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GHG COMPARISON ASSESSMENT
Biohazardous Waste Processing Technologies
Report 1.0

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Presented to: Client
Company

Date: 13 July 2022

Signed on Behalf of CA:

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Executive Summary:

An organisation that generates biohazardous waste typically appoints a specialist firm to remove and process it. The standard path for treatment, which has remained unchanged for almost 50 years, involves removing the bagged, untreated waste from the generation site by road freight to a central disinfection site. Specifically:

1. Waste is sterilised through an autoclave / rotaclave or incinerator. Autoclaves and Rotaclaves kill harmful pathogens using steam applied at high pressure for a pre-set period of time, and incinerators using very high temperature furnaces to burn the biohazardous waste.
2. The processing path of these wastes vary around the world, but include:
    - Autoclave / Rotaclave to Landfill
    - Autoclave / Rotaclave to Incineration to Landfill
    - Incineration to Landfill.
3. Each processing stage and every transportation link between these stages generates GHG emissions. According to a recent report by My Green Lab, the global biotechnology and pharmaceutical industry alone has a significant carbon footprint (197 million tCO_2e), which is more than the forestry & paper and semiconductor industries.

Current disinfection processes are effective but can create other problems. This in turn has stimulated a rethinking of how the life-science industry can overhaul the treatment of biohazardous laboratory waste. The design goals of the new approach are to sustain disinfection effectiveness while radically lowering Greenhouse Gas (GHG) emissions, improving circularity, and reducing costs.

Our report, which is peer-reviewed, concludes that onsite disinfection and shredding potentially lowers emissions by over 93% for equal quantities of waste treated by autoclave or rotaclave. A further challenge for waste management in Ireland is the widely anticipated legislation ban on the landfilling of post-incineration ash in the country. Onsite processing technology removes the need for landfilling, making labs sustainable, treatment efficient, and resilient to the escalation risk of emissions and costs while being legislatively compliant.

This report provides a comprehensive GHG emissions inventory spanning Scopes 1-3, of various waste processing chains. This enables the life-science industry to understand their complete value chain emissions and to focus their efforts on the greatest GHG reduction opportunities in relation to the treatment of biohazardous waste material. In addition to the specific emissions benefits, other compelling benefits can be realised and monetised throughout the processing chain. Some sample benefits are identified in this report, both direct and indirect. Quantifying their value, however, is beyond the scope of this report.

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Project Scope:

Carbon Action was asked to conduct an analysis of the life cycle Greenhouse Gas (GHG) emissions created in the processing of biohazardous laboratory waste. As there are multiple paths by which such waste is processed, this report will provide an analysis of the most commonly used methodologies. The report sets out to calculate GHG emissions created across scopes 1-3 for each processing path, to allow a comparison of the emissions efficiency of all.

For the purposes of comparison, the starting point is the existence of biohazardous materials waste in a laboratory. The end point is when that waste is brought to the last stage of the processing chain. This is either the creation of disinfected municipal grade waste that can be recycled – or post incineration ash that can be landfilled.

To establish a benchmark, we used a site that generates such waste in Ballina, Co Tipperary. The site currently uses a waste contractor to remove and process its biohazardous materials and waste offsite, through autoclave/rotaclave sterilisation and incineration. In this chain, waste generated in Ballina is road hauled to Dublin for autoclave treatment, then road hauled to Poolbeg, Co Dublin for incineration. The post incineration ash is then road hauled for disposal in a landfill. At time of writing, the residual ash post incineration can be landfilled in the Republic of Ireland which is where the processing chain ends. It is expected that this option will sooner than later, close – requiring export of the ash to a landfill licensed to accept it. When that happens, associated emissions will increase accordingly.

The common denominator for emissions comparison used is based on the output capacity of the machine used in the onsite disinfection and shredding. The technology has a cycle time of up to 20 minutes, in which it disinfects and shreds a 60L batch of waste. The analysis is based on running the machine for 8 hours per day, 5 days per week and for 50 weeks per annum. In that time, it turns 360 m3 of mixed infected laboratory waste, into confetti like, disinfected, municipal grade waste, suitable for recycling without any further processing. The long-term average waste density is estimated at 200 Kg/ $m^{3.}$ (Per Sustainability Exchange Data, see Appendix 4). Therefore 360 m^3 equates to 72 metric tonnes. All subsequent comparisons in this report will be based on these two interchangeable metrics. For comparative purposes, all other processing paths are assessed to determine their GHG emissions to process this same amount of waste.

Carbon Action Approach

GHG Emissions quantification has been calculated in conformance with ISO 14064-1: *Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*. The standard is built on the principles of Transparency, Relevance, Accuracy, Consistency, Completeness and Conservativeness.

Confidentiality

Carbon Action assures the confidentiality of all information provided to us during the course of this process as well as documents (if any) provided by the client. No information on the company will be communicated to any third party.

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Independence

Prior to entering into a contract to conduct GHG assignments, we undertake a review of potential conflict-of-interests and threats to impartiality which may arise, and we only enter into engagements where our impartiality is not impaired. During the course of the engagement, we continue to monitor to our impartiality to ensure our services comply with the requirements of both the ISO 14064; 1 and ISO 14064-3 standards and the GHG Protocol. Carbon Action confirms that we are not aware of current or potential conflicts-of-interest that would prevent us from providing independent assurances to Client Company.

Processing Paths Options:

Figure 1 illustrates the alternative processing paths commonly used and indicates where GHG emissions are generated throughout the processing chain. We deem that each processing chain is to have reached the end when the following criteria are achieved:

- The level of infectious organisms is reduced to a level at which no additional precautions are needed to protect workers or the public against infection from the waste,
- All clinical waste including any equipment and sharps, are rendered unusable and unrecognisable as clinical waste,
- The component chemicals of medicinally contaminated waste are destroyed.
- The waste is brought to the point of final disposal, or has become a clean, easily recyclable commodity.

The Processing Options are:

Now including new onsite processing technology, the options are expanded to:

1. Autoclave/Rotaclave + Landfill – hereafter referred to as Channel A
2. Autoclaving/Rotaclave+ Incineration + Disposal of post incineration ash. (Channel B)
3. Incineration + Disposal of post incineration ash. (Channel C)
4. Onsite disinfection and shredding (Channel D)

Processing Technology Descriptions

1. **Autoclaving:** here the biohazardous wastes are sterilised or disinfected prior to incineration and disposal in a landfill. Bags of waste are placed in a chamber and steam is introduced for a determined period of time at a specified pressure and temperature.
2. **Rotaclaving:** is a type of autoclave which has an additional waste disintegration or maceration process. Disintegrating the waste helps to ensure the steam can access all parts of the waste so the waste is more reliably sterilised.
3. **Hybrid Disinfection/Shredding**: This process is designed to disinfect materials onsite, creating a residual recyclate of municipal grade waste that can be easily recycled. Unlike other technologies, no subsequent steps are necessary to conclude the processing chain.
4. **Landfill of autoclaved materials:** Post Autoclaving, the treated wastes of various materials, approximately 90% plastics can be disposed of in a landfill, should the jurisdiction and landfill be licensed to accept such waste.

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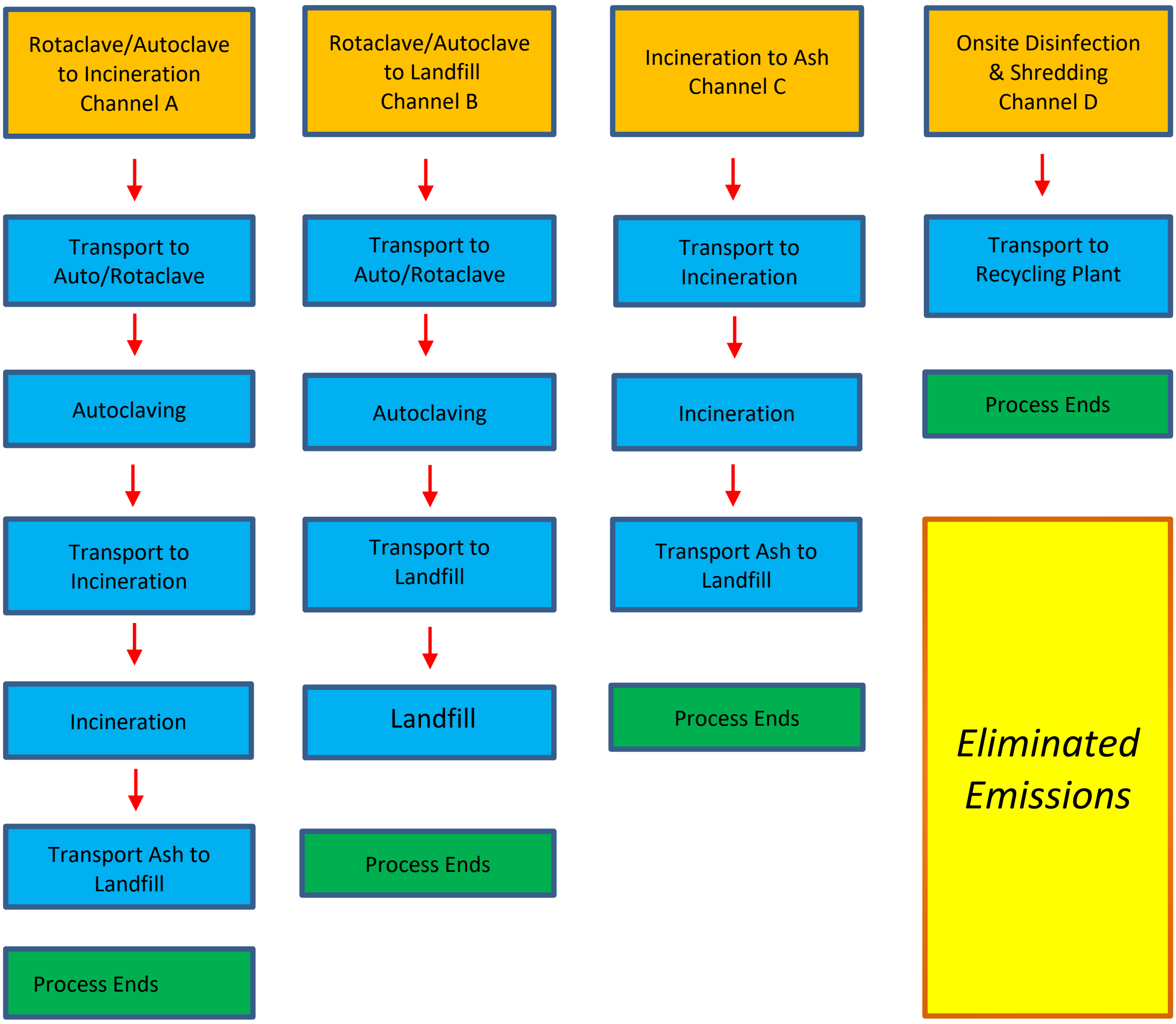
5. **Incineration:** Biohazardous waste can be treated in an anatomical incinerator or incinerated in a standard temperature incinerator, once it has been sterilised and is safe for handling. Incineration creates a residual ash that must be landfilled: this can still be done in Ireland, but it is expected that option will not remain for much longer. That will then add both ocean and further road transport to bring the ash to whatever jurisdiction is willing to accept it.

Figure 1 illustrates the sequential steps required to process biohazardous waste, by processing chain. While the paths share some common components, each distinct processing channel has its own emissions footprint. Identifying the steps in the path and their associated GHG emissions, allows a direct comparison of the emissions efficiency of the various paths. The processing chain ends when the biohazardous material meets the disinfection, recognition and component chemical removal criteria above – and is ready for final disposal in a landfill, or is suitable for recycling into a useful product.

Figure 1: Biohazardous Waste Processing Chains

GHG Emissions are generated at each stage of the respective processing chains, depicted below.



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The Onsite Disinfection and Shredding Process

One company has developed a stand-alone cleantech solution to be installed onsite to process and transform biohazardous waste and material, rendering it non-hazardous.

The process simultaneously shreds and disinfects biohazardous waste and material using a patented destruction and disinfection process. The approach includes disinfection with a proprietary biodegradable chemical which contains peracetic acid and mechanical shredding of the waste material. Peracetic acid also known as peroxyacetic acid or PAA, is an organic chemical compound used in numerous applications, including chemical disinfectant in healthcare, sanitizer in the food industry, and disinfectant during water treatment.

The approach results in the creation of a “confetti-like” solid residual material, which is then categorised as regular waste, entirely safe to handle, and can be used directly in making various recycled products. The technology requires no heat in the process, and no dangerous chemicals are claimed to be discharged from the system at the end of a treatment cycle with a maximum cycle time of 20 minutes depending on the biological load of the materials and waste being processed.

The technology requires electric power, peroxychem chemical and water: it requires no combustion fuels. Total process emissions therefore are the Scope 2 emissions for purchased electricity and the scope 3 emissions of production and transport of peracetic acid, as well as wastewater disposal. Given that our case study/base of comparison is in Ireland, the grid emission factor (GEF) used to calculate emissions is that of the Irish grid.

Total emissions for the Channel D processing chain are contained in Appendix 2. They are based on the demonstrated engineering requirements of the machine (water, acid, power, disposal, transportation) and cited, independent emission factors.

For the comparison quantum of 360 m^3 or 72 metric tonnes considered, total GHG emissions from the Channel D process are 4.11 MT CO_2e.

<u>Other Processing Chains:</u>

Emissions data for all technologies, as well as their associated life cycle emissions are outlined in Appendices 1-5. These emissions include the scopes 1 and 2 emissions from the primary component processes as well as the scope 3 transport emissions required to complete the processing chain. Those emissions include transport between stages, incineration and more. Some emissions are not included even though they exist: no emissions are included for landfilling post incineration ash for instance. In cases like this, where robust data is hard to determine, either a conservative, defensible assumption is made, or in other cases, the emissions are excluded. While this may understate the emissions of the existing market technologies, their absence is insufficient to distort the comparative analysis.

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Comparative Analysis

Emissions Created – *By Processing Chain:*

Processing Path			Channel D	Channel A	Channel B	Channel C
	Process Steps	1	Onsite D&S	Transport	Transport	Transport
		2	Transport	Auto/Rotaclave	Auto/Rotaclave	
		3	-	Transport	Transport	
		4	-	Incineration	-	Incineration
		5	-	Transport	-	Transport
		6	-	Landfill	Landfill	Landfill
Process End			Recycling Centre	Landfill	Landfill	Landfill
Emissions Source			*Tonnes CO2e per base quantity (360 M3 or 72 MT)*			
1	Machine Emissions (including embedded emissions)		4.110	4.110	4.025	0.000
2	Road Transport Ballina to Ballymount/Poolbeg			23.810	23.810	23.810
3	Incineration - Without Sterilisation					29.880
4	Road Transport Ballymount - Poolbeg Incinerator			1.404		0.000
5	Incineration - Post Sterilisation			29.880		
6	Road Transport - Post incineration Ash			5.571	5.571	5.571
7	Road Transport to Recycling		0.000	0.000		0.000
	Totals		4.110	64.774	33.405	59.260
	Indices: Rotaclave to Landfill = 100		6.35%	100.00%	51.57%	91.49%

Note: For the purposes of this comparative analysis, GHG emissions for Autoclave and Rotaclave have been assumed to be equal. We have also assumed that the Scope 1 emissions for both Channels A and D, to be equal. In reality, we expect the direct emissions from Autoclave/Rotaclave to be substantially higher than those of the Channel D technology (as far less combustion emissions occur in Channel D). Given the number of variables involved in accurately computing those emissions – and the fact that these change in every situation – we have used a conservative assessment to reflect the emissions, chosen to be at the lower end of the emissions range. See Appendix 3.

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Benefits extend beyond GHG emissions:

This report has focussed on the emissions profile of various processing technologies and chains. However, additional benefits are also created by deploying onsite disinfection and shredding, which fall out of the scope of this report's scope. The authors have provided a list of benefits including but not limited to:

1. Elimination of road congestion: every Channel D machine working one shift per day, takes 62 (40 foot) truck journeys off the road per annum.
2. Enhanced circularity: paths that include incineration remove the option to recycle the waste. With onsite disinfection and shredding, the end product is easily recycled and therefore is *likely to be* recycled.
3. Energy Efficiency: as the Channel D technology uses chemicals that displaces power for steam and electricity, it is a smaller drain on the power grid and reduces energy bills.
4. Wider environmental impact: the air pollution associated with transportation journeys and incineration are by definition, avoided.
5. Avoidance of Transport of Dangerous Goods: of the 62 truck journeys eliminated in the study – 31 of these would fall in scope for ADR – "**Accord Européen relatif au transport international des marchandises dangereuses par route**", which translates as "The European Agreement concerning the International Carriage of Dangerous Goods by Road." ADR requirements are onerous, including the need for information on handling and shipments of all dangerous goods to be catalogued in annual reports by a qualified DGSA. Most countries in the world are signatories to the ADR, so this particular benefit is near universal.

The emission reduction occurs outside the organisational boundaries of the waste generator. The largest environmental impact of Channel D is its capacity to drive GHG emissions out of the *entire processing chain.* This emissions preclusion can be reliably quantified with the methodologies used in this report.

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Appendix 1: Assumptions

Various assumptions have been made in the course of this report to preserve a basis of comparability or to err on the side of conservativeness when more precise data was not available. The assumptions made are:

1. All calculations are based on the emissions generated by the processing of a fixed amount of infectious waste, that can be processed through multiple technologies or processing chains. This quantity is 360 m^3 or 360,000 litres.
2. The study is based on waste being generated in Ballina Co. Tipperary, being shipped for Autoclaving/Rotaclaving and Incineration in Dublin, and then on to landfilling the ash in the nearest available landfill site at Drehid, Co Kildare, Ireland.
3. Autoclaving and Rotaclaving are very similar processes, with the Rotaclaving process being slightly more emissions intensive, other things being equal. This study uses Rotaclave data as representative of both Autoclaving and Rotaclaving, as it is the higher and therefore more conservative of the two.
4. The 360 m^3 metric is also expressed interchangeably – as 72 tonnes. This conversion is done on the basis of Sustainability Exchange data that calculates the long-term average waste density at 200 kg per cubic metre.
5. Waste transportation is assumed to be by 40 Ft curtain sided trailers, with waste packed into 240 Litre wheelie bins. A long-term truck utilisation rate of 80% is assumed for this: i.e. the average truck carries 48 out of a possible 60 bin maximum capacity. As the waste is untreated due to its infectious status, no volume compression occurs pre shipment. This means that we are shipping a lot of air in the form of intact, emptied containers. This factor substantially increases the necessary transport required and with it, GHG emissions.
6. Unless otherwise stated, emission factors used are from Defra/BEIS 2021.
7. Transport emission factors used include "Freighting of Goods" emissions factor (1.0974) and a WTT (well to tank) emission factor (0.12009). Freighting captures the emissions of combusting the fuel to drive the truck's engine. WTT includes the embedded emissions of extracting, refining and bringing the fuel in usable form (diesel) to the fuel tank of the truck.
8. No provision is made however for the *retail* distribution of such waste. Smaller volume users often have waste collected in smaller vehicles: this is sent to a staging post from where 40 ft loads are dispatched to the next processing stage. The additional emissions of the small fleet transport stage are not included in this analysis. This conservative assumption will have the effect of *understating* the emissions for processing chains involving transport.
9. Data from international sources has been adjusted to preserve comparability where necessary. Of the Rotaclave emission data derived from France, we have only used the electricity, water as those factors were also measured in the Channel D emissions calculation. Unlike Channel D, there is no chemical use – however, there is steam. Our steam properties assumption was very conservative – in which the steam accounts for less than 4% of Rotaclaving emissions. The French study concluded that high pressure steam was approximately 75% of Rotaclave emissions.
10. Equipment is assumed to be used in Ireland – therefore, Irish emission factors have been used accordingly, when available.
11. Normal procedure for calculating scope 2 emissions involves a two-step process. Emissions are

derived from Transmission and Distribution of the electric power (T&D) and also from the emissions of using the power itself – in turn based on the jurisdictions grid emission factor (GEF). In this analysis, we have used the GEF for Ireland as that is the location of the analysis. However, SEAI Source of the relevant emission factors in Ireland) – does not publish T & D emission factors. Partly for that reason and partly because they are very marginal anyway, T&D emissions are excluded from emission calculations from all processing chains.

12. The study is focussed on the emissions of the respective processing chains. It lists some – but does not seek to quantify some other non-emission benefits, even though these may be of value to the members of the processing chain.
13. For steam generation emission calculations, we would normally consider the thermodynamic properties (e.g. saturation temperature and pressure) of the steam being used in a particular autoclave or rotaclave. In this case we have assumed those properties to be at an average level of the normal ranges we see.
14. Volume Reductions: Sterilisation and incineration both reduce the volume of the input materials: 100 litres of mixed input waste, will emerge from both processes as less than 100 litres. The degree of shrinkage varies, with the composition of the input material. In the circumstances, we have assumed conservatively – that the volume shrinkage is at the midpoint of the range we would expect to see.

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Appendix 2: Channel D GHG Emissions

Scope	Basis of Calculation	Usage per annum	Units	EF	Trucks Per Annum	Unit	Comment	GHG Emissions Tonnes CO2e Per Annum
1	No combustion process or other direct GHG						Source:- Onsite D&S Manufacturer "Product Specifications, July 2021.	
2	The Onsite D&S machine can process 72 Mt per annum based on an 8 hour shift, running 50 weeks per annum. Therefore, in one 8 hour annualised shift, total power consumption is 5520 Kwh.	5520	kWh	295.8		g/CO2/kWh	Emission Factor Assumptions: Transport and Distrbution = 0.02005 Electricty Generation = 0.23314	1.633
3	Peracetic Acid - Embedded Emissions							
3	0.6L per batch: 24 batches per day - 5 days per week - 50 weeks per annum x 1 shifts- requires 3600 litres of Peracetic acid.	3600	litres				Source:- Onsite D&S Manufacturer "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. (5400L = 5616 kg).EF expressed as kg CO2e per kg of acid. EF does not include last mile shipment to from port of Entry (Dublin) to point if use (Killaloe, Co Clare)	2.284
3	Last Mile Distribution of Peracetic Acid to point of use.	122	miles	2.10219	0.5		EF in kg CO2e does not include shipment to point of use - only port of entry. We assumed shipment from Dublin Port to Ballina Co. Clare - 122 miles = 196 km.	0.128
3	Waste Water Treatment: 40L per batch - 24 batches per day - 50 weeks = annulaised 240,000 L or 240 M3	240	M3	0.272		kg CO2e/m3	EF: Defra/BEIS 2021 EF's	0.065
	Total Emissions Per 72 Tonnes							4.110
	Total Emissions Per Mt							0.057
	Total Emissions Per kg							57.086

Appendix 3: Rotaclave GHG Emissions

A Rotaclave is similar to an autoclave, except that it contains an additional shredding process, reducing the process waste to a shredded state. For comparative purposes, we have used data from the ECODAS T100 Rotaclave. This machine has a 100 Litre batch processing capacity and a 30-minute cycle time per batch.

Steam and power consumption rates are taken from the company's specification for the machine. While the power consumption is relatively straightforward, steam is more complicated as many more variables affect the steam characteristics and the energy require to produce these. Variables include: the porosity of what is being processed, the need or not for purified water, use of steam jackets, shape of the sterilisation chamber, the need for cold water discharge in managing the effluent and more. All of these variables will change in *every* situation. For that reason, the only responsible approach in our comparative approach is to take a conservative estimate of the steam related emissions. This will understate the long term emissions from the autoclave/rotaclave part of the processing chain, rather than overstate them.

For consistency, we have applied the Irish GEF to the electric power consumption – as our comparative model is based on processing waste in a specific location in Ireland, through various technologies. While the Rotaclave reduces the processed waste to a similar state to that of the Channel D machine, we note that generators of such waste are required to have post Rotaclave waste sent for incineration.

Emission Source	Input	GHG EF	GHG kgCO2e	Comment
The Ecodas T100 Rotaclave has a 30 minute cycle time and capacity to sterilise and shred 100 litres per cycle. Running one 8 hour shift per day, 5 days per week, 50 days per year (assuming no breaks, as done with Channel D capacity). The machine can process 400,000 litres of biohazardous waste - in 4000 cycles.				
Steam use per cycle = 6 kg	6	0.17073	0.091	Ecodas Machine Specifications. Conservative steam property assumptions likely *understate* whole process emissions. Other secondary reports we have reviewed consider steam emissions to account for more like 75% of total GHG emissions.
Adjusted Steam Consumption Factor			0.86215	Autoclaves irrespective of design and usage considerations sterilise through the creation of steam. The Channel D machine design requires no steam and hence no steam emissions. On a like for like basis, the steam emissions should substantially exceed any power consumption emissions required in the Channel D machine and the Scope 3 emissions of producing the acid, which is used in very limited quantities. For this analysis therefore, we will assume very conservatively, that the Channel D and Autoclave emissions (Channel A) are equalised: both therefore, are considered to produce 4.025 tCO2e for the sample quantity of 360,000 L.
Electricity use per cycle = 0.55kWh	0.55	0.2985	0.164175	Ecodas Machine Specifications
Water use per cycle = 5L	5	0.000149	0.000745	Ecodas Machine Specifications
Total GHG per cycle			1.11807	Ecodas Machine Specifications
Total Annual Emissions			4,472.28	For 400,000 litres
Emissions to process 360 M3			4,025.05	Selected base amount for comparison

Appendix 4: Incineration GHG Emissions

Assuming the biohazardous waste goes un-treated from laboratory to an Incinerator.

The incineration of 1 tonne (1,000 kg) of municipal waste in MSW incinerators is associated with the production/release of about 0.7 to 1.2 tonnes CO_2e. Although this carbon dioxide is directly released into the atmosphere and thus makes a real contribution to the greenhouse effect, only the climate- relevant CO_2 emissions from fossil sources are considered for the purposes of a global analysis.

Since the waste incinerated is a heterogeneous mixture of wastes, in terms of sources of CO_2 a distinction is drawn between carbon of biogenic and carbon of fossil origin. In the literature, the proportion of CO_2 assumed to be of fossil origin (e.g. plastics) and consequently to be considered climate relevant, is given as 33 to 50 percent. Assuming that carbon dioxide emissions from incineration averages in the middle of the range observed over time at 1 tonne CO_2e per tonne of waste, then of these CO_2 emissions 0.33 (0.50) Mg are of fossil and 0.67 (0.50) Mg are of biogenic origin. In subsequent calculations, the proportion of climate-relevant CO_2 is figured out as an average value of 0.415 tonnes CO_2e per tonne of waste.

For our purposes we are using a waste volume of 360 m^3 of waste with a density of 200 kg / cubic meter (Sustainability Exchange data https://cordis.europa.eu/project/id/283130). Thus The channel D equivalent mass of waste is 72tonnes of waste per annum.

Therefore, for incineration of 72 tonnes of waste an incinerator will emit 0.415 [tCO_2e] * 72 {tonnes of waste] or 29,880 kg tCO_2e per annum.

Post Sterilisation Incineration:

In most cases, waste in Ireland is incinerated after being already processed by an Autoclave or Rotaclave. This incineration takes place at two licensed facilities, located at Poolbeg in Dublin, or Duleek, Co. Meath. For comparative purposes, we assume Poolbeg is used as it is the closest to the Sterilisation site in Ballymount, Dublin.

These incinerators reduce the post Rotaclave waste to an ash, which must be landfilled. Only one site in Ireland still accepts this material for landfilling: accordingly, we have assumed post incineration ash is sent to this Drehid facility at Carbury, Co Kildare. It is expected that this facility will be removed, which will require that post incineration ash be shipped abroad, to a country willing to accept such wastes in their landfill systems. When that happens, substantially more emissions will be created through ocean and further road freight.

Pending the nature of the incineration equipment used, metal components (e.g. medical sharps) may not be removed. Where post incineration ash is used for industrial processing (e.g as a calcium substitute in cement manufacturing), an additional process can be needed to remove the metals. This analysis ignores those additional emissions, and instead is confined to the lowest emission case of simply landfilling the ash, unfiltered.

Appendix 5: Transport GHG Emissions

For estimation of transport emissions by road, we have used the Defra emission factor (2021) of 1.0974 Kg CO2e per km driven. Our comparative model assumes the waste is transported from Ballina Co. Tipperary to Ballymount Dublin – a return journey of 344 km. Untreated, mixed waste is loaded into 240 litre wheelie bins, of which 60 maximum can fit into the truck. For the analysis we assume that transport achieves an average utilisation rate for the truck of 80% - or the equivalent of 48 filled wheelie bins. In all 3 separate journeys are required to reach the end of the traditional processing chain:

1. Shipment of untreated laboratory waste from Ballina, Tipperary to Ballymount Dublin.
2. Shipment of post sterilisation waste to Poolbeg for incineration – with some volume reduction.
3. Shipment of post incineration the Drehid Landfill, Carbury, Co Kildare – round trip 98km.

The respective transport journey emissions are calculated below, using actual load factors and round-trip distances and appropriate emission factors. The waste volumes are also adjusted for the prior processing stage, and we use a reasonable shipping capacity utilisation assumption per mode of transport. These factors are contained in the computations below. The purpose of all calculations is the emissions associated with moving the 360 m^3 of mixed laboratory waste (i.e., the capacity of one Channel D machine running on one shift per annum), through to the end of the various processing chains.

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GHG Emissions per 360 M3 Input									
Stage	**Volume Shipped Litres**	**Volume Reduction % From Prior Step**	**Truck or Sea Container Utilisation %**	**Shipments Per Truck or Sea Container Litres**	**Annualised Trucks/Sea containers Required**	**Total km Shipped**	**EF per KM By road/sea**	**Total Annual GHG kgCO2e Per 360M3 or per 72 Tonnes**	**Comment**
Biohazardous Waste: Ballina - Ballymount	360,000	0	80	11520	31.25	344	1.21749	13,088	360M3 = 360,000 L. Capacity per truck limited as waste in not compressed as it includes intact, air-filled containers. Emissions include round trip transportation. Emission factor includes Freighting of goods (1.0974) and WTT factor (0.12009). Total EF therefore is 1.21749 kg CO2e per km.
Post Sterilisation Waste to Incineration	180000	50	80	11520	15.625	62	1.21749	1,179	62 km round trip from Ballymount to Poolbeg Incinerator.
Post Incineration Ash to Landfill	18000	90	80	11520	1.5625	98	1.21749	186	Poolbeg to Carbury Co. Kildare - round trip of 98km. Assumption is that incineration reduces input volume by 90%.
Road Transport to Recycle Channel D Output material – in Castletroy Limerick	180000	50	80	11520	15.625	40	1.21749	0.69	We base calculations on a 50% volume reduction of input materials - achieved by processing in the Channel D machine. Therefore, 360 M3 input reduces to 180 M3 or, 36,000 Kg. It is then shipped from Ballina for recycling to Greentech Plastics, Castletroy, Limerick, a round trip journey of 40 km.