Carbon Action

Unlocking Environmental Benefits:

Comparing Plastics Recovered from Biohazardous Waste to Virgin Plastics in an Emissions Avoidance Study.

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Unlocking Environmental Benefits: Comparing Plastics Recovered from Biohazardous Waste to Virgin Plastics in the Laboratory Setting

Executive Summary:

Envetec has commissioned Carbon Action to explore how using recycled plastics instead of new plastics, typically virgin polymers derived from fossil fuels, could reduce absolute Greenhouse Gas (GHG) emissions. Our study seeks to quantify this GHG reduction where the recyclable waste is recovered from on-site shredding and disinfection of biohazardous materials in laboratory settings. By adopting innovative recycling strategies and technologies, the report outlines the benefits of repurposing biohazardous plastics into new products, effectively precluding emissions associated with producing virgin polymers used in creating fresh plastic products.

Historically, biohazardous materials from laboratories have been treated using autoclave sterilisation, incineration, or both, with the residual ash disposed of in landfills. With onsite shredding and disinfection, the end product is a clean flake like material comprised of a mixture of polymers, pending the waste being processed. Advanced technologies can now separate these different types of plastics, such as polypropylene, polyethylene, polystyrene and PET, into separate streams. This opens up the possibility of creating a recycling or circular loop where each type of plastic can be repurposed, allowing manufacturers to include recycled materials in their products and thereby reducing dependency on using new materials. Ultimately, with this process we can envisage a circular loop where the logistics of collecting and processing these recycled materials can be scaled efficiently and quickly, creating a secure pipeline for recycling and reusing plastics. This would substantially reduce the need for new raw materials and contribute to a more sustainable approach to manufacturing.

Our calculation model sets out to quantify the emissions difference between two polymer production paths. The first path is the production of a wide array of virgin polymers suitable for manufacturing. The second is, from processing biohazardous waste, using an onsite shredding and disinfection technology and converting the treated polymer flake from this process into a material that is suitable for use in manufacturing new plastic products.

Our report incorporates conservative estimates from earlier studies for the emissions generated by the recycling process, and we compared them to the emissions caused by producing virgin plastics on a global scale, including transportation to the point of use. Specifically, we analyzed the emissions associated with bringing 1 metric tonne of mixed recycled polymer and 1 metric tonne of virgin polymer to a manufacturing site in Ireland.

Our conclusion is that for every metric tonne of polymer recovered waste we can recycle, we can achieve a significant reduction in emissions - specifically a net emission saving of **2,104.52 kgCO2e**, which is equivalent to a 91% reduction compared to virgin plastic production. Annually the biohazardous waste generated in laboratories is 14.6 M tonnes; every 1% of this total generated biohazardous waste globally per year is recycled through onsite shredding and disinfection, displacing virgin polymer, creates an absolute emissions reduction of 138,268.37 tonnes CO2e *every year based on our assumed biohazardous*

waste materials content mix. Meaning, 10% would equate to 1.3826 million tonnes CO2e reduction per year globally.

The conclusions are stark and highlight the immense potential of recycled biohazardous waste materials in mitigating climate change and reducing the environmental impact of using plastic in manufacturing. GHG emissions from polymer production are high by definition, given the basic raw materials are fossil fuels and refining is highly energy intensive. By recycling previously biohazardous plastics into new products, a situation only possible now that it is no longer ash in landfill, a low emissions solution is presented to the end user. That solution leads to an environmental win.

Plastics and the Environment

Plastics have been a development driver for decades but have turned into a development problem because of their omnipresence in the environment. Plastics have become ubiquitous in modern life, given their unique properties. In recent decades, however, the downside of plastic consumption to society has become apparent as plastic waste has incurred huge costs to the environment, biodiversity, livelihoods, and human health (The World Bank: Where is the value in the Chain? Pathways out of Plastic Pollution, 2022). In addition, the impacts of plastics on climate change are already considerable and are expected to increase. Plastics can be either hydrocarbon based, or bioplastics, which are sourced from renewable biomass materials.

Greenhouse gas emissions from plastic production and after-use incineration cause the most prominent environmental impact of the plastics value chain. This is because the source materials are derived from fossil sources (i.e., crude oil) and the refining processes are themselves, energy intensive. As much of the world's oil is refined in high emission grid jurisdictions, emissions are compounded by dirty power grids. Dirty power grids refer to 'dirty energy' which is made up of fossil fuel sources such as coal, oil, and gas (Phiri & Nyoni, 2023). When production shifts from the UK where the grid emission factor is 193 kg CO2e per kWh to say Indonesia where the Grid EF ranges between 520 – 1770 kg CO2e per kwh – processing emissions increase dramatically (IGES Grid Emission Factors, 2023). However, in addition to GHG emissions, the plastics value chain creates other environmental problems, such as degradation of natural systems as a result of resource extraction and leakage, particularly to oceans, and health and environmental impacts from various substances of concern. A breakdown of the virgin plastics value chain can be seen in Figure 1. (European Environment Agency ETC/WMGE)

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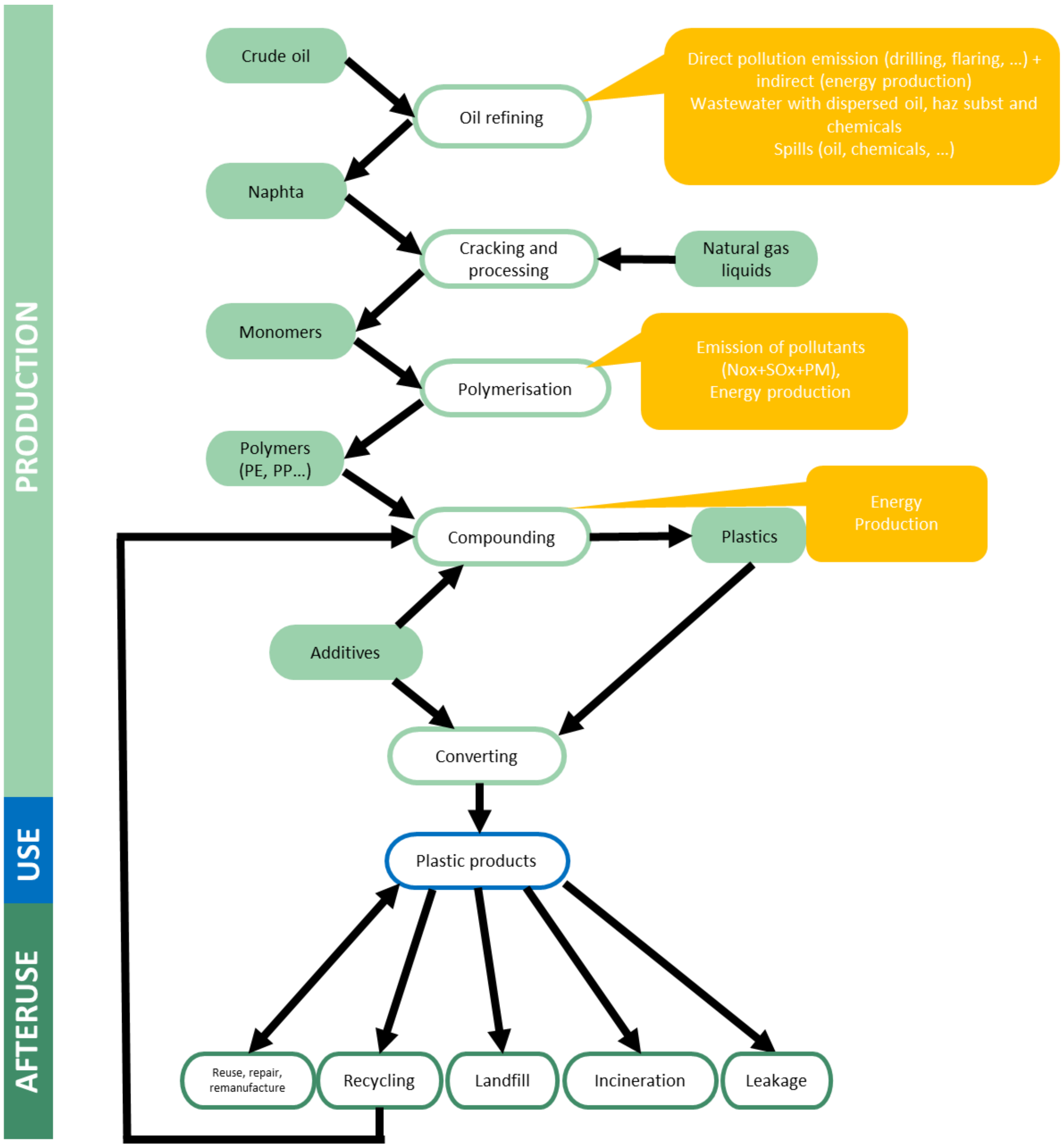

Figure 1. Externalities in the plastics value chain (European Environment Agency ETC/WMGE, 2021)

The Plastic Production Process

Plastics are high molecular weight organic polymers composed of various elements such as carbon, hydrogen, oxygen, nitrogen, sulphur, and chlorine. Chemistry allows us to vary different parameters to fine tune the properties of polymers. We can use different elements, change the type of monomers, and rearrange them in different patterns to change the shape of polymer, its molecular weight, or other chemical/physical properties. This allows plastics to be designed to have the desired properties for a specific application (British Plastics Federation, accessed 2023).

Virgin plastic production is based on a series of emissions intensive activities. These include three basic phases - raw materials extraction and conversion, conversion into final products and end of life disposal. The latter two emission stages are common to our comparative study. Our study therefore compares emissions of polymers from both recycled and virgin sources – *up to the point of conversion into a new plastic product.* For virgin plastic production the first phase of emissions activities, are outlined below.

1. **Raw material extraction and distribution:** largely crude oil, natural gas, and coal – these are a complex mixture of thousands of compounds that then need to be processed.

2. **Refining process** transforms crude oil into different petroleum products – these are converted to yield useful chemicals including "monomers" (a molecule that is the basic building blocks of polymers). In the fractional distillation process, crude oil is heated in a furnace, which is then sent to the distillation unit, where heavy crude oil separates or fractionates into lighter components. One of these, naphtha, is the crucial compound to make many types of plastic.

3. **Polymerisation** is a process whereby light olefin gases (gasoline) such as ethylene, propylene, butylene (i.e., monomers) are converted into higher molecular weight hydrocarbons (polymers). This happens when monomers are chemically bonded into chains.

4. **Compounding/Processing**: In compounding, various blends of materials are melt-blended (mixed by melting) to make formulations for plastics. Generally, an extruder of some type is used for this purpose which is followed by pelletising the mixture. Extrusion or a different moulding process then transforms these pellets into a finished or semi-finished product.

The Onsite Shredding and Disinfection Process for Biohazardous Waste

This technology offers an alternative to legacy processing options that involved multiple stages including Autoclaving, Incineration and Landfill. Previous studies have compared the life cycle Greenhouse Gas (GHG) emissions of both the legacy and the onsite technologies in multiple jurisdictions. The conclusions of all studies have been broadly similar. As a single onsite shredding and disinfection process displaces multiple steps and the necessary transport between steps, a substantial reduction in emissions can be made with the new technology. This reduction is of the order of magnitude of 90% depending on the legacy solutions, which do vary slightly across jurisdictions.

All legacy processing paths for treating biohazardous waste we have observed around the world, despite their slight variances – do conclude in incineration and landfill. These paths make recycling, or circularity,

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impossible. By comparison, onsite shredding and disinfection unlocks new opportunities for this material. The end product in this case is not ash destined for landfill, but a clean flake like material that can be recycled. These mixed flake polymers can be segregated into their constituent polymer components (and also from non-polymeric waste streams), becoming part of the recycling supply chain. The commercial feasibility of doing this may be limited by the logistics costs of recovering various polymers. However, *even if unsegregated,* the mixed waste can and is being used in suitable recycling applications. Regardless of the product made from recycled polymers - the GHG emissions of substituting for virgin – are the same. This comparative study calculates the emissions reduction when this substitution is made.

Quantifying the Avoided Emissions

As previously stated, the objective of this report is to quantify the carbon emissions difference from two polymer production paths that can produce 1 tonne of polymer. The first is the traditional cradle to gate (extraction of raw materials to the point of product production) process. The second is onsite shredding and disinfection process of biohazardous waste, that results in a clean mixed recyclate. In order to calculate the emissions per tonne of usable polymer from the onsite process however, we need to consider the input-output ratios of the biohazardous waste processed. We know two things about the input waste: 1. It contains residual fluids and 2. Some non-plastic materials can be involved. Our model therefore makes the conservative assumption that 50% of the total weight of the input waste is made up of residual test materials, which of course, do not provide any polymer materials. We further assume that 5% of the total weight of input materials are non-residual and non-plastic (i.e., glass, etc). That means that the usable (output) polymer equates to 45% of the input weight processed. Therefore, to produce 1 tonne of reusable polymer flock the onsite disinfection and shredding machine must process 2.222 tonnes of biohazardous waste.

Plastics are designed for different applications and are made in different jurisdictions around the world. Furthermore, the energy emissions will vary depending on where in the world the plastics are being produced. Calculations of the carbon intensity of various sources, therefore, will vary.

Published emission metrics for plastics production deal with life cycle emissions – starting with raw material extraction – and concluding with end-of-life disposal. For our comparative study however, we need to isolate one key part of that journey – namely, bringing plastics to the point of use, where the plastic resin is made into a product by another business. To arrive at a representative metric for the carbon intensity of global plastics production therefore, we need to rely on two distinct data sources. The first, is the life cycle emission factor plastics updated by DEFRA: this gives the emissions in CO2e per tonne of plastic produced anywhere in the world. The second is the extensive plastic value chain emissions study produced in 2021 by the European Environment Agency: European Topic Centre on Waste and Materials in Green Economy (ETC WMGE) titled *'Greenhouse gas emissions and natural capital implications of plastics (including bioplastics)'*. The ETC WMGE study outlines the most common plastics in the value chain and gives a breakdown of the emissions occurring at each stage of the life cycle. This is illustrated in Figure 2. The majority of GHG's caused by the value plastics chain are related to the production of polymers (blue) (extraction of raw materials, transport to refining plant, and distribution to customer) which equate to 63% of the total value chain emissions. Converting these plastics into products (orange) accounts for 22% of the value chain emissions, and the remaining 15% of emissions are mainly due to end-of-life treatment (grey).

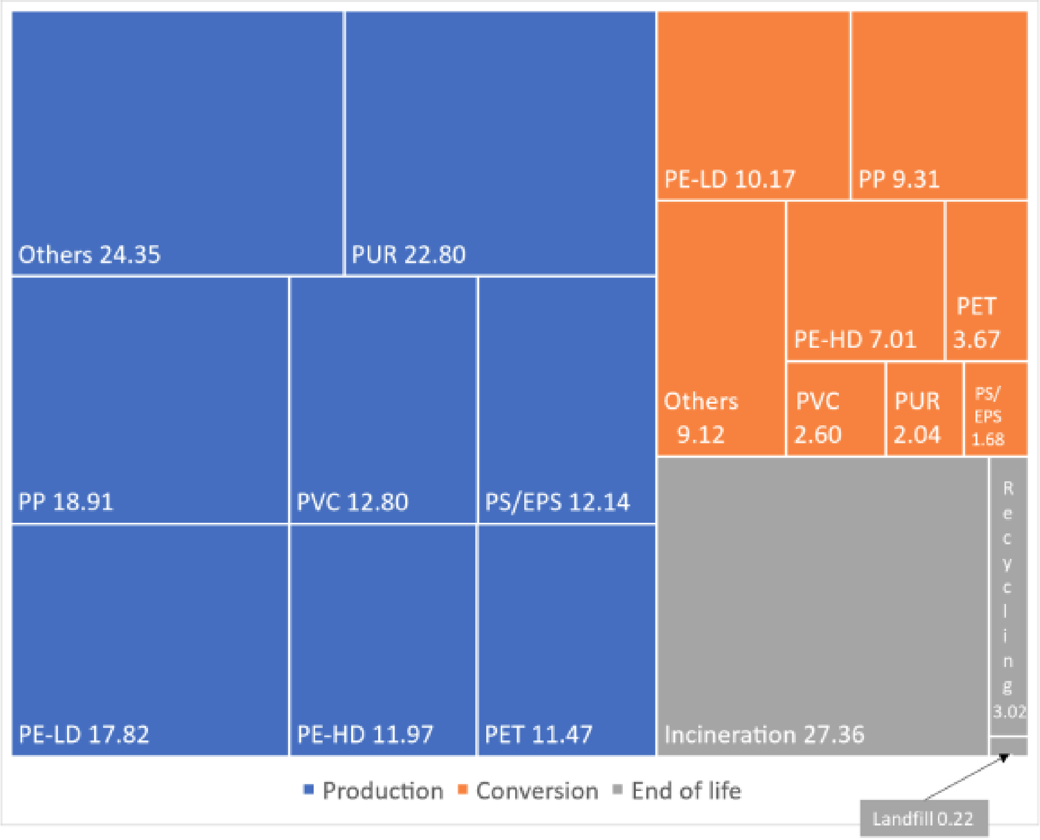

Figure 2. Source ETC WMGE, 2021

Our comparative analysis needs to understand the *percentage split of emissions* along this value chain. The ETC study provides the answer: 63% of life cycle emissions accrue to the activities that bring plastic as a raw material to the point of manufacture of a plastic product. The figure includes the extraction and transport of raw materials to the processing plant which refines the materials into polymers which are then ready for the compounding into plastic products phase (manufacturing).

Using the Department of Environment, Food & Rural Affairs (DEFRA) emissions factors from the UK GOV 2022 we obtained the average virgin plastic emissions intensity in kg CO2e per unit (tonnes). This emission factor is applicable here as it accounts for the cradle-to-gate emissions in global context for average plastics in the value chain, which represents 85% of emissions in the ETC WMGE study. The ETC WMGE value chain emissions results are split 63/22/15. As this report's calculation does not include the end-of-life processing emissions (15%), which are also not accounted for in the DEFRA emission factor (EF), and the 22% production emissions, which are accounted in the DEFRA EF, we must first adjust the split of percentages to identity the percentage of upstream emissions which need to be quantified.

DEFRA Emission Factor: 100% = extraction, primary processing, manufacturing, and transportation of materials to the point of sale.

ETC WMGE: 63% = extraction, primary processing, and transportation to point of sale.
ETC WMGE: 22% = manufacturing.

Adjusted %'s: 63% = 74.1176% and 22.8824% = 25.89%

We can now disregard all figures except for the 74.1176%. This is the value chain emissions portion we need to calculate.

When the new polymers are produced by onsite shredding and disinfection, they are ready to enter the value chain again but this time right before the product manufacturing stage. Therefore, all emissions before this in the value chain are avoided. These avoided emissions were calculated as follows.

- One tonne of virgin plastics taken from the point of extraction to the point of distribution is 3,116.2915639 kgCO2e (DEFRA EF, account for manufacturing emissions).
- This figure becomes 2,309.72051614263 kgCO2e (74.1176% of DEFRA EF, not including manufacturing emissions).
- Onsite shredding and disinfection processes create 1 tonne of recycled polymer for every 2.222 tonnes of biohazardous waste which is processed.
- For every metric tonne of usable polymer recovered from onsite disinfection we generate an emissions total of 124.22715278 kgCO2e (see Appendix 2 for metric tonne energy usage).
- To transfer one tonne of recycled polymer to a manufacturing facility is 80.973 kgCO2e. This report assumed a distance of 100 miles, using a diesel HGV Rigid (>3.5-7.5 tonnes), travelling with 50% laden.

With all the variables needed for the calculation now created, the avoided emissions can be easily calculated (Set out in Figure 3):

2309.72051614263 – (124.22715278 + 80.973) = 2,104.520363 kgCO2e avoided emissions per one tonne of recycled polymer

This equates to a 91.12% reduction in upstream emissions.

The GHG Emissions associated with production of 1 tonne virgin polymers versus 1 tonne recycled polymers – within the boundaries of interest, are below:

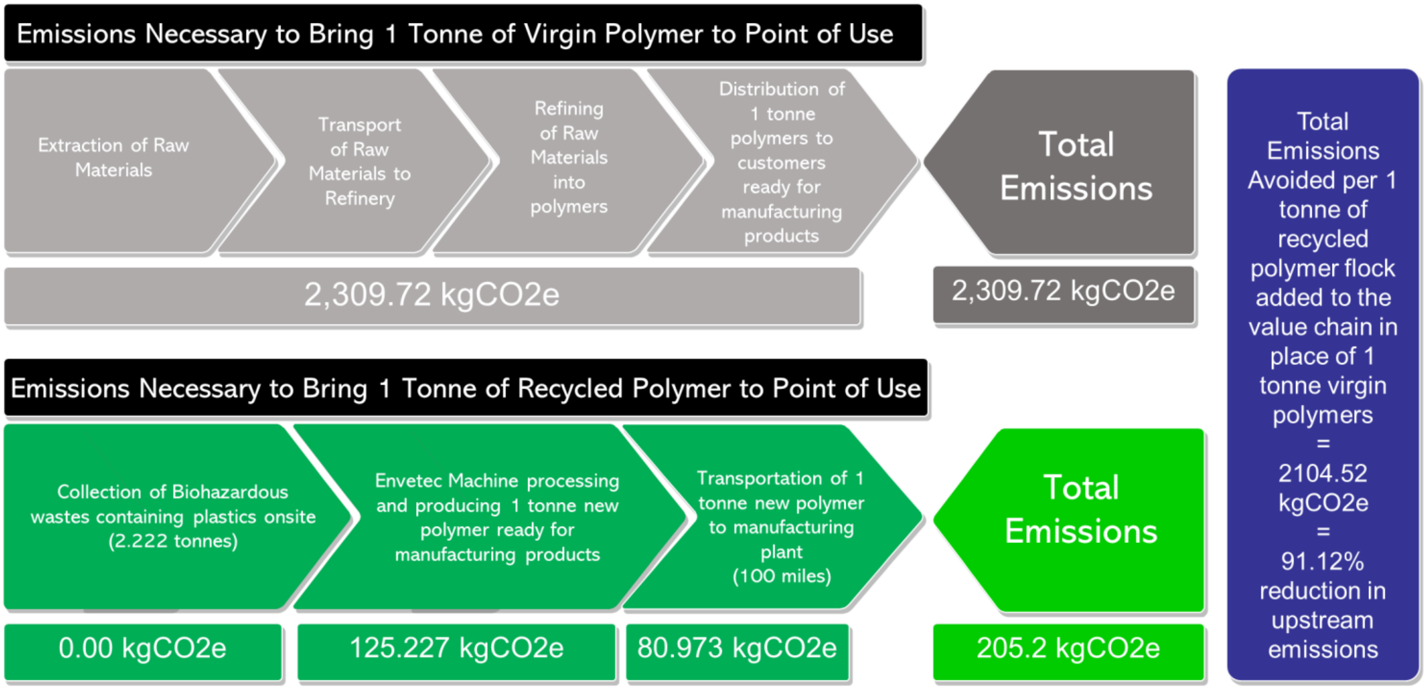

Figure 3: Emissions Summary for Each Production Chain

Placing the Avoided Emissions Figure in a Larger Context

According to the World Health Organisation, production of biohazardous healthcare waste in the US alone, reached a level of 2.5M tonnes per month – or nearly 82,192 thousand tonnes per day, during the pandemic (World Health Organisation: Safe Management of Waste from Health Care Activities, 2014). While biohazardous waste production has declined sharply since then, the WHO has conservatively estimated that the world still produces some 40,000 tonnes per day (14.6 million tonnes per year). If even 10% of the polymer could be recovered from this amount – and recycled into new product – 1.382 million tonnes CO2e emissions would be eliminated.

To place this saving in a broader context, we have extrapolated this saving against a comparative sequestering of carbon from native species forest ecosystems. The global biodiversity crisis requires the restoration of these native ecosystems, to act both as a host for necessary biodiversity creation, and as a carbon sink. An average broadleaf tree will sequester about 1 metric of carbon in 100 years of life (University of New Mexico, 2023). The two choices we have to neutralise these 1.382 million tonnes of emissions, therefore, are either *one year* of achievable plastic recycling of biohazardous waste - or *13,827 thousand years* of natural sequestration through trees.

Moving from a Linear to a Circular Life Cycle

Figure 4 below demonstrates how the traditional linear life cycle of virgin plastics compares with a partially circular and fully circular product life cycle. In the linear life cycle, there are zero avoided emissions. In the partially circular life cycle, the upstream emissions before polymerisation are avoided and the materials are reused once in new products before potentially going for incineration and landfill. Our study calculates the avoided emissions in reprocessing polymers once. Assuming multiple recycling loops were created; it would create further benefits.

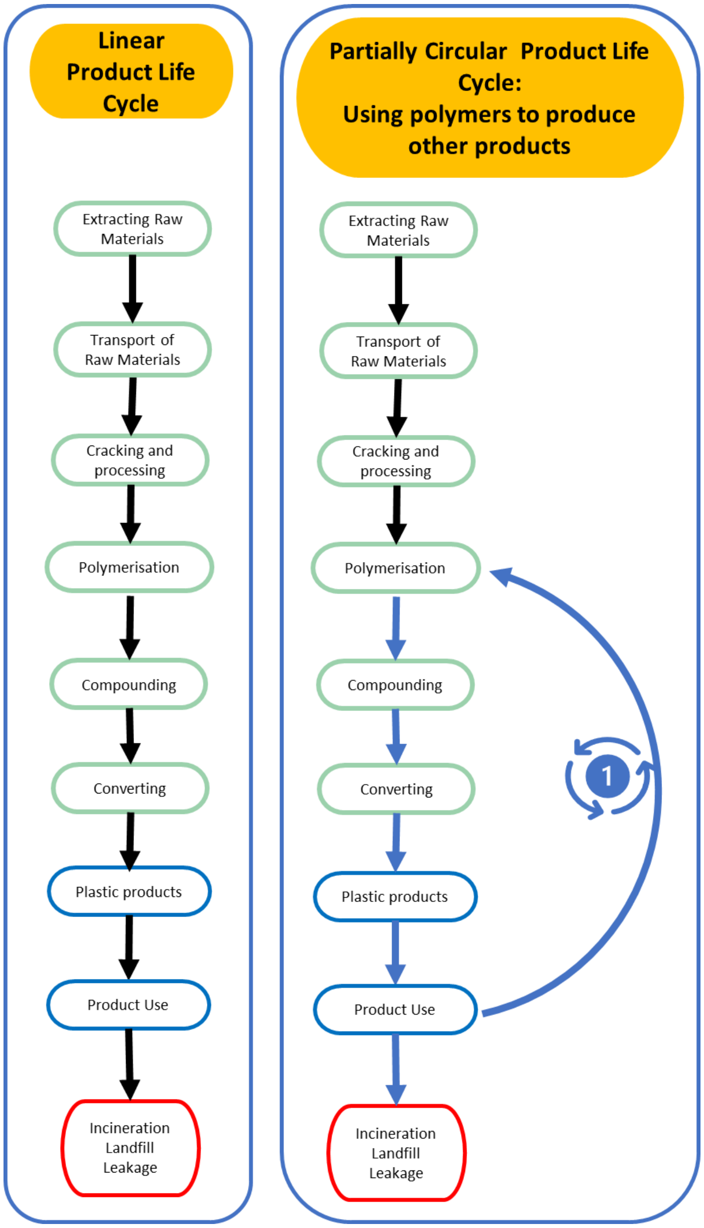

Figure 4. Linear life cycle to Circular life cycle if polymer machine is utilised.

Conclusions

1. Substituting virgin plastic with recycled biohazardous waste will create a reduction in the relevant life cycle emissions of 91.12%. The absolute difference in emissions per tonne of virgin plastic substituted is 2.1045 tonnes CO2e.
2. Annually, the Biohazardous waste generated in laboratories is 14.6 million tonnes; if 1% was treated by shredding and disinfecting this would lead to an absolute emissions reduction of 138,268.37 tonnes CO2e every year *based on our assumed biohazardous waste materials content mix*.
3. Enhancing the circularity rates would not only cut emissions but reduce other damaging side effects associated with end-of-life disposal through incineration and landfilling. Examples of such side effects are contained in Appendix 1.
4. While our model calculates the avoided emissions from using biohazardous waste to substitute for virgin polymer – it also assumes *we only do this once*. Of course, plastics can be recycled multiple times, eventually reaching a point where yields are not economic. This study does not include the avoided emissions from subsequent, repeat recycling. Figure 4 (box 3) suggests this circular loop. As onsite shredding and disinfection avoids incineration and landfilling – the repeatable circular loop is possible. This repeated recycling is a key tool to unlock further Scope 3 emissions reduction. Conversely, if incineration does occur, no repeatable recycling – and associated emissions avoidance ever happens.

Assumptions

1. Emission factors for the calculation of life cycle GHG emissions from plastics production include emissions from conversion of plastic materials into products, as well as end of life disposal. Our study has adapted these emission factors appropriate to our comparative analysis.
2. Our comparative analysis considers the emissions necessary to bring usable plastic raw materials to a plastics manufacturing plant in Ireland. The recovered materials are deemed to come from the processing of Biohazardous waste generated in Ireland and processed by onsite shredding disinfection. The alternative option is to use virgin plastics, derived from fossil fuels and transported to the point of manufacture in Ireland.
3. Emission factors for onsite shredding and disinfection, as well as transport to the point of use, are derived from primary studies previously conducted by Carbon Action. Summary data is listed in the appendices.
4. Our study is confined to emissions up to the point of making a product from the plastics, whether virgin or recovered. It does not include emissions for product manufacturing or end of life disposal (common to both polymer sources).
5. We assume that biohazardous waste processed is comprised of 50% sample residuals, and that 5% of the solids are non-plastic. That means that 45% of the input tonnage can be available as recyclable polymers.
6. Transport emissions for carrying recycled polymers to the point of use are based on the use of a diesel HGV Rigid truck, 50% laden, carrying product for 100 miles.

Limitations of the Report

The report quantifies neither the non-emissions nor the cost benefits of benefits of recycling polymers.

Assessment Team

The team conducting the assessment was composed of:

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Appendix 1: Supplementary Info on Plastics

The Policy and Market Failures on Plastics

Policy and market failures create bottlenecks and broken links in the plastic value chain and prevent market-based investment and consumption decisions toward plastic circularity:

• There is a lack of incentives to influence decisions of producers and consumers of plastic materials and products before they become waste. Existing policies to address plastic pollution usually focus on waste management, although some countries try to ban or charge for the use of certain plastic products, and extended producer responsibility systems are emerging. While improving waste management systems is fundamental, it is not enough to prevent plastic pollution. Without incentives for upstream reduction of consumption of single-use plastics, the exponential volumes of waste overstretch downstream waste management systems. This risk is even more acute in countries with weak capacity and governance in the solid waste management sector.

• Government interventions are often fragmented and incoherent. This results in limited success of policy instruments, excess burden on public budgets, and the risk of shifting the problem from one place to another rather than solving it comprehensively. An example is an upstream state support to plastic producers (such as subsidizing hydrocarbons used in the petrochemical industry) coexisting with downstream subsidies to waste management; they cancel each other's effects and waste public funds.

• Many governments do not consider the environmental and societal costs of plastics and their alternatives when formulating targets and developing policies. Unlike other pollution problems, the external costs of plastics are generated not only at different stages during production and consumption, but also in multiple places in the post consumption phase, after the plastic product has become waste. This complexity, exacerbated by multiple interest groups operating along the plastic life cycle, often clouds the decision-making process.

The onsite disinfection and shredding machine allow customers to bypass these policy and marker failures to make sure the plastic value chain become more circular while creating value, protecting natural capital, and reducing carbon emissions globally.

Why we need to avoid landfilling of plastics

The landfilling of plastics is a concern as it may cause chemicals contained within the plastics to become more available to leach into the environment. Additives and some plastic precursors such as bisphenol A are known to be harmful or hazardous when leached into soil and water. Some of these compounds are phthalates, including di(2-ethylhexyl) phthalate, benzylbutylphtalate, dibutyl phosphate, diisononyl phthalate, diisodecyl phthalate and di-n-octylphthalate, which are used as plasticisers. Flame retardants, such as commercial octabromodiphenyl ether, commercial pentabromodiphenyl ether and decabromodiphenyl ethane, are known to be hazardous because they contain halogenated compounds. Even though the use of these compounds in new materials is increasingly regulated, they still occur in the waste fractions. Incineration of plastics can also be a source for heavy metals, persistent organic pollutants, solid residue ash and airborne particulates in the environment, animals, and humans as they are transported through the atmosphere and are deposited in waters, soil, and crops.

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Appendix 2: Conversion Factors & Metrics

GHG Emissions per Tonne of Polymer by Process

Plastics Weight	Stage in value chain	Extraction of raw materials	Transport of raw materials to refinery	Refining of raw materials into polymers	Distribution to customers	Onsite disinfection and shredding machine Processing 1 tonne of plastic (2.2222 tonnes biohazardous waste) (kgCO2e)	Transport of new Recylable Polymers to manufacturing plant in Ireland (100 miles) (kgCO2e)	**Total Emissions (kgCo2e)**	**Total Emissions Avoided per 1 Tonne recycled polymer from onsite disinfection and shredding machine if used for manufacturing products instead of using virgin polymers (kg CO2e)**
1 tonne	Traditional: total emissons from extraction of raw materials to end of treatment process (kgCO2e)	2,309.720516143				No Activity	No Activity	**2309.720516**	
1 tonne	Disinfection and shredding machine; total emissions from extraction of raw materials to final output of envetec machine (kgCO2e)	No Activity				124.2271528	80.9730	**205.2001528**	
1 tonne	Avoided emissions when recycled polymers are bought after disinfection and shredding machine process	2,309.720516143				124.22715278	80.9730	**2309.7205161 − 205.2001528**	**= 2104.520363**

Avoided Emissions Per Tonne of Recylced Polymer – Compared to Virgin Production

205.20	8.88	-91.12
Total emissions disinfection and shredding machine+Transport (kgCO2e)	% Total Emissions if using disinfection and shredding machine materials	% Total Emissions saved by using disinfection and shredding machine materials

Onsite Disinfection and Shredding Emissions

Scope	Basis of Calculation	Usage per annum	Units	EF	Unit	Comment	GHG Emissions Tonnes CO2e Per Annum
1	No combustion process or other direct GHG					Source:- Envetec "Product Specifications, July 2021.	
2	Machine runs 8 hours per day, 5 days per week for 50 weeks per annum. Power consumption taken from Envetec product specifications. Irish grid emission factor applied.	5520	kWh	295.8	g/CO2/kWh	Source: SEAI	1.633
3	Peracetic Acid - Embedded Emissions						
3	0.6L per batch: 24 batches per day - 5 days per week - 50 weeks per annum	3600	litres			Source:- Envetec "Product Specifications, July 2021.	
3	Embedded Emissions in Acid Manufacturing and Global Distribution	3744	kg	0.61		Density Conversion @ 1.04 S.D.S for PERACETIC ACID 35% W/H2SO5. EF expressed as kg CO2e per kg of acid. EF does not include last mile shipment to user (in Ballina)	2.284
3	Last Mile Distribution of Peracetic Acid to Ballina	356	km	0.12175		EF in kg CO2e does not include shipment to Ballina. Assume shipment form major chemical distributor in Dublin (Lennox) to Ballina - round trip 356 km	0.043
3	Waste Water Treatment: 40L per batch - 24 batches per day - 5 days - 52 weeks = 240,000 L	240	m3	0.272	kg CO2e/m3	EF: Defra/BEIS 2021 EF's	0.065
	Total Emissions Per 360 M3/72 Tonnes						**4.025**

Figure 5. Excel workings figures

		Primary material production
Material	Unit	Total kg CO_2e per unit
Plastics: average plastics	tonnes	3,116.29

Figure 6. DEFRA (2022) Emissions Factor for average primary (virgin) plastics

			50% Laden
Activity	Type	Unit	Total kg CO_2e per unit
HGV (all diesel)	Rigid (>3.5 - 7.5 tonnes)	tonne.km	0.48922
		km	0.50315
		miles	0.80973

Figure 7. DEFRA (2022) Emissions Factor for Freight Vehicle

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Sample Grid Emission Factors - Indonesia

No.	Name of Grid	Province	OM (ton CO2/MWh)	BM (ton CO2/MWh)	Emission Factor (ton CO2/MWh) CM Ex-Post OM = 0,5 BM = 0,5	Emission Factor (ton CO2/MWh) CM Ex-Post OM = 0,75 BM = 0,25	Emission Factor (ton CO2/MWh) CM Ex-Ante OM = 0,5 BM = 0,5	Emission Factor (ton CO2/MWh) CM Ex-Ante OM = 0,75 BM = 0,25
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1	3 Nusa	Bali	0,52	N/A	N/A	N/A	N/A	N/A
2	Adonara	Nusa Tenggara Timur	0,59	0,59	0,59	0,59	0,88	1,03
3	Alai (Kepri)	Kepulauan Riau	0,53	N/A	N/A	N/A	N/A	N/A
4	Alor	Nusa Tenggara Timur	0,58	0,58	0,58	0,58	0,58	0,58
5	Ambon	Maluku	0,65	0,66	0,66	0,65	0,66	0,66
6	Ampana	Sulawesi Tengah	0,61	N/A	N/A	N/A	N/A	N/A
7	Balantak	Sulawesi Tengah	0,67	N/A	N/A	N/A	N/A	N/A
8	Bangka	Bangka Belitung	1,04	0,74	0,89	0,97	0,88	0,95
9	Bantal	Bengkulu	0,64	N/A	N/A	N/A	N/A	N/A
10	Barito	Kalimantan Tengah	1,20	1,41	1,31	1,25	1,28	1,21
11	Batam-Tanjung Pinang	Kepulauan Riau	0,76	0,88	0,82	0,79	0,85	0,83
12	Bau-Bau	Sulawesi Tenggara	0,97	0,51	0,74	0,86	0,67	0,76
13	Belitung	Bangka Belitung	1,40	1,42	1,41	1,40	1,46	1,48
14	Bengkalis (Riau)	Riau	0,01	0,00	0,01	0,01	0,01	0,02
15	Bere-Bere (Morotai)	Maluku Utara	0,69	N/A	N/A	N/A	N/A	N/A
16	Biak	Papua	0,57	0,56	0,57	0,57	0,61	0,63
17	Biaro	Sulawesi Utara	0,60	N/A	N/A	N/A	N/A	N/A

Source: Extracted from IGES List of Grid Emission Factors: https://www.iges.or.jp/en/pub/list-grid-emission-factor/en