Date: December 29, 2024

To,
**National Stock Exchange of India Ltd.**
Exchange Plaza,
Plot no. C/1, G Block,
Bandra-Kurla Complex,
Bandra (E) Mumbai - 400 051

**Script: HIGREEN**

**Subject: Product Life Cycle Assessment Report**

Respected Sir,

We are pleased to announce that the company has received the Product Life Cycle Assessment Report for our product, Recovered Carbon Black (rCB). The production of rCB through the pyrolysis of waste tyres not only significantly reduces greenhouse gas emissions but also minimizes environmental impact far more effectively than producing virgin carbon or processing waste tyres in haphazard manner. It will support the company's mission for sustainable solutions, advancing a circular economy and fostering a cleaner, greener world.

Product Life Cycle Report for Recovered Carbon Black (rCB) issued by Bevolve is attached herewith.

Request you to take the same on record.

Yours Faithfully.

**For, Hi-Green Carbon Limited**

AMITKUMAR HASMUKHRAI BHALODI

Digitally signed by AMITKUMAR HASMUKHRAI BHALODI
Date: 2024.12.29 14:34:41 +05'30'

**Amitkumar H. Bhalodi**

**Managing Director & CFO**

**DIN: 00410150**

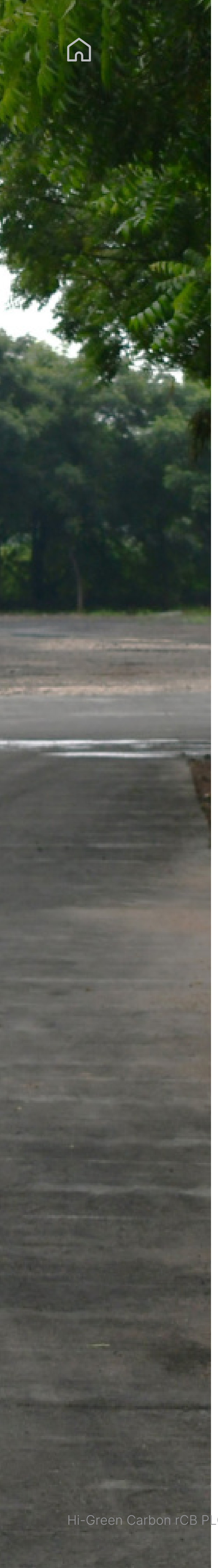
# Hi-Green Carbon rCB Product Life Cycle Report 2024


The Real Green Carbon Black

Assessed by

bevolve


HI-GREEN
CARBON
TM
Grade:
Net Weight :
www.higreencarbon.com



# Table of Contents

## Note from Bevolve

Bevolve Technologies Pvt Ltd has been commissioned by the management of Hi-Green Carbon Ltd. to carry out an independent life cycle assessment of their recovered Carbon Black's (rCB's) environmental performance.

### Scope and Limitations

Our assessment has been based on the data provided by the company. The scope excludes verification and 3rd party audit of the data provided, and of the LCA study.

This LCA study follows ISO 14040 and 14044 guidelines where applicable.

### Management Responsibility

The management of Hi-Green Carbon Ltd. has sole responsibility for the collection, reporting and integrity of the data shared with us during the assessment of the report. In performing the assessment work, our responsibility is to the management, however, this statement represents our independent opinion and is intended to inform the outcome of our analysis to the stakeholders of Hi-Green Carbon Ltd.


CONTINENTAL

# Executive Summary

Hi-Green Carbon's patented pyrolysis process compares favourably against other possible fates of used tyres in India, namely incineration and unmanaged pyrolysis in small plants. The difference in emitted $CO_2e$ gases is striking, summarised in the chart:

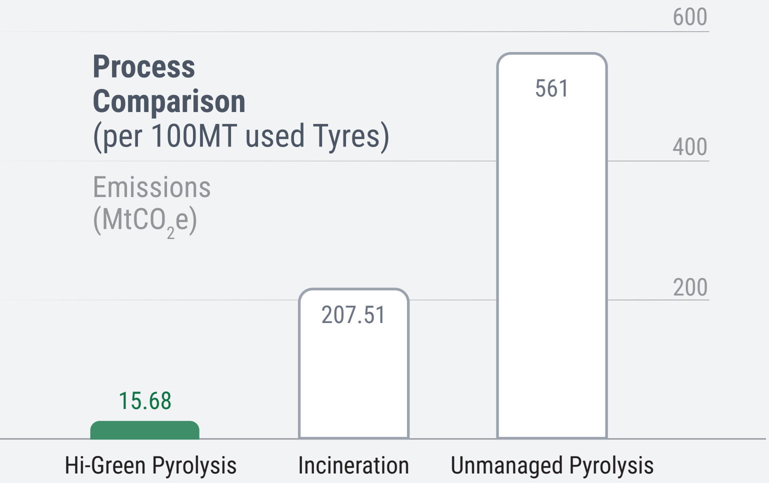



Chart 1: Comparison of fates of used tyres (Hi-Green Carbon Pyrolysis vs. Incineration vs. Unmanaged Pyrolysis)

* This comparison serves to illustrate the difference between the value ranges. Values of incineration and unmanaged pyrolysis are based on assumptions outlined in respective sections

Additionally, Hi-Green Carbon's rCB compares favourably to virgin Carbon Black, measuring only **11.68%** to **4.22%** of vCB's $CO_2e$ emissions.

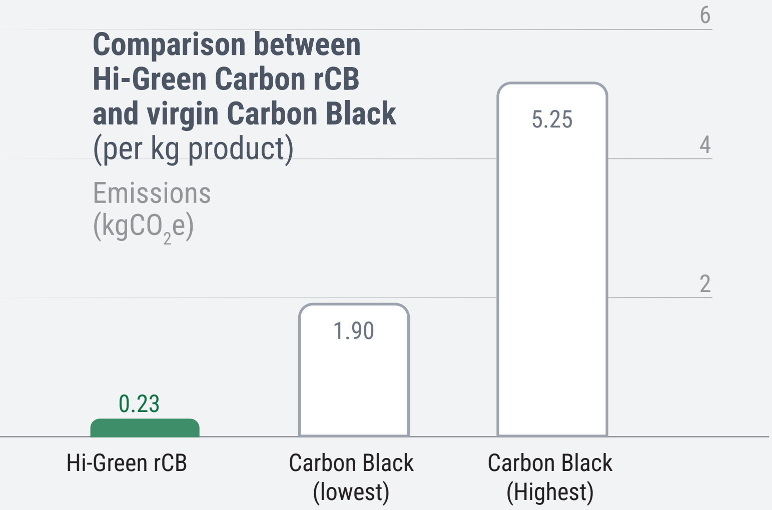



Chart 2: Comparison of GWP values of Hi-Green Carbon rCB and virgin Carbon Black

Overall Global Warming Potential (GWP) of the Hi-Green Carbon pyrolysis process

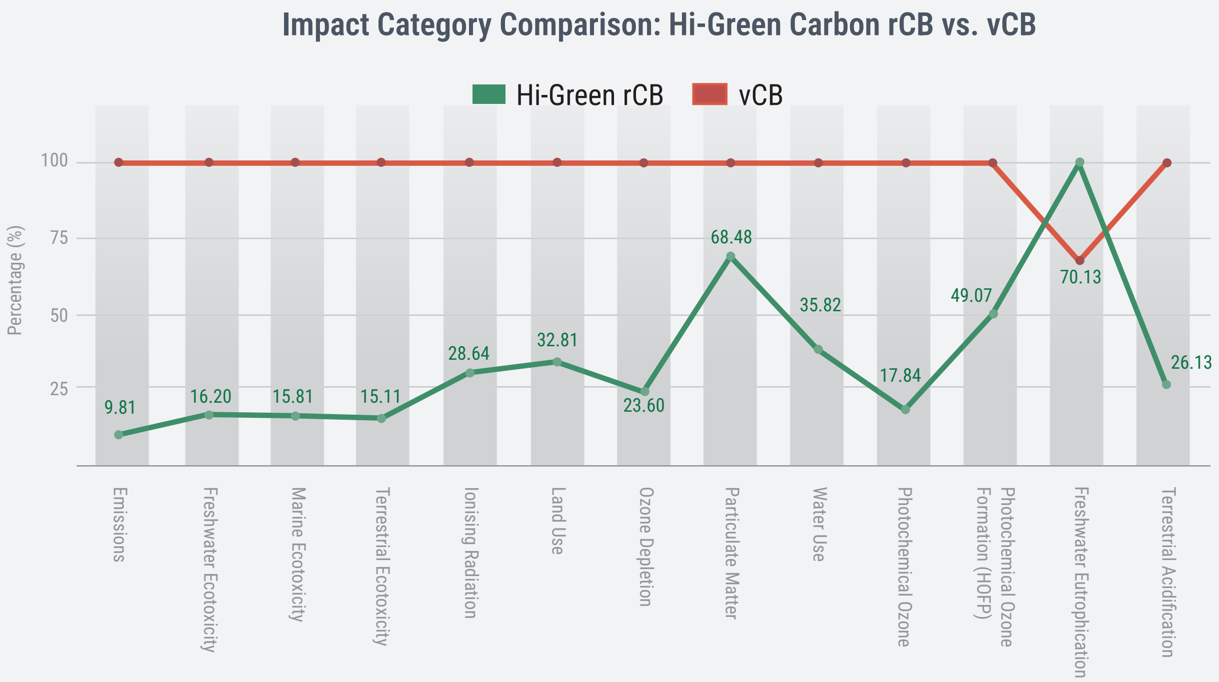
**15,681.77** $kgCO_2e$
(for 100 MT used tyres)

**0.232** $kgCO_2e$
(per kg of rCB manufactured)

These values are going to reduce even further in the future, as Hi-Green Carbon is in the process of installing solar panels at its Bhilwara facility. Once the solar farm is operational, the GWP values will be as follows:

Overall GWP value,
100 MT used tyres: **11,815.547** $kgCO_2e$
GWP per 1 kg rCB: **0.134** $kgCO_2e$

## Environmental Impacts Comparison: Manufacturing and Packaging 1kg of Hi-Green Carbon rCB vs. 1kg of vCB




**Note:** One point that might stand out in the impact category comparison is the higher Freshwater Eutrophication of rCB as compared to vCB. Eutrophication occurs due to excessive accumulation of nutrients such as Nitrogen (N) and Phosphorus (P) into water bodies, and causes algal blooms, reduction of oxygen levels, and water quality degradation.

At the time of the study, Hi-Green Carbon's rCB manufacturing was powered by Indian grid electricity, which is mainly coal based (70.69% of total power generation, NITI Aayog 2024). Coal mining and coal washing processes cause significant runoffs of nutrients such as phosphates into local water bodies. This leads to increased eutrophication.

With the introduction of a 529kW solar farm, which has become operational since September 2024, Hi-Green Carbon has reduced its reliance on coal-based energy. Hence, the rCB manufactured post this date will have a Freshwater Eutrophication value which is 61% of that of virgin Carbon Black, leading to less harmful impacts on water bodies and their ecosystems.

# Overview

## About This Report

This report aims to quantify the environmental impacts of manufacturing one kilogram of recovered Carbon Black using Hi-Green Carbon's patented pyrolysis process at the Hi-Green Carbon facility at Bhilwara, Rajasthan. The report compares the environmental impacts of Hi-Green Carbon's process with a conventional carbon black production process, thus outlining the comparative benefits of Hi-Green Carbon's circular approach. The report also estimates the potential benefits or pitfalls of using Hi-Green Carbon's pyrolysis process on Used Tyres, instead of having the tyres incinerated or pyrolysed in an unmanaged facility, which are two common fates for tyres in India.

The intended audience for this report is the internal team at Hi-Green Carbon, as well as current and prospective investors who might be interested in understanding the environmental benefits (avoided environmental harms) of Hi-Green Carbon's recovered Carbon Black.

This report introduces the company, the product, and the entire manufacturing process. It then outlines the goal of the study and explains the parts of the manufacturing process that will and will not be considered. It then showcases the elemental and material inputs for manufacturing a declared unit of the product. Based on the inputs, it gives the final values of decided impact categories. Finally, it will explain what the values mean by comparing against some other popular industry scenarios, and give recommendations for the future.

*Note: Hi-Green Carbon has recently installed a 529kW solar farm on its premises, which has become operational since September 2024.*
*Since the study for this report was conducted during July 2024, the report considers the impact of this solar farm in the 'Future Emissions' category.*

## Product Life Cycle Assessment

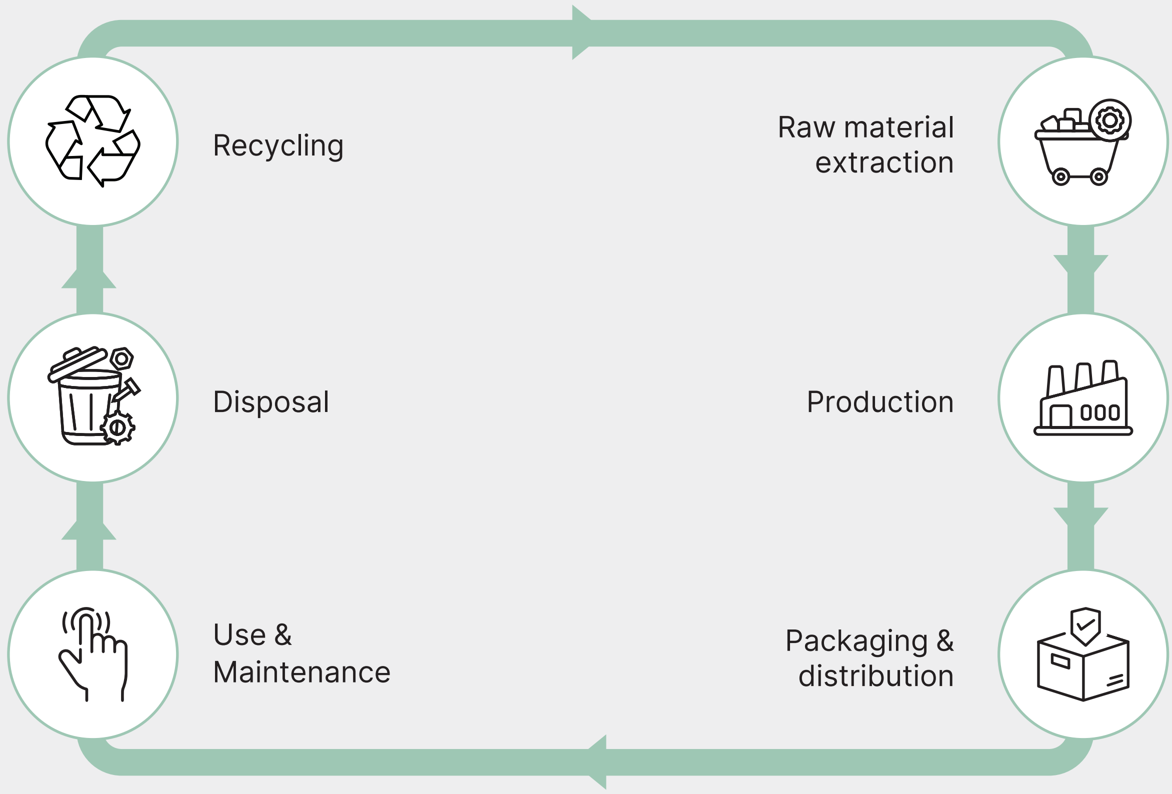
A Product Life Cycle Assessment (PLCA) is a systematic method to calculate the environmental impact of a product throughout its entire lifecycle. Conducting an LCA offers numerous benefits, enabling businesses to make informed, sustainable decisions. With an LCA, a business can Identify Environmental Hotspots, Compare Alternatives, Support Data-Driven Marketing, and Reduce Environmental Footprint.

The scope of an LCA determines the materials and processes that are considered important for the LCA, and those which are not considered for the study. Scopes change based on the objective or goal of the LCA.

These scopes can popularly be 'Cradle to Grave', which is an entire lifecycle analysis, or 'Cradle to Gate', which is an analysis of the process till the product is manufactured and leaves the factory gates.

In summary, an LCA is one of the most comprehensive ways of measuring a product's environmental impacts, and communicating them to stakeholders.

### What is Life Cycle Assessment?



## Hi-Green Carbon and Recovered Carbon Black (rCB)

Fig. 1: The Hi-Green Carbon Facility at Bhilwara, Rajasthan, India

Hi-Green Carbon Ltd. is an Indian chemical company listed on the Indian stock exchange, with a market capitalization of ₹644 cr at the time of writing (Moneycontrol, 2024).

Hi-Green Carbon Ltd., a venture of the Radhe Group of Energy, specialises in processing waste hydrocarbons to produce valuable products like recovered Carbon Black (rCB). rCB is created by the pyrolysis of used tyres that would have otherwise been sent to the incinerator, or have ended up in a landfill. It is sold in pelletised form.

The global rCB market is estimated to grow from US $161 Mn in 2024 to around US $1.9 Bn by 2032 (Fortune Business Insights, 2024). rCB as a product is used in the Tyre industry as a reinforcement material, Paint and Textile industries as a pigment or dye, and also as an additive in the Plastics and Cement industries. Since its production involves pyrolysis of used tyres or crumb rubber, it is an important component of the circular economy, and is looked upon as a viable path towards a zero-waste future.

Hi-Green Carbon has 15 years of experience in the rCB manufacturing field. It has been operating one of the world's largest patented 100 TPD (tonnes per day) continuous processing plants at Bhilwara, Rajasthan for the last 15 years.

It is committed to circular economy principles and continuously innovates to reuse resources, reduce waste, and greenify its premises.
As the world wakes up to the importance of sustainability in business operations, Hi-Green Carbon is well positioned to become a frontrunner among companies prioritising environmental sustainability.

Fig. 2: rCB granules


Fig. 3: Final packaged product - rCB

## Process (Pyrolysis)

Pyrolysis process involves heating pieces of shredded tyres (of 1-2" size) in the absence of Oxygen in a sealed kiln at temperature up to 700°C. This causes the tyres to break down and certain byproducts to form, as outlined in the table below:

| Sr. No. | Major Products | Quantity (tonnes) /85 tonnes of waste tyres |
|---|---|---|
| 1 | Green Oil | 36.55 |
| 2 | Carbon Black | 29.75 |
| 3 | Fuel Gases (Syngas) | 17 |
| 4 | Carbon Slurry | 1.7 |

Table 1: Pyrolysis Byproducts

Note: Steel Scraps (15 tonnes) are generated upstream and are not included in this table

Of these, the non-condensable gases are called Syngas. Syngas has a calorific value of ~10,000 Kcal/kg, and is collected and used as fuel for the pyrolysis process. Since the kiln is operated round the clock, some of the generated syngas (~8 MT) is re-routed continuously and used to operate the kiln at 700 ºC. Jacketed heating is adopted so that odour, VOC and other pollutants do not escape in the process area or into the open atmosphere, making the entire process closed loop.

Fig. 4: Crumb Rubber - the raw material

All the syngas isn't consumed in kiln operations, so the extra syngas (~9 MT) is re-routed to the Silica Glass plant on the premises, where it is used as fuel to turn the Soda Ash and Silica Sand into Sodium Silicate glass.

Meanwhile, the condensable gases are liquefied using a condenser setup into Green Oil (Low sulphur fuel oil; calorific value 10,500 Kcal/kg). This oil can be considered the main product of the pyrolysis process, with the highest yield and selling price. This oil is then stored in containers on the premises, where it is allowed to settle and minor carbon impurities in the oil settle down. These are then separated and sold as Carbon Slurry.

Fig. 5: Green Oil is stored on-site, where Carbon Slurry is separated

The syngas is treated using dry sulfur scavenger technology. Iron ore pellets are used to absorb sulfur from the NCG (Non-condensable Gases), converting it into ferrous sulfate ($FeSO_4$), a good fertilizer for gardening and agriculture. This avoids the production of hazardous $H_2SO_4$ liquid effluent, which would have resulted from the use of conventional water scrubbers.

The flue gas from the baghouse filter passes through Environmental Protection Equipment (EPE). This system includes three components in series: a dry sulfur scavenger to absorb minor SOx, a water scrubber to control any remaining PM, and a mist remover. Finally, clean gas is released into the chimney through an ID fan.

The solid carbon black formed in the kiln is then cooled, cleaned, dried, and grinded to different specifications to form several variants of rCB. A heat recuperator is used to absorb the excess heat contained in the flue gas, and it is used to dry the rCB before pelletisation. The rest of the hot flue gases are re-routed into the pyrolysis kiln with the syngas. The pelletised rCB variants are then packaged in LDPE bags (15kg-25kg of rCB in each bag)  and sold to buyers.

The pyrolysis kiln is operated for 25 days per month, keeping the other 5 days for cleaning. During cleaning, the kiln undergoes nitrogen purging and it is then manually cleaned of residue and chips. The residue is then turned into fertilisers to be used on site, in the Hi-Green Carbon garden and orchards. The nitrogen for the purging process is also generated on-site in the Nitrogen plant, which runs on grid electricity.

During the time the kiln is shut down for cleaning, the carbon grinding mill works on grinding the extra rCB stored in the storage tank. Once the cleaning process is complete, the kiln is fired back up using Green Oil (approx. 1000 kg per month), after which the generated syngas takes over as the primary fuel for the process.

In this manner, Hi-Green Carbon utilises circular design and approach in its processes. It is currently in the process of installing solar panels on the plant site, which when activated would provide 529 kW of clean power, further driving down $CO_2$ emissions.

Fig. 6: On-site Nitrogen plant, which is instrumental in kiln cleaning and maintenance

Fig. 7: Storage for rCB, used when kiln is shut down for cleaning

# Goal and Scope

The goal of this study is to understand the total environmental impact of manufacturing one kg of Hi-Green Carbon's rCB, and understanding the benefit of Hi-Green Carbon's recovery business model by quantifying the avoided emissions that would have otherwise occurred if the tyres were incinerated or subjected to unmanaged pyrolysis instead of Hi-Green Carbon's patented pyrolysis into rCB.

The scope of this study begins with the collection of used tyres by the shredding plant, and the scope ends with the production and packing of rCB at the Hi-Green Carbon plant at Bhilwara. Since the scope begins with the used tyres already produced and it ends at the Hi-Green Carbon factory gate, this is a 'Gate to Gate' study.

## Technical Information About the Study

| | |
|---|---|
| Product under study | Recovered Carbon Black (rCB) |
| Product Reference Unit(s) | 1kg of rCB |
| Scope | Gate to Gate |
| Allocation Method for Multi-Product system | Economic Allocation |
| Databases used | Ecoinvent v3.10, DEFRA 2024 |
| System Model | Allocation, cut-off by classification |
| Impact Categories | Global Warming Potential (GWP) in kg$CO_2$e, Freshwater Ecotoxicity, Marine Ecotoxicity & Terrestrial Ecotoxicity in kg 1,4-DCB-eq, Ionising Radiation in kBq Co-60-Eq, Land Use in m2*a crop-Eq, Ozone Depletion in kg CFC-11-Eq, Particulate Matter in kg PM2.5-Eq, Water Use in $m^3$ |
| Characterisation Method | IPCC AR4/5 100a, ReCiPe 2016 v1.03, midpoint (H) |

# System Boundary

## Diagram and Inclusions

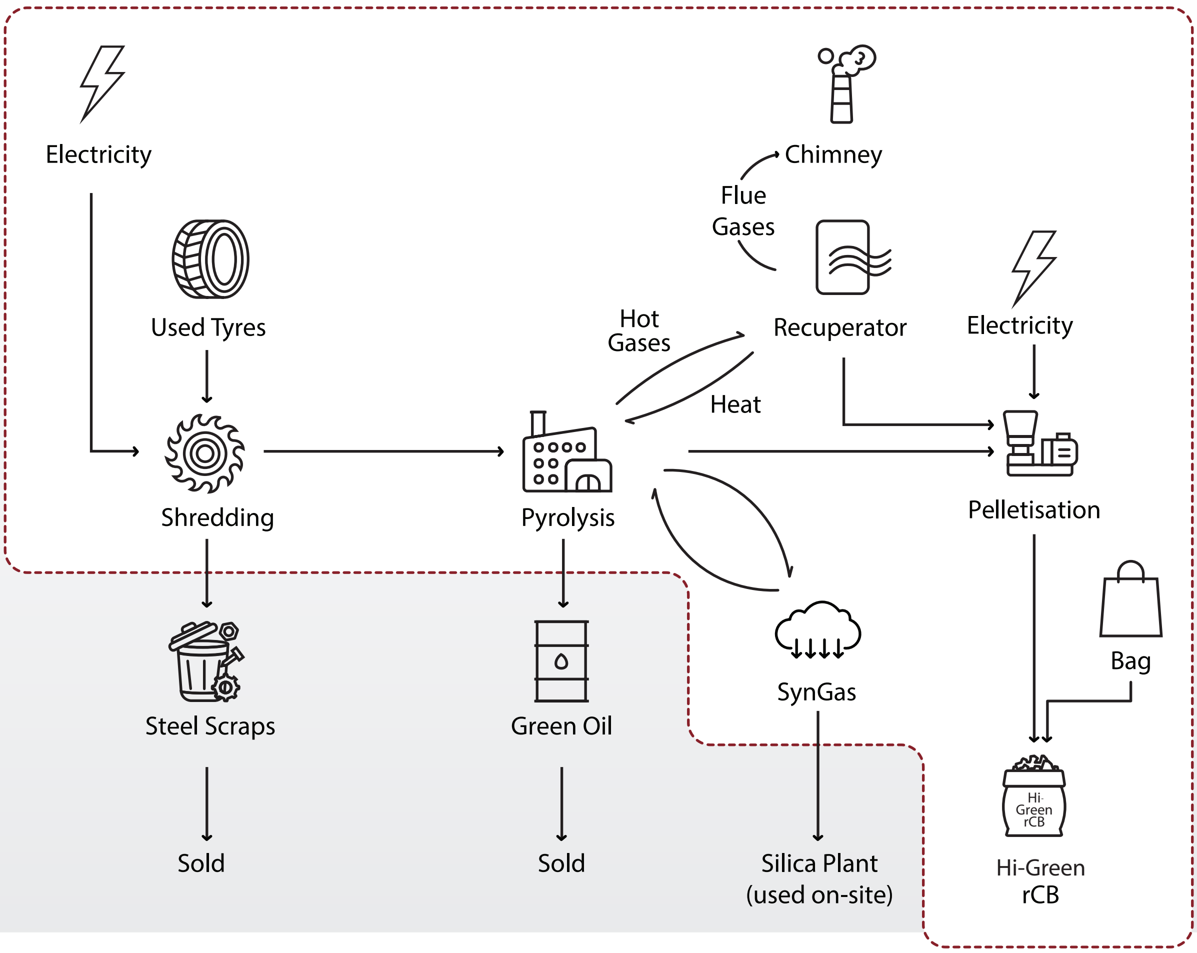



Fig. 8: System Boundary of this study

This study begins at the collection of used tyres, which kickstarts the entire process. It covers the transport of the tyres to shredding location and subsequent transport to Hi-Green Carbon facility. It also covers the shredding, pyrolysis, and pelletisation processes. The study ends at the factory output, with 1 kg of Hi-Green Carbon rCB (with packaging) as the reference product.

### Exclusions

This study does not cover the following:

- The environmental impacts of creating the used tyres that are inputs for the pyrolysis process. (as per 'Allocation, cut-off by classification' system model)
- The use and disposal of co-products (steel scraps, low sulphur fuel oil, syngas, carbon slurry) created as a result of the pyrolysis process
- Any activities post the Hi-Green Carbon factory gate

# Life Cycle Inventory

### Data Collection Methodology

The Life Cycle Inventory (LCI) is a comprehensive list of material flows and reference flows that go into making a declared unit of the product under study. The LCI for Hi-Green Carbon rCB was created during a Site Visit to the Hi-Green Carbon manufacturing facility at Bhilwara, Rajasthan. The visit was conducted over two days (29-7-2024 and 30-7-2024). Processes were observed and data was collected on-site, via verbal information sharing and reports.

Once collected, the various data was normalised to a single day's consumption, and then shared with the Hi-Green Carbon Team for final confirmation. Upon receiving the confirmation, the Life Cycle Impact Assessment (LCIA) phase was started.

### Final Approved LCI Table

It is important to note that the collected data was for the entire manufacturing process. Since the process yields multiple products (Steel Scraps, Green Oil, rCB, Syngas, Carbon Slurry), the emissions for the process cannot be attributed to rCB alone. A process of Economic Allocation was performed to determine what percentage of the overall process emissions should be attributed to rCB. Following is the table of inputs attributable to the production of only rCB in Hi-Green Carbon's process:

### Inputs

| Name | Quantity | Unit | Comments |
|---|---|---|---|
| Used Tyres | 1.01669 | kg | |
| Diesel | 0.00076 | L | for transporting used tyres to shredding site |
| | 0.07625 | metric tonne *km | |
| Electricity for shredding | 0.05083 | KWh | Crumb rubber supplier |
| Diesel | 0.00253 | L | for transporting crumb rubber to pyrolysis site |
| | 0.25493 | metric tonne *km | |
| Grid Electricity | 0.01138 | KWh | to operate pyrolysis machinery |
| Syngas | 0.08274 | kg | Part of syngas re-routed from output |
| Water | 0.20684 | L | for cooling of syngas to Green Oil |
| Diesel | 0.00017 | L | for DG and on-site equipment |
| Grid Electricity | 0.06723 | KWh | to operate carbon grinding mill - pelletisation of rCB |
| LDPE bag | 0.005 | kg | empty - to store rCB |
| Diesel | 0.001 | metric tonne*km | (equivalent to) LDPE transport to factory |

*(for 1kg rCB, normalised after economic allocation)

### Outputs

Following is the table of all outputs of the entire process, normalised to correspond to 1 kg of rCB:

| Name | Quantity* | Unit |
|---|---|---|
| rCB | 1 | kg |
| Green Oil | 1.19496 | kg |
| Syngas | 0.57143 | kg |
| Carbon Slurry | 0.05714 | kg |
| Steel Scraps | 0.5042 | kg |
| NOx | 0.30396 | g |
| NO | 0.19629 | g |
| CO | 0.01789 | g |
| $SO_2$ | 1.14612 | g |
| VOC | 0.33054 | g |
| SPM | 0.16641 | g |

*(for 1kg rCB, normalised after economic allocation)

Table 2: Inventory of Outputs for the rCB manufacturing process

After compiling the Life Cycle Inventory, the respective impact factors for each impact category are considered, and the final environmental impact values are obtained.

# Life Cycle Impact Assessment

### Results

Following is the GWP value for the entire Hi-Green Carbon process, from used tyre collection to eventual packaging of Hi-Green Carbon rCB, including all co-products:

Following is the GWP value for manufacturing 1 kg Hi-Green Carbon rCB, with packaging, after performing economic allocation:

Total GWP value
(for 100 MT used tyres)

**15,681.77**
kg $CO_2e$

GWP value attributable to
1kg Hi-Green Carbon rCB

**0.232**
kg $CO_2e$

The overall environmental impacts for all considered impact categories are as follows:

| Impact Category | Value | Unit |
|---|---|---|
| Freshwater Ecotoxicity | 0.007072936182 | kg 1,4-DCB-eq |
| Marine Ecotoxicity | 0.01119121348 | kg 1,4-DCB-eq |
| Terrestrial Ecotoxicity | 2.013559613 | kg 1,4-DCB-eq |
| Ionising Radiation | 0.005627547392 | kBq Co-60-Eq |
| Land Use | 0.005553934465 | m2*a crop-Eq |
| Ozone Depletion | 0.0000000533 | kg CFC-11-Eq |
| Particulate Matter | 0.002085182444 | kg PM2.5-Eq |
| Water Use | 0.001351163346 | $m^3$ |
| Photochemical Ozone Formation (EOFP) | 0.0009054248635 | kg NOx eq |
| Photochemical Ozone Formation (HOFP) | 0.002065186451 | kg NOx eq |
| Freshwater Eutrophication | 0.0001680910108 | kg P eq |
| Terrestrial Acidification | 0.001573526975 | kg SO eq |

**Table 3: Final values for listed impact categories, for rCB manufacturing process**

These numbers might not mean much to the average reader, so the next section will work towards demystifying them. To stay within the scope of this report, the upcoming section will delve deeper into explaining the significance of the 'Global Warming Potential' impact category; a term which is often called 'Carbon Emissions', the most popular metric of environmental impact in today's business landscape.

# Interpretation

### Breakdown of Current Process Emissions

The overall Hi-Green Carbon process can be divided into three distinct stages: Shredding, Pyrolysis, and Pelletisation. Following are the emissions for each stage.

| Process Stage | Overall Emissions (kg $CO_2e$) |
|---|---|
| Stage 1: Shredding | 7,388.85 |
| Stage 2: Pyrolysis | 5,212.57 |
| Stage 3: Pelletisation | 3,080.35 |
| SUM | 15,681.7 |

Table 4: Total emissions split by process stage for the entire manufacturing process

Table 4 and Chart 3 show that the Shredding process is the most carbon intensive process in the entire manufacturing cycle, taking up almost half of the entire process emissions.

This is because of the high electricity use in the process (5000 KWh per day), coupled with the high emission factors of India's Northern grid, which is primarily dependent on coal.

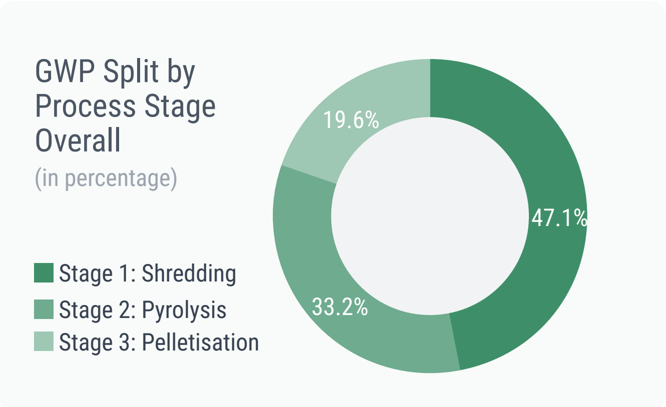



Chart 3 : GWP split by process stage for the entire process (all co-products)

## Comparison with Conventional Carbon Black

To better understand the significance of Hi-Green Carbon's rCB emission factor, let us compare it with standard emission factors of virgin Carbon Black. There are several ways to manufacture carbon black, namely furnace black process, gas black process, channel black process, lamp black process, thermal black process and acetylene black process. Depending on the process, the emission factor for the carbon black changes.

Generally, the value ranges from 1.90 to 5.25 kg of carbon dioxide per kg of carbon black (Rosner et al., 2024). Considering this range, following is the comparison between Hi-Green Carbon's rCB and virgin Carbon Black:

Hi-Green Carbon's rCB has a GWP equaling 11.68% of the Carbon Black with the lowest GWP, and 4.22% of the Carbon Black with the highest GWP. This means the rCB manufacturing process emits somewhere between one-tenth to one-twenty fifth of conventional vCB manufacturing process' $CO_2$e emissions.

**1.67 - 5.02**
$kgCO_2$e saved per kg rCB

**49.68 - 149.34**
$MtCO_2$e saved per day

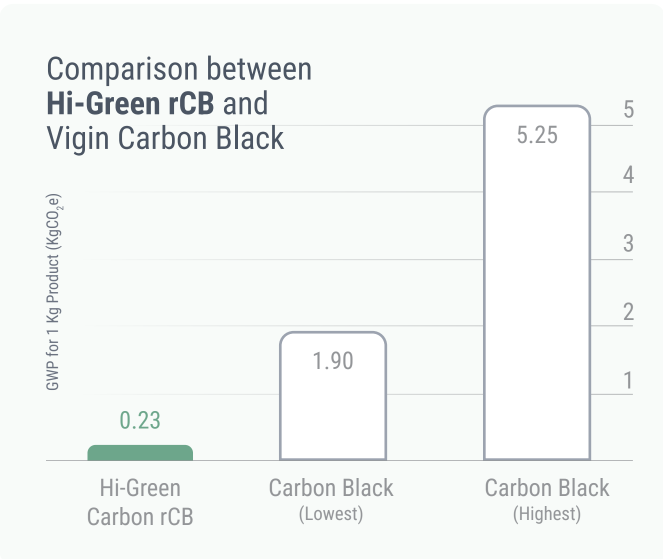



Chart 4: Comparison of GWP values of Hi-Green Carbon rCB and virgin Carbon Black

## Estimating the Avoided Environmental Impacts of Unmanaged Pyrolysis

For 85 MT Crumb Rubber
561 $MtCO_2e$
(Unmanaged Pyrolysis)

For 85 MT Crumb Rubber
**15.68** $MtCO_2e$
(Hi-Green Carbon rCB)

545.32
$MtCO_2e$
Saved per day

In India, waste tyres are often collected and burnt in unmanaged pyrolysis plants (Singh, S. R., 2024). This releases methane ($CH_4$) into the atmosphere. Since methane is a greenhouse gas with a higher GWP than Carbon Dioxide, this practice of releasing gases into the air is harmful for the environment. An estimate can be made of the quantity of $CO_2e$ emitted by unmanaged pyrolysis of hundred metric tonnes of used tyres.

Therefore, Hi-Green Carbon's pyrolysis provides significant environmental benefits as opposed to small-scale, unmanaged pyrolysis plants. By using syngas for the pyrolysis process, Hi-Green Carbon avoids the use of coal or natural gas to operate the pyrolysis kiln. By using scrubbers in their chimney stacks, they capture a considerable amount of pollutants and then use them to produce fertilisers to be used on-site.

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## Estimating the Avoided Environmental Impacts of Incineration

Assuming complete combustion, $CO_2e$ emissions for 100 MT used tyres:
207.51 $MtCO_2e$

For 100 MT used tyres
**15.68** $MtCO_2e$
(Hi-Green Carbon rCB)

191.83
$MtCO_2e$
Saved per day

If not pyrolysed, some tyres are incinerated in Waste to Energy plants, brick kilns, jaggery making units, or even burnt in unmanaged heaps by scrap dealers looking to extract steel from the tyres. This releases many harmful gases into the atmosphere, one of which is Carbon Dioxide. Besides $CO_2$, tyre burning also emits carcinogens, such as aromatic hydrocarbons into the atmosphere. Careless tyre burning in India is also responsible for garbage landfill fires (Kaur, R., 2024).

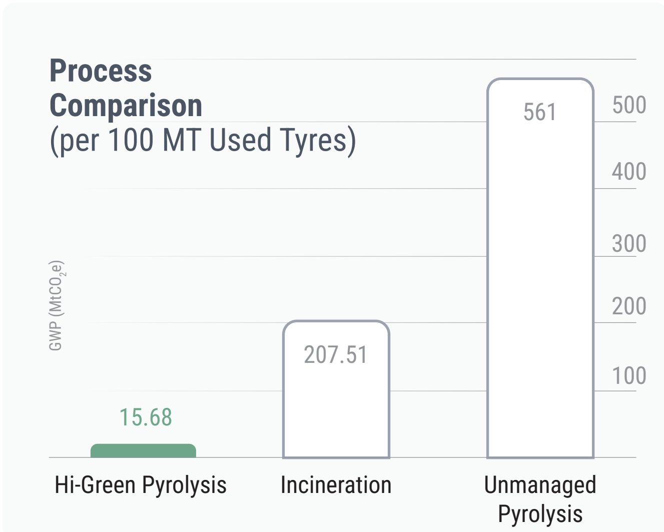


Chart 5: Comparison of fates of used tyres (Hi-Green Carbon Pyrolysis vs. Incineration vs. Unmanaged Pyrolysis)

## Estimating Future Emission Reductions After Shift to Renewable Energy

It has been observed that electricity usage of the Northern Indian grid is a significant contributor to the overall Hi-Green Carbon pyrolysis emissions.

Hi-Green Carbon is currently in the process of installing solar panels at its Roopaheli plant. Once fully operational, these panels will provide 529 kW of power, meeting almost all of the plant's electricity requirements, resulting in the following projected process emissions:

| Process Stage | Overall Emissions (kg $CO_2e$) |
|---|---|
| Stage 1 : Shredding | 7,388.85 |
| Stage 2 : Pyrolysis | 3,839.95 |
| Stage 3 : Pelletisation | 586.75 |
| **Total** | **11,815.55** |

Table 5: Total emissions split by process stage for the entire manufacturing process (after shifting to renewables)

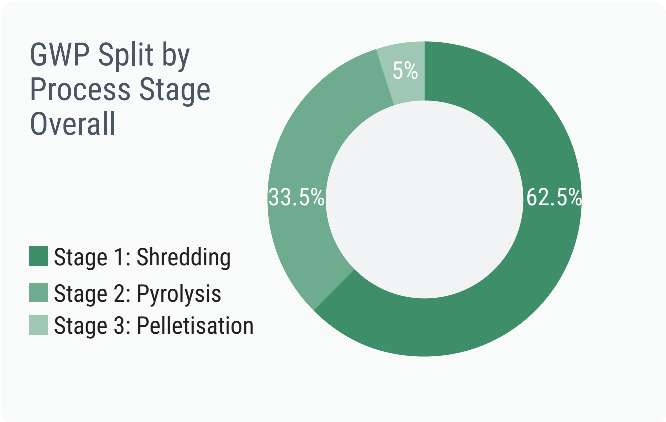


Chart 6: GWP split by process stage for the entire process (all co-products, after shifting to renewables)

Side by side comparison:

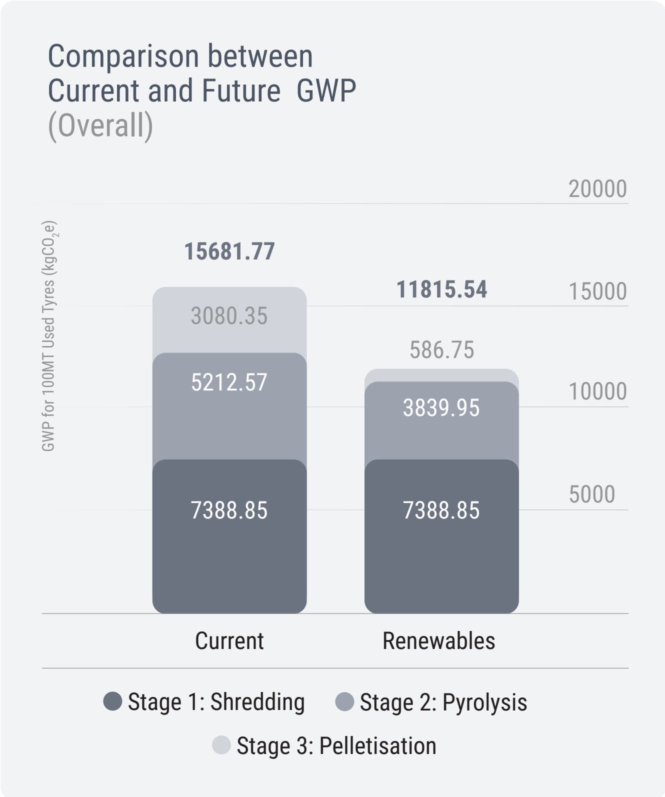


Chart 7: Side by side comparison of overall process GWP (current scenario vs future scenario with renewables)

The overall emission factor will be reduced by 25%.

For rCB, the following will be the new emission factor:

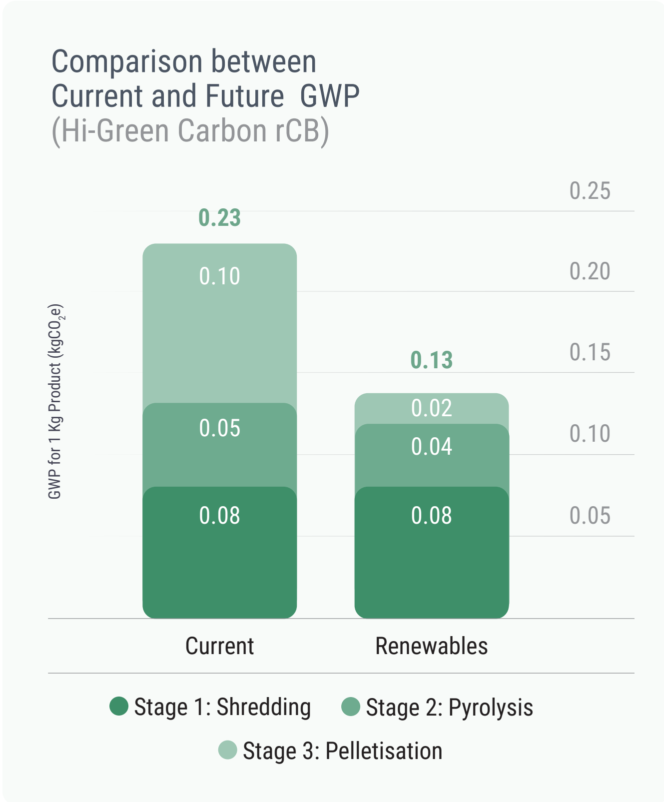


Chart 8: Side by side comparison of rCB GWP (current scenario vs future scenario with renewables)

This is an almost 45% reduction in the emission factor of Hi-Green Carbon rCB.

Thus, the overall environmental impact of Hi-Green Carbon's manufacturing process, including its rCB, is expected to decrease further with the introduction of solar panels at the Bhilwara plant.

# Recommendations

By installing the solar panels on-site, Hi-Green Carbon has already taken important steps towards a net-zero product. After the solar panels become operational, the majority of the process emissions will become attributable to activities outside the Hi-Green Carbon premises, mainly shredding and transport of crumb rubber. Following are some recommendations for Hi-Green Carbon:

1. Ensure crumb rubber suppliers (Shredders) move to renewable energy
2. Source crumb rubber from suppliers closer to the Bhilwara facility

To sum up, Hi-Green Carbon is taking steps towards reducing the emissions attributable to its rCB, and is on its way towards a net-zero product.

It is important to note that this study has measured the environmental impacts of manufacturing Hi-Green Carbon's rCB. A study measuring the eventual use and disposal of rCB, as well as of all the other co-products of the process, including the use of syngas for silica production, is recommended to further explore the total environmental impact of Hi-Green Carbon's operations.

# Glossary

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| Characterisation Method: IPCC AR4/5 100a, ReCiPe 2016 v1.03, midpoint (H) | Characterisation Method is a way to combine all emissions of a process to a single metric. For instance, one kg of Methane ($CH_4$) is equivalent to 28 kg of Carbon Dioxide ($CO_2$), so CH4 = 28 $CO_2$e.<br><br>This is according to the IPCC AR5 100a, which takes into account the effect of GHGs over 100 years. If the Characterisation Method were IPCC AR4 100a, the value would have been 25. Thus, changing the Characterisation Methods will change the conversion values by a bit, leading to differing results.<br><br>ReCiPe 2016 v1.03, midpoint (H) also considers a time span of 100 years, so it was chosen to maintain uniformity. |
| Freshwater Ecotoxicity | Indicates the potential harm of toxic substances to freshwater ecosystems, affecting organisms like fish and aquatic plants. |
| Freshwater Eutrophication | Indicates the nutrient overload (mainly phosphorus) in freshwater systems, which can lead to harmful algal blooms, oxygen depletion, and loss of biodiversity.<br>Unit : kg-P-eq. |
| GHGs | Greenhouse Gases |
| GWP and GWP Value | Reflects the contribution of greenhouse gases to climate change over a 100-year period. GWP100 is crucial for understanding the long-term impact of emissions on global warming |
| Ionising Radiation | Indicates the harmful effects of ionising radiation on humans and ecosystems, primarily from nuclear energy or medical sources.<br>Unit : kBq Co-60-Eq |
| kg $CO_2$e - kilograms of $CO_2$ equivalent | A common unit for measuring GHG emissions. All GHG emissions are converted to $CO_2$ equivalent, just as how weights are converted to kg or distances are converted to km. For instance, one kg of Methane ($CH_4$) is equivalent to 28 kg of Carbon Dioxide ($CO_2$), so $CH_4$ = 28 $CO_2$e |
| Land Use in | Quantifies the occupation of land for agricultural purposes, with potential impacts on biodiversity, ecosystem services, and land availability.<br>Unit : m2*a crop-Eq |
| LCI - Life Cycle Inventory | This is an inventory of all the inputs and outputs that go into a process. An analogy could be a list of ingredients for a recipe. |

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| Marine Ecotoxicity | Assesses the impact of pollutants on marine environments, where toxic substances can harm marine life and disrupt ecosystems.<br>Unit : kg 1,4-DCB-eq |
| Ozone Depletion | Measures the release of substances that deplete the stratospheric ozone layer, which protects life on Earth from harmful UV radiation.<br>Unit : kg CFC-11-eq |
| Particulate Matter | Also called particle pollution are fine inhalable particles, with diameters that are generally 2.5 micrometres and smaller. A mixture of solid particles and liquid droplets found in the air.<br>Unit : kg PM2.5-eq |
| Photochemical Ozone Formation (EOFP & HOFP) | An impact category that accounts for the formation of ozone at the ground level of the troposphere caused by photochemical oxidation of Volatile Organic Compounds (VOCs) and carbon monoxide (CO) in the presence of nitrogen oxides (NOx) and sunlight. High concentrations of ground-level tropospheric ozone damage vegetation, human respiratory tracts and manmade materials through reaction with organic materials.<br>Unit : kg-NOx-eq |
| PLCA - Product Life Cycle Assessment | PLCA is a comprehensive analysis of the environmental impacts associated with all stages of a product's life cycle, from raw material extraction (cradle) to disposal (grave). The assessment can be limited to specific phases, such as cradle-to-grave, which includes all impacts from raw material extraction to product disposal, or gate-to-gate, which focuses on specific production phases. PLCA helps identify opportunities for reducing environmental impacts throughout a product's life. It also helps companies communicate their products' environmental impacts to stakeholders. |
| Pyrolysis | The process of heating feedstock (in this case rubber) in the absence of oxygen, in order to cause a breakdown in its compounds to obtain new chemicals/products. |
| Terrestrial Acidification | This measures the acidification of soil caused by air pollutants like sulphur dioxide. Excessive acidification can harm plants, reduce soil fertility, and disrupt ecosystems.<br>Unit : kg SO2-eq. |
| vCB and rCB | Virgin Carbon Black and recovered Carbon Black |
| Water Use | Quantifies the freshwater consumed during a product's life cycle, considering its impacts on water scarcity and ecosystem health.<br>Unit : $m^3$ |

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# Disclaimers

* In order to stay focused on its scope, the study does not calculate the use and disposal of the co-products: steel scraps, syngas, green oil, and rCB. This approach ensures that focus is on Hi-Green Carbon's pyrolysis process. This also means that the study does not include the total effects of the entire value chain, and all comparisons with other processes are made keeping this in mind.

* It is important to note that rCB is not equal to vCB in terms of performance, since it has lower reinforcement capabilities due to its composition (Urrego-Yepes, W., Cardona-Uribe, N., Vargas-Isaza, C. A., & Martínez, J. D., 2021). Thus, it cannot completely replace conventional vCB in its applications. Particulate emissions are also not covered in the scope of this report. It is recommended to keep these factors in mind before making direct comparisons with vCB. However, the reduction in $CO_2e$ emissions is notable.

* The temperature, fuel usage, and other parameters in unmanaged pyrolysis processes differ from Hi-Green Carbon's operations, reducing accuracy of direct comparisons. However, this study provides valuable insight into the potential emissions levels if Hi-Green Carbon's process were not in place.

* The Hi-Green Carbon pyrolysis vs. incineration comparison assumes full combustion of an SBR tyre, and is based on researched estimates and assumptions. Real values will vary, and hence it is not recommended to make a direct comparison between the $CO_2e$ values of incineration and pyrolysis. However, the difference between the scales of the values is significant and provides an indication of the avoided emissions due to Hi-Green Carbon's pyrolysis process.

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