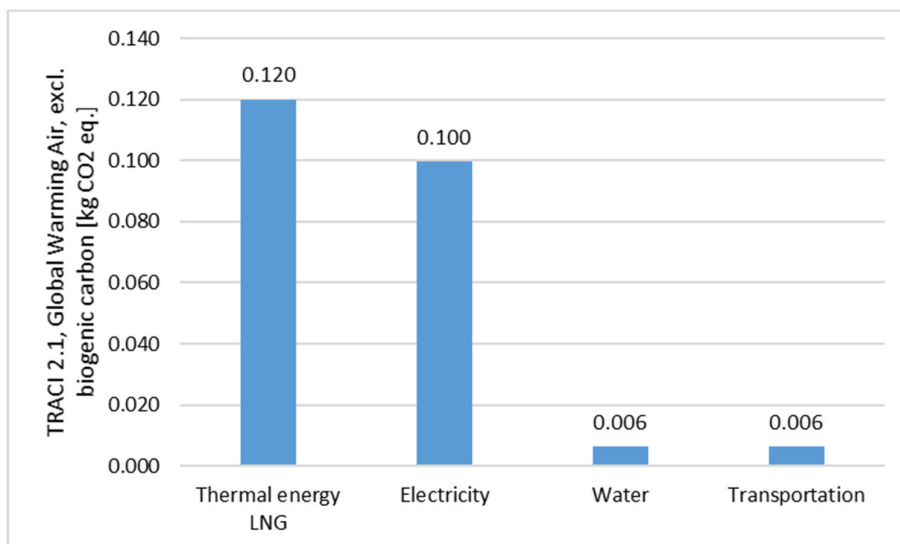
Figure S9. Global warming impact assessment shows the dominance of thermal energy from natural gas and electricity in the polypropylene recycling process, with an impact of 0.23kg CO_2 eq per 1kg recycled polypropylene granulate. Virgin polypropylene has an impact of 1.66 kg CO_2 eq per 1kg.
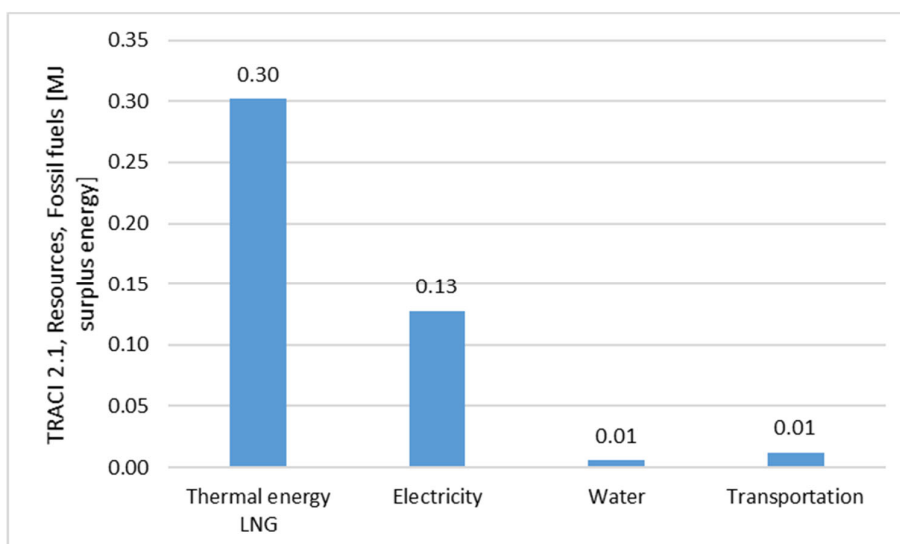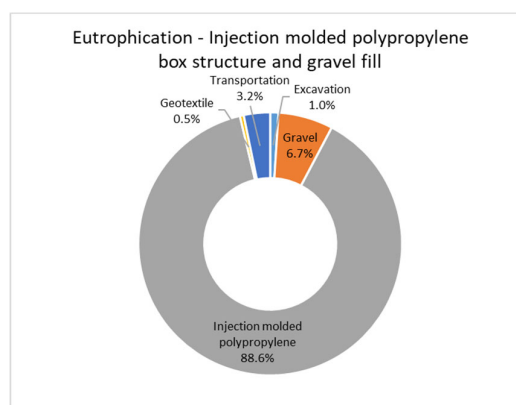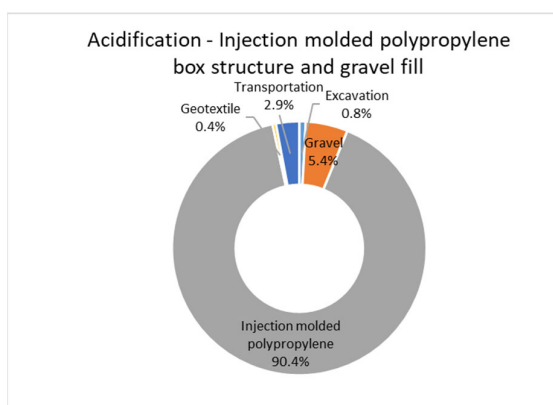

Figure S10. Fossil fuel resources impact assessment shows the dominance of thermal energy from natural gas and electricity in the polypropylene recycling process, with an impact of 0.45 MJ surplus energy per 1kg recycled polypropylene granulate. Virgin polypropylene has an impact of 9.39 MJ surplus energy per 1kg.
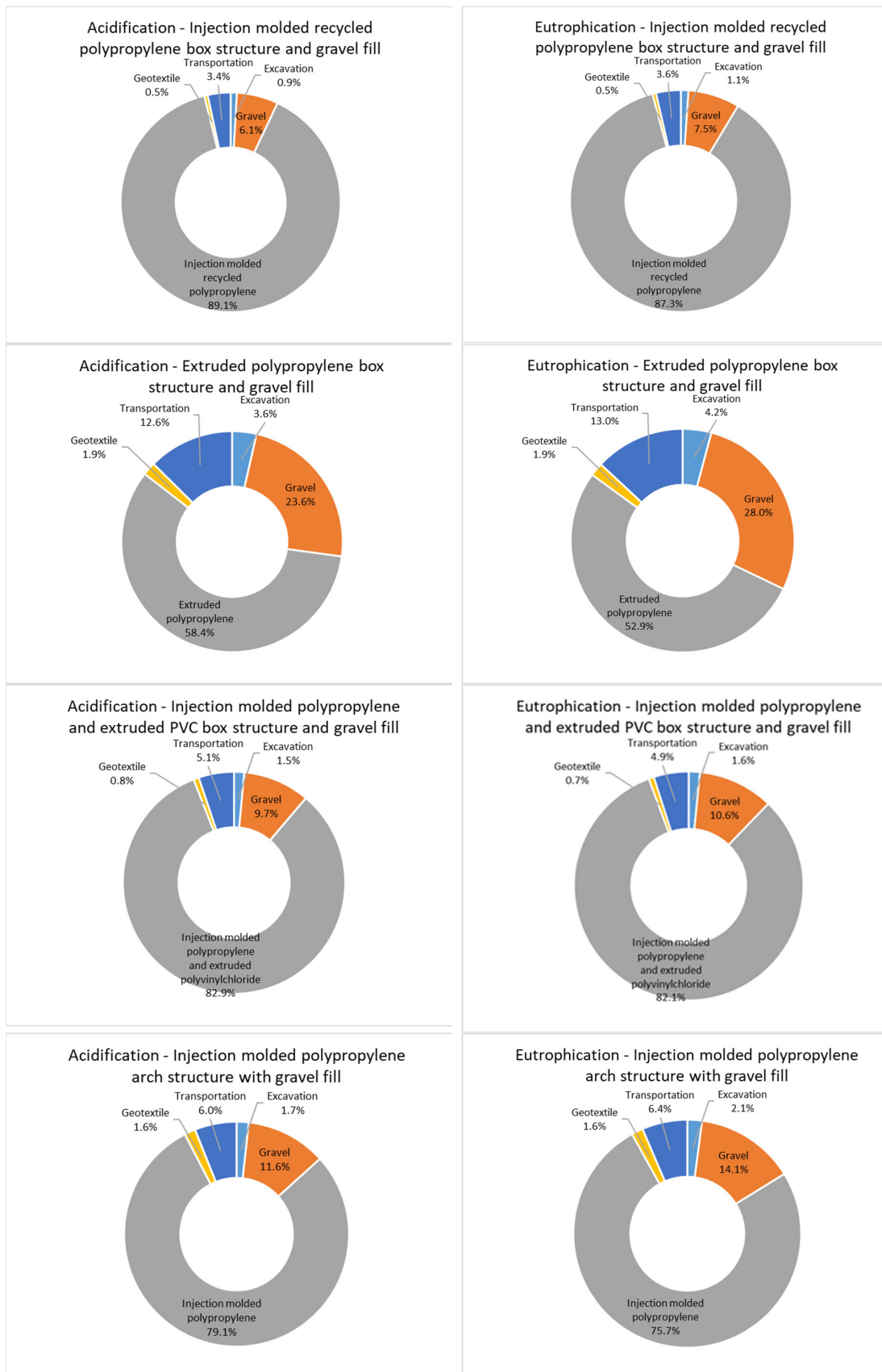
Figure S11. Sunburst charts show the plastic components as more than 50% of the acidification and eutrophication midpoint impact followed by the backfill material for each of the material and process alternatives. The plastic components in the extruded polypropylene box represent the lowest acidification and

eutrophication midpoint impact at 58% and 52%, respectively, with the gravel backfill representing 23% and 28 %, respectively.

Figure S12. Sunburst charts show the plastic components as approximately 75-90% and backfill material as 7-20% of the global warming midpoint impact for each of the material and process alternatives.
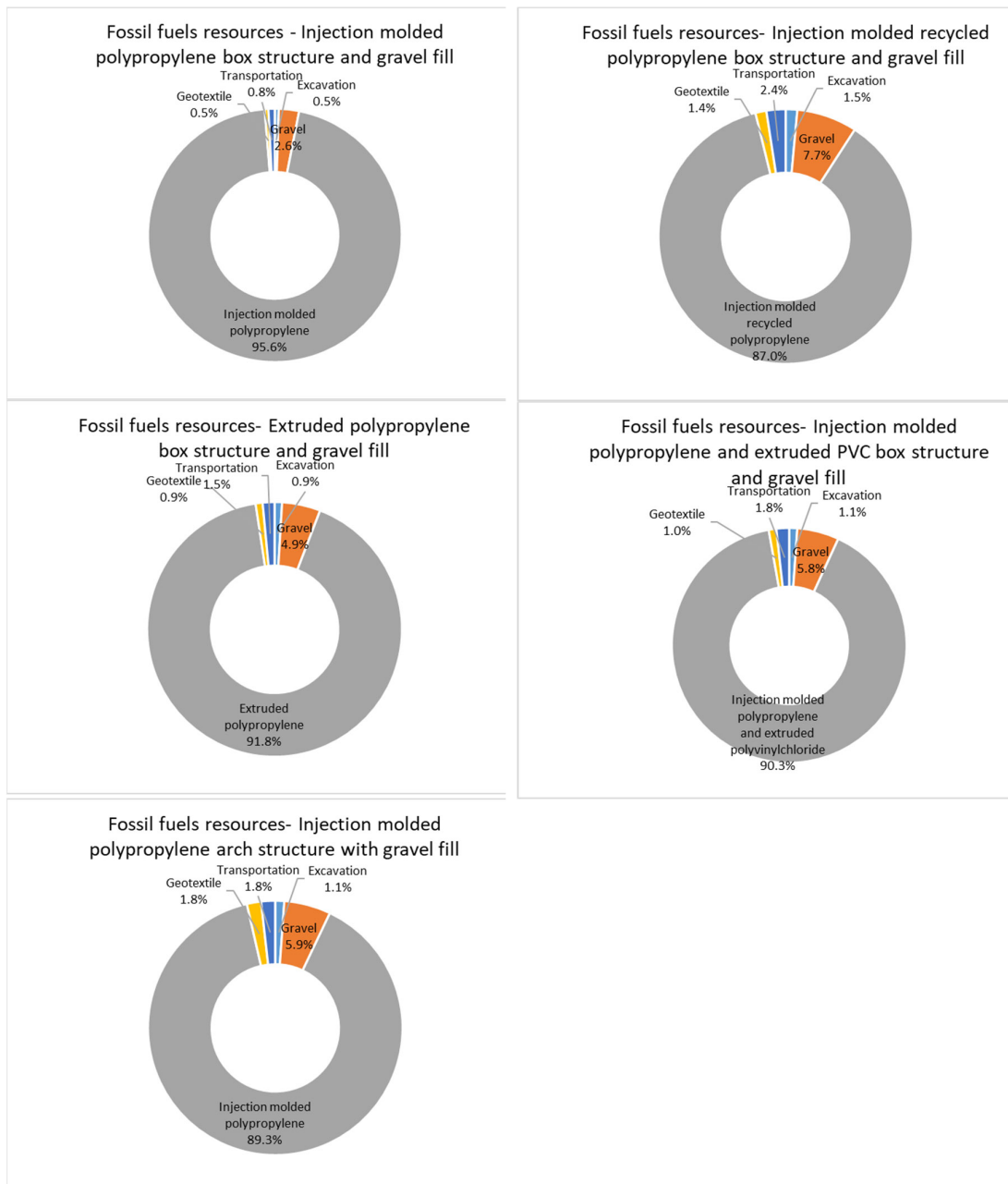
Figure S13. Sunburst charts show the plastic components as approximately 87-96% and backfill material as 2-8% of the fossil fuels resources midpoint impact for each of the material and process alternatives.

Table S4.

Impact Category	Structure	Range	Plastic Structure	Transpor-tation	Backfill	Excavation	Geotextile
TRACI 2.1, Acidification (kg SO2 eq.)	Box	Min	1.6E-01	4.3E-03	2.3E-03	5.5E-03	1.8E-03
		Base Model	5.7E-01	3.5E-02	6.7E-02	1.0E-02	5.5E-03
		Max	1.5E+00	6.9E-01	1.3E-01	1.5E-02	9.3E-03
	Arch	Min	2.0E-01	1.0E-02	2.0E-02	5.5E-03	6.4E-03
		Base Model	4.2E-01	3.2E-02	6.2E-02	9.3E-03	8.5E-03
		Max	6.5E-01	5.4E-01	1.0E-01	1.3E-02	1.0E-02
	Box	Min	1.0E-02	3.2E-04	1.5E-04	4.5E-04	1.3E-04
		Base Model	4.3E-02	2.6E-03	5.6E-03	8.3E-04	3.9E-04

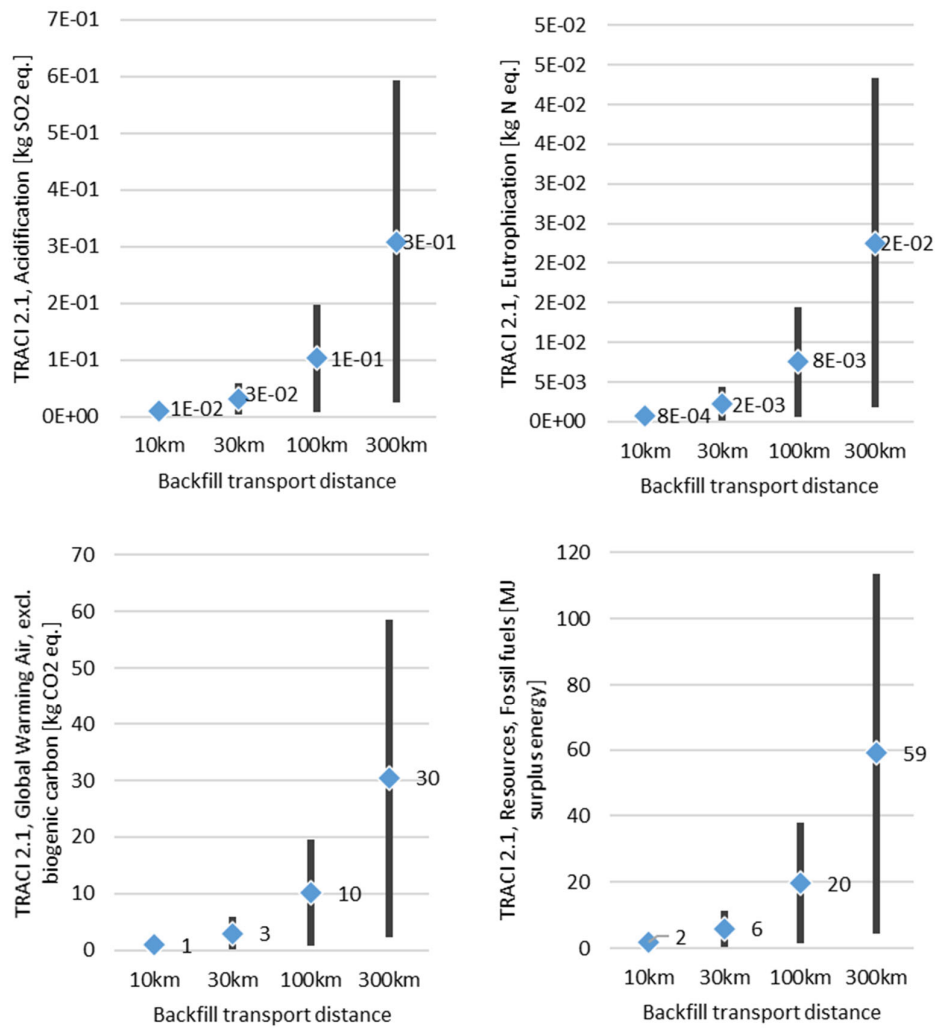|							
TRACI 2.1, Eutrophication (kg N eq.)	Arch	Max	9.8E-02	5.0E-02	1.1E-02	1.2E-03	6.6E-04
		Min	1.3E-02	7.6E-04	1.6E-03	4.5E-04	4.5E-04
		Base Model	2.8E-02	2.3E-03	5.2E-03	7.7E-04	6.0E-04
		Max	4.2E-02	3.9E-02	8.7E-03	1.1E-03	7.4E-04
TRACI 2.1, Global Warming Air, excl. biogenic carbon (kg CO2 eq.)	Box	Min	85.4	0.4	0.3	1.3	0.4
		Base Model	136.9	3.5	23.3	2.3	1.2
		Max	375.2	68.0	44.8	3.4	1.9
	Arch	Min	49.9	1.0	6.8	1.3	1.3
		Base Model	106.0	3.2	21.5	2.1	1.8
		Max	162.0	53.2	36.2	3.0	2.2
TRACI 2.1, Resources, Fossil fuels (MJ surplus energy)	Box	Min	170.0	0.8	0.5	2.3	1.3
		Base Model	347.9	6.8	22.2	4.3	4.0
		Max	1092.4	131.5	42.7	6.2	6.8
	Arch	Min	145.5	2.0	6.5	2.3	4.7
		Base Model	309.0	6.2	20.5	3.9	6.3
		Max	472.1	103.2	34.5	5.5	7.7

Figure S14. Midpoint impact of arch backfill transportation distance shows the increase in potential impact with additional distance of transport.

References

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