Report

On

LIFE CYCLE ANALYSIS (LCA)

For

M/s SUPREME PETROCHEM LTD

At Village – Amdoshi-Wangani, Wakan-Roha Road,
Taluka-Roha, District-Raigad, Maharashtra 402106.

PREPARED BY

Goldfinch Engineering Systems Private Limited

Plot No. A-288, Road No. 16 Z, Thane Industrial Area,

MIDC (Wagle Estate) Thane - 400 604

Maharashtra, India

Index

List of Tables

List of Figures

Chapter 1

Introduction

SUPREME PETROCHEM LTD (SPL) was founded and incorporated in 1989 at Mumbai, with a manufacturing facility located at Amdoshi-Wangani, Near Nagothane, Dist. Raigad, Maharashtra, 110 Km from Mumbai on Mumbai-Goa Highway.

SPL owns and operates state-of-the art production facilities from two locations in India, the first at Amdoshi – Wangani Village near Nagothane in District Raigad, Maharashtra and the second at Manali in Chennai.

SUPREME PETROCHEM LTD (SPL) has proposed project for expansion in manufacturing capacity of existing products and addition of new products under the category of synthetic resins. Since inception SPL has focused on providing quality products while maintaining high manufacturing standards. These facilities have been approved by various regulatory bodies. SPL wants to increase its market share by increasing manufacturing capacity and adding new products.

SPL have appointed Goldfinch Engineering System Ltd. for consultancy services in getting the necessary clearances. SPL has been in operation at the existing site since 1995 and in accordance with the EIA Notification S.O. 1533 dated 14th September 2006, project is covered under Synthetic Organic Chemical Industry 5(f) and needs prior environmental clearance for expansion. In the 166th (A) meeting of SEAC-I dated 14th June 2019, ToR was granted to SPL with additional ToR for conducting a Life Cycle Analysis (LCA) of activities carried out at the project site. Goldfinch Engineering Systems ltd. has conducted the Life Cycle Analysis Study in-house with the help of special software such as SimaPRO which includes the latest data-bases from around the world.

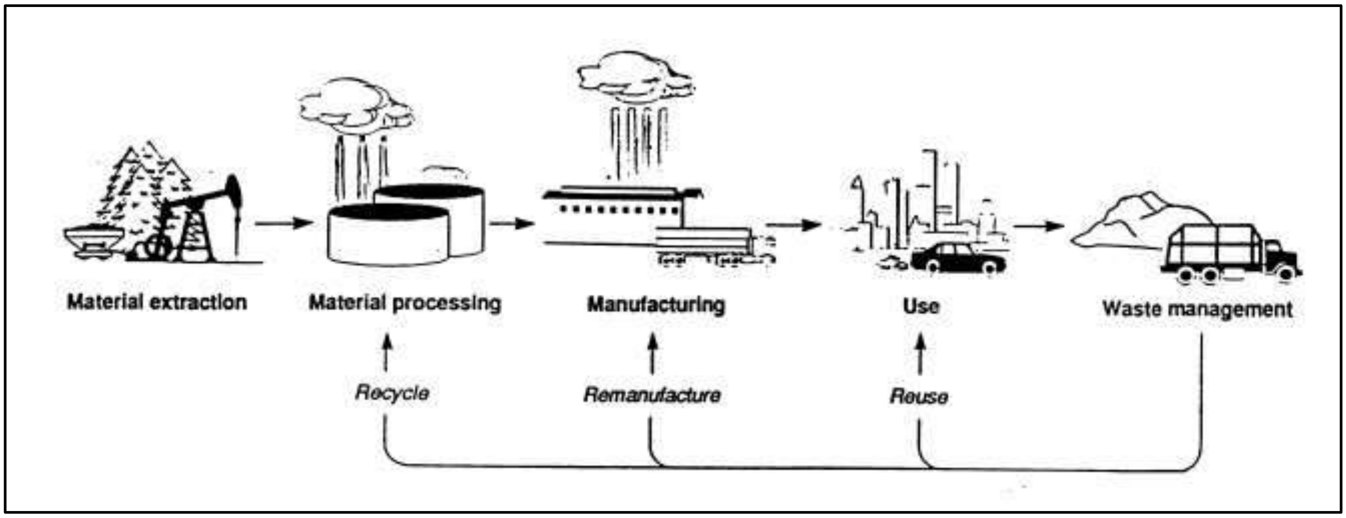

Figure 1- Overview of a typical Life cycle for a product

The entire life cycle for a manmade product goes from obtaining the raw materials needed to make the product, through manufacturing it, using it, and then deciding what to do with it once it is no longer usable. This means going from the birth of the product to its death. As such, this kind of view is often called a "cradle to grave" view of a product, where the cradle represents the birthplace of the product and the grave represents what happens to it when we are done with it– often to be thrown into a landfill. Life-cycle assessment (LCA), also known as life-cycle analysis is a "cradle to grave" analysis technique to assess environmental impacts associated with all the stages of a product's life from raw material to the finished product to un-usable/recyclable waste.

The goal of LCA is to compare the full range of environmental impacts due to products and services in order to improve processes, support policy and provide a sound basis for informed decisions. The term *life cycle* refers to the notion that a fair, holistic assessment requires the assessment of raw-material production, manufacture, distribution, use and disposal including all intermediate transportation steps necessary or caused by the product's existence. A Life Cycle Analysis can help broaden the outlook on environmental concerns by:

1. Compiling an inventory of relevant energy and material inputs and environmental releases;
2. Evaluating the potential impacts associated with identified inputs and outputs;
3. Interpreting the results to help make a more informed decision.

By understanding the potential impacts of the concerned activities, suitable mitigation measures to address these issues can be suggested. These mitigation measures can vary from implementation of better technology for production, implementing better inventory handling measures for reducing the usage of raw material to simple measures such as increasing the green cover to mitigate the carbon emissions related to concerned activities. Other direct applications of such a study are- To incorporate the interpretations of the result into the product strategy, public policy formation and marketing purposes. LCAs can be used as a marketing tool to highlight the eco-friendly nature of a product by comparing it with a similar product. LCAs are conducted according to ISO 14040:2006 and ISO 14044:2006 which describes the principles and framework for life cycle assessment (LCA) including: definition of the goal and scope of the LCA, the life cycle inventory analysis (LCI) phase, the life cycle impact assessment (LCIA) phase, the life cycle interpretation phase, reporting and critical review of the LCA, limitations of the LCA, the relationship between the LCA phases. Such a LCA is carried out in four distinct phases as follows- (a) Goal and Scope definition, (b) Life Cycle Inventory Analysis, (c) Life Cycle Impact Assessment and (d) Interpretation.

In the first phase of Goal and Scope definition, the objective of the study is to be summarized. Here it is necessary to mention whether this study will be an internal study document for the company or become a public document. Scope of the study should mention the system boundaries, i.e. in this section the product system should be examined to define a clear boundary condition for the study due to the complex nature of a LCA. Every such assumed product system will have some assumptions and limitations that form a part of the scope of the study. The assumptions and limitations mentioned in goal and scope section determine the interpretations that can be drawn from the study.

The next phase is Life Cycle Inventory Analysis. This phase is the most important part of entire LCA because here we have to compile and summarize the raw materials, water, electricity, heat and other such inputs required to manufacture the considered product. The outputs from the manufacturing process also have to be summarized.

Life Cycle Impact Assessment (LCIA) is the next phase where all the summarized inputs and outputs are accounted for and flow diagrams are constructed on the LCA software such as SimaPro, Gabi, UMBERTO, etc. Various datasets are available for this software. These data sets vary according to the country where the product is to be manufactured, the category of the product etc. Newer and more efficient data sets and inventories are reviewed by the Intergovernmental Panel on Climate Change (IPCC). The IPCC also recommends the LCA methodologies for various categories. These data sets and the primary data collected from proponent, secondary data from such data sets is compiled In the LCA software to form a detailed process flow diagram where the values for these inputs and outputs are incorporated. This gives us a Sankey Diagram which helps to better understand the flow of energy and, material for the manufacturing of the concerned products. Using the LCA software the values obtained from this are normalized and weighted for uniformity for comparison purpose.

Interpretation is the phase where results obtained from LCA software are to be analyzed for the considered product system. Here it is important to note that many times the interpretations that can be derived are limited due to the assumptions and limitations considered in goal and scope phase. To incorporate a more general and broader sense to the integration phase it becomes necessary to make changes to our product system and assumptions which can at times further complicate the study.

Chapter 2

Inventory Analysis and Life Cycle Impact Assessment (LCIA)

2.1 Goal and Scope

Supreme Petrochem Limited (SPL) has proposed an expansion in manufacturing capacity of existing products and addition of new products under the category of synthetic resins. SPL have appointed Goldfinch Engineering System Ltd. for consultancy services in getting the necessary clearances. SPL has been in operation at the existing site since 1995 and in accordance with the EIA Notification S.O. 1533 dated 14th September 2006, project is covered under Synthetic Organic Chemical Industry 5(f) and needs prior environmental clearance. In the 166th (A) meeting of SEAC-I dated 14th June 2019, ToR was granted to SPL with additional ToR for conducting a Life Cycle Analysis (LCA) of activities carried out at the project site. Goldfinch Engineering Systems ltd. has conducted the Life Cycle Analysis Study in-house with the help of special software such as SimaPRO which includes the latest data-bases from around the world. This report deals with the Life Cycle Analysis of production activities carried out at SPL and is carried out according to ISO 14040 and ISO 14044 standards. Such a LCA is carried out in four distinct phases as follows- (a) Goal and Scope definition, (b) Inventory Analysis, (c) Impact Assessment and (d) Interpretation.

Objective of this study is to quantify the carbon footprint due to activities being carried out at the factory site of SPL & suggest mitigation measures to reduce it. This LCA will be incorporated in the EIA report for Environmental Clearance (EC) purpose and hence will be a document in the public forum. This LCA should be studied by the proponent, interpretations drawn from it and incorporated into their existing operations as far as possible. All the products mentioned in the product list were considered for this study. The raw materials required for each product and the energy requirement for production (heat and electrical energy) and emissions from transport were considered. The following products with their total production in MT/A mentioned below were selected for this study.

Table 1- Products studied in this LCA

<table>
<tr><th>Sr. No.</th><th>Name of Product</th><th>Existing Quantity (TPA)</th><th>Proposed additional Quantity (TPA)</th><th>Total Quantity (TPA)</th></tr>
<tr><td rowspan="2">1</td><td>1a.
General Purpose Polystyrene (GPPS), High Impact Polystyrene (HIPS), Styrene Methyl Methacrylate (SMMA)</td><td>275000</td><td rowspan="2">200000</td><td rowspan="2">475000</td></tr>
<tr><td>1b.
Acrylonitrile Butadiene Styrene (ABS), Styrene Acrylonitrile (SAN), Polymethyl Methacrylate (PMMA)</td><td>0</td></tr>
<tr><td>2</td><td>Expandable Polystyrene(EPS)</td><td>50000</td><td>150000</td><td>200000</td></tr>
<tr><td>3</td><td>Extruded polystyrene (XPS)</td><td>10000</td><td>10000</td><td>20000</td></tr>
<tr><td>4</td><td>Specialty Grades/Compounds/Master Batches of Thermoplastics & Elastomers</td><td>40000</td><td>100000</td><td>140000</td></tr>
<tr><td></td><td>TOTAL</td><td>375000</td><td>460000</td><td>835000</td></tr>
</table>

The total production is computed in terms of MT/A, but for ease of calculation and modeling, the product quantity was limited to 1 kg size. Hence the raw materials, heat and electricity requirements for manufacturing only one kg of each product were considered during this study.

2.1.1 System boundaries

The LCA being carried out concerns only the activities carried out at the factory site. Hence, end user and end-of-life stage are not a part of this study. This restricted scope means that this is a gate-to-gate study instead of a cradle-to-grave approach. Hence the Geographical Boundary is limited to the factory site only. This implies that all the environmental impacts occurring due to these activities are covered in the scope of this study. All the products mentioned above are considered for the study. The quantity of these products is limited to one Kg size and hence the raw material, heat and electrical energy and transport of raw materials to the factory site which are required for production of only one Kg are considered in this study. For each product, the inputs required for unit operations are considered e.g. inputs required for filtration process, centrifugation, crystallization, drying, etc. These above conditions give us a clear system boundary for the study. Furthermore a few assumptions were considered which are mentioned in the next section.

As the Material Balance was available stage-vise, the LCA of each product has been modeled according to this format only. The heat and electricity required during each stage has been considered. The transport of raw materials and fuels from suppliers to the factory site is also considered while modeling the process in software.

2.1.2 Assumptions and limitations

a) Assumptions

Due to the complex nature of LCA and limited availability of data, it becomes important to make certain assumptions. This report is based on data provided by the proponent and has the following assumptions-

1. The impacts associated with the production of the raw material itself are considered, as the software and its databases are designed to link the environmental impacts of raw materials.
2. The environmental impact analysis considers only the production process on site. The health impacts due to these identified impacts are not a part of this study.
3. The major energy inputs considered for the entire study is electricity and steam production.
4. Midpoint Indicators- Indicators that measure the impacts of a product/process during its life cycle are Mid-point indicators. E.g.- Global Warming Potential (GWP), Ozone Depletion Potential (ODP), Photochemical Ozone Creation Potential (POCP), Acidification Potential (AP), Eutrophication Potential (EP), etc. Since we are interested in investigating the impacts of the considered products during their manufacturing processes, we are not going to consider the Endpoint indicators which quantify the impacts only at the end-of-life stage for a product.

b) Limitations

Every LCA conducted has limitation in Life Cycle Inventory Analysis (LCIA) stage, and hence there are limitations to the interpretation that can be made from the obtained results. We have data sets available for manufacture of products at the concerned factory Site. Hence the results obtained from this LCA will have limitations in interpretation. Due to the available data set the results can be interpreted to observe the scale of impacts only for the considered products. Since geographically specific data relevant to the project site is not available, Worldwide Averaged Data provided in the various databases of SimaPRO software are used for the analysis. Due to this, the results obtained have a limited scope for interpretation. The obtained results can only quantify the scale of impacts in terms of different indicators (e.g. - GWP, AP, EP, ODP & POCP) however, interpreting whether these quantified amounts are highly environmentally damaging or have a small impact at the global stage cannot be said since there is no relevant data available for such a comparative study.

2.1.3 Impact categories selected

Various emissions occur due to modern human activities (industrial, domestic, agricultural etc.) these emissions are CO_2, CH_4, CFC, HCFC, $C2F_6$, CF_4, HFC etc. All these chemical emissions have different impacts on the environment such as global warming, Ozone depletion etc. It is a recognized fact that CO_2, CO, CH_4 etc. are responsible for global warming. These chemicals have same effect on environment but different chemical and physical properties. Due to this difference it is not possible to summarize them as one pollutant. Hence these pollutants are translated into its CO_2 equivalent values. Other pollutants are also translated into their relevant equivalents according to their impact categories. These translations have been recognized and established by Intergovernmental Panel on Climate Change (IPCC). Among the various identifiable indicators, most notable ones are- Global Warming Potential (GWP), Ozone Depletion Potential (ODP), Photochemical Ozone Creation Potential (POCP), Acidification Potential (AP), Eutrophication Potential (EP), Eco toxicity, Abiotic Depletion Potential (ADP). For this study the following indicators were selected-

a) Global Warming Potential (GWP)-

Global warming is a phenomenon that refers to the rising average surface temperature of the Earth, primarily due to the increasing level of GHG emissions. The standard substance for GWP is CO_2.

b) Ozone depletion Potential (ODP)-

Ozone depletion refers to the phenomenon of decreasing ozone density through the thinning of the stratospheric Ozone layer (15-30 km altitude) as a result of anthropogenic pollutants. This leads to increased UV exposure to skin, which implies a potential rise in incidences of Melanoma The standard substance for ODP is CFC-11.

c) Photochemical Ozone Creation Potential (POCP)-

Photo-chemical oxidant creation refers to the reactions of airborne anthropogenic pollutants with sunlight that produces chemical products such as Ozone (O_3), leading to increase in ground level ozone concentration causing smog of chemical compounds which adversely affect ecosystem and are hazardous to human health and agriculture. Ethylene is used as standard substance for POCP.

d) Acidification Potential (AP)-

Acidification is an environmental problem caused by acidified rivers/streams and soil due to anthropogenic air pollutants such as SO_2, NH_3 and NOx. Acidification increases leaching of heavy metals in soil and exerts adverse impacts on aquatic and terrestrial animals and plants by disturbing the food web. The standard substance for assessing AP is SO_2.

e) Eutrophication Potential (EP)-

Eutrophication is a phenomenon in which inland waters are heavily loaded with excess nutrients due to chemical fertilizers or discharged wastewater, triggering rapid algal growth and red tides. The standard substance for EP is PO_4^{3-}.

We are limiting the LCA to study only the activities at the project site, hence only these 5 parameters were taken into consideration as these indicators define the environmental health of our earth. Secondary parameters such as human toxicity, effect of these 5 parameters on the food web, effect on wildlife and bio-diversity etc. are not considered due to their broad based nature.

2.2 Inventory Analysis

Inventory Analysis can be defined as the phase of life cycle assessment involving the compilation and quantification of inputs and outputs for a product throughout its entire life cycle. To undertake LCA all the data related to a product's life is required. Since the defined system boundary is for the analysis of only the activities at factory site we need data such as raw material required to manufacture the final product, heat inputs in the form of steam, electrical energy usage, water required, etc. All this data was provided by the proponent for the concerned products under study. For this LCA, SimaPro software was used. The Eco-invent database was incorporated for the study. Using the software system flow diagrams were developed to examine each unit process and its inter-dependencies with other unit processes required for manufacturing the product.

2.3 Life Cycle Impact Assessment (LCIA)

LCIA can be defined as part of life cycle assessment aimed at understanding and evaluating the magnitude and significance of the potential environmental impacts for a product system throughout the life cycle of the product. The process flow chart developed in the LCA worksheet in the previous stage is assigned values. The values obtained from this are normalized and weighted for uniformity for comparison purpose. As stated earlier, the product quantity to be manufactured was limited to one Kg size and hence only the relevant inputs and outputs were considered.

2.3.1a. General Purpose Polystyrene (GPPS), High Impact Polystyrene (HIPS), Styrene Methyl Methacrylate (SMMA)

The analysis is done using the data provided for 1 Kg production of GPPS, HIPS & SMMA.

Cradel to grave & Gate-to-Gate analysis was performed.

The total heat and electricity requirement were studied and the process for manufacturing 1 Kg of final product was modeled in SimaPRO software. The obtained results are as shown in Table 2 and Figure 2.

Table 2- Midpoint Indicators per Kg of GPPS

Impact category	Raw Material Processing	Process Heating	Electricity	Transport	Cradle-to-Grave	Gate-to-Gate
Global warming Potential (GWP kg CO_2 eq)	3.277	0.043	0.229	0.039	**3.587**	**0.272**
Ozone layer depletion Potential (ODP kg CFC-11 eq)	1.33205E-07	1.58317E-12	1.69504E-09	6.62945E-09	**1.41531E-07**	**1.6966E-09**
Photochemical ozone creation Potential (POCP kg C_2H_4 eq)	0.015508	0.000011	0.000037	0.000007	**0.015562**	**0.000047**
Acidification Potential (AP kg SO_2 eq)	0.012435	0.000186	0.000826	0.000146	**0.013593**	**0.001012**
Eutrophication Potential (EP kg PO_4^{3-} eq)	0.003916	0.000015	0.000364	0.000035	**0.004330**	**0.000379**

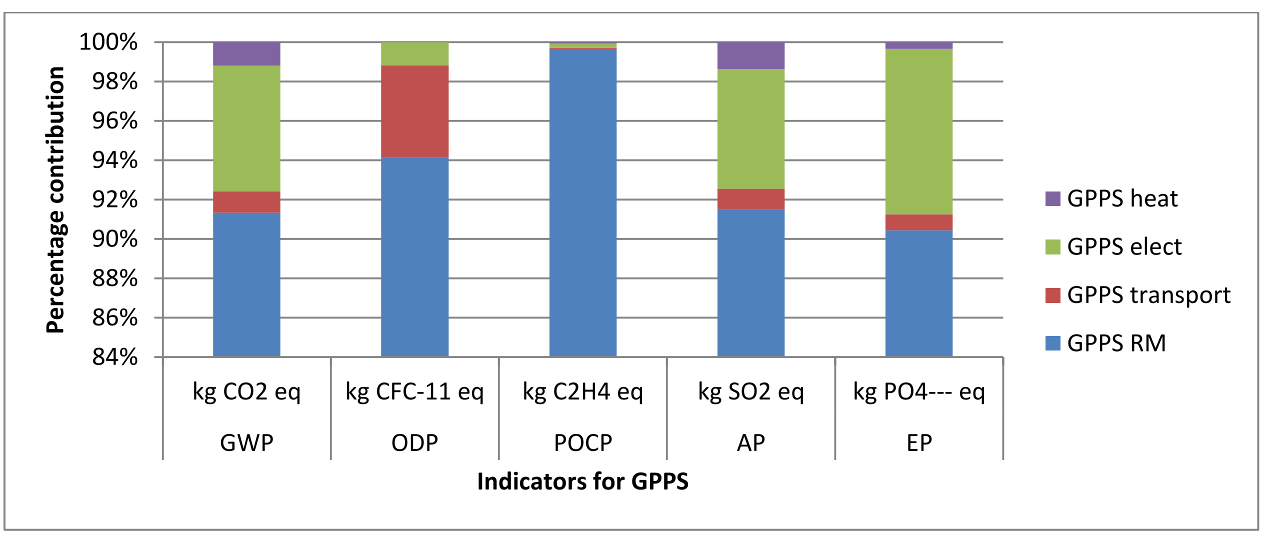

Figure 2- Contributions to midpoint indicator for GPPS

2.3.1b. Acrylonitrile Butadiene Styrene (ABS), Styrene Acrylonitrile (SAN), Polymethyl Methacrylate (PMMA)

The analysis is done using the data provided for one Kg production of Acrylonitrile Butadiene Styrene (ABS). The detailed material balance and the total heat and electricity requirement were studied and the process for manufacturing 1 Kg of final product was modeled in SimaPRO software. Hence the results are obtained for only a gate-to-gate analysis. The obtained results are as shown in Table 2 and Figure 2.

Table 3- Midpoint indicators per Kg of ABS

Impact category	Raw Material Processing	Process Heating	Electricity	Transport	Cradle-to-Grave	Gate-to-Gate
Global warming Potential (GWP kg CO_2 eq)	3.3159	0.0426	0.2291	0.0390	**3.6266**	**0.2718**
Ozone layer depletion Potential (ODP kg CFC-11 eq)	1.26403E-07	1.58317E-12	1.69504E-09	6.62945E-09	**1.34729E-07**	**1.6966E-09**
Photochemical ozone creation Potential (POCP kg C_2H_4 eq)	9.990E-03	1.059E-05	3.664E-05	6.677E-06	**1.004E-02**	**4.723E-05**
Acidification Potential (AP kg SO_2 eq)	1.390E-02	1.858E-04	8.263E-04	1.458E-04	**1.506E-02**	**1.012E-03**
Eutrophication Potential (EP kg PO_4^{3-} eq)	4.643E-03	1.546E-05	3.635E-04	3.514E-05	**5.057E-03**	**3.790E-04**

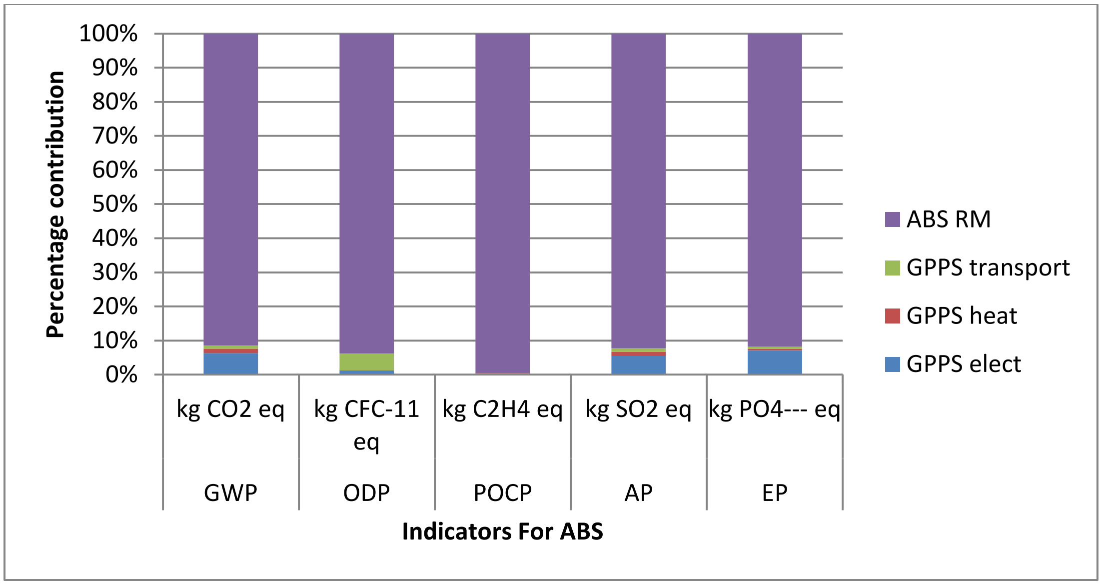

Figure 3- Contributions to midpoint indicator for ABS

2.3.2 Expandable Polystyrene (EPS)

The analysis is done using the data provided for one Kg production of EPS. The detailed material balance and the total heat and electricity requirement were studied and the process for manufacturing 1 Kg of final product was modeled in SimaPRO software. The obtained results are for a gate-to-gate analysis and are shown in Table 3 and Figure 3.

Table 4- Midpoint indicators per Kg EPS

Impact category	Raw Material Processing	Process Heating	Electricity	Transport	Cradle-to-Grave	Gate-to-Gate
Global warming Potential (GWP kg CO_2 eq)	3.105	0.043	0.180	0.040	**3.368**	**0.223**
Ozone layer depletion Potential (ODP kg CFC-11 eq)	1.3181E-07	1.58457E-12	1.33182E-09	6.76204E-09	**1.39906E-07**	**1.3334E-09**
Photochemical ozone creation Potential (POCP kg C_2H_4 eq)	0.01436	0.00001	0.00003	0.00001	**0.01441**	**0.00004**
Acidification Potential (AP kg SO_2 eq)	0.01182	0.00019	0.00065	0.00015	**0.01280**	**0.00084**
Eutrophication Potential (EP kg PO_4^{3-} eq)	0.00367	0.00002	0.00029	0.00004	**0.00400**	**0.00030**

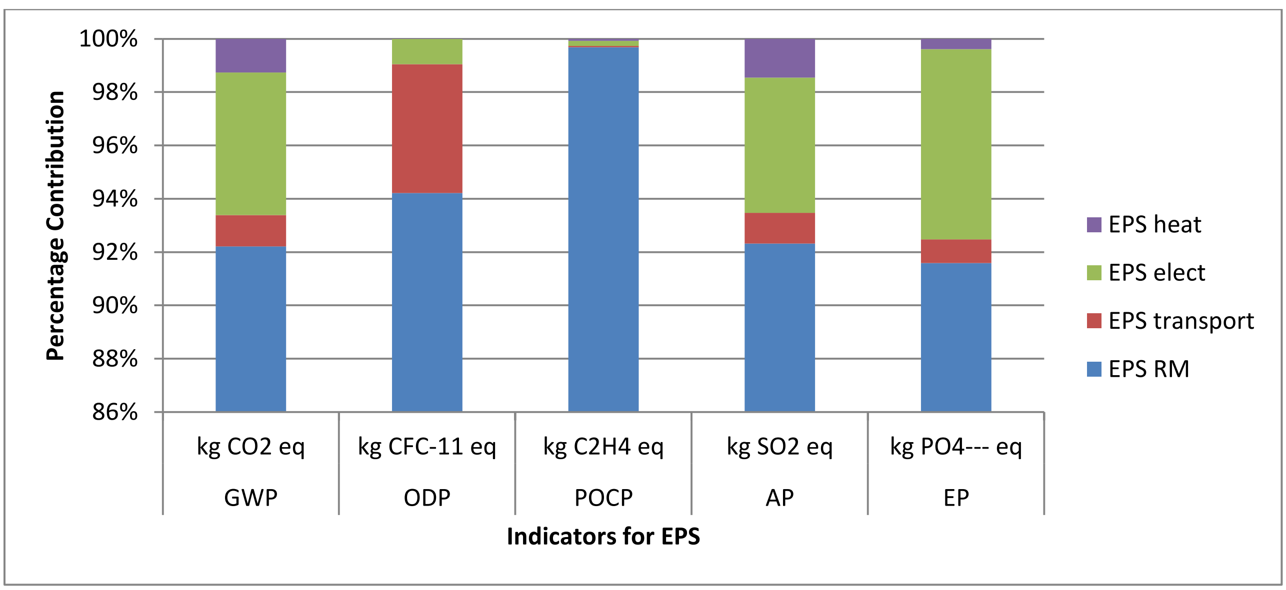

Figure 4- Contribution to midpoint indicator for EPS

2.3.3 Extruded polystyrene (XPS)

The analysis is done using the data provided for one Kg production of XPS. The detailed material balance and the total heat and electricity requirement were studied and it was observed that there is no heat of reaction involved hence process heating is not required. the process for manufacturing 1 Kg of final product was modeled in SimaPRO software. The obtained results are for a gate-to-gate analysis and are shown in Table 4 and Figure 4.

Table 5- Midpoint indicators per Kg of XPS

Impact category	Raw Material Processing	Electricity	Transport	Cradle-to-Grave	Gate-to-Gate
Global warming Potential (GWP kg CO_2 eq)	3.740	1.964	0.048	**5.752**	**1.964**
Ozone layer depletion Potential (ODP kg CFC-11 eq)	1.57602E-08	1.45289E-08	8.16086E-09	**3.845E-08**	**1.45289E-08**
Photochemical ozone creation Potential (POCP kg C_2H_4 eq)	0.00078	0.00031	0.00001	**0.00110**	**0.00031**
Acidification Potential (AP kg SO_2 eq)	0.01197	0.00708	0.00018	**0.01923**	**0.00708**
Eutrophication Potential (EP kg PO_4^{3-} eq)	0.00103	0.00312	0.00004	**0.00419**	**0.00312**

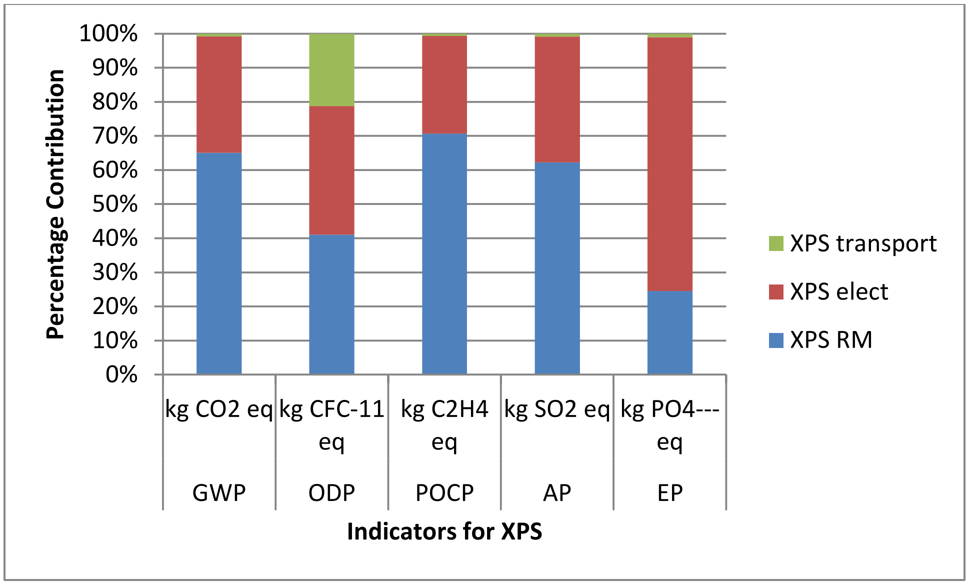

Figure 5- Contribution to midpoint indicator for XPS

2.3.4 Specialty Grades/Compounds/Master Batches of Thermoplastics & Elastomers

The analysis is done using the data provided for one Kg production of Specialty Grades. The detailed material balance and the total heat and electricity requirement were studied and it was observed that there is no heat of reaction involved hence process heating is not required. The process for manufacturing 1 Kg of final product was modeled in SimaPRO software. The obtained results are for a gate-to-gate analysis and are shown in Table 5 and Figure 5.

Table 6- Midpoint indicators per Kg of Specialty Grades

Impact category	Electricity	Transport	Cradle-to-Grave	Gate-to-Gate
Global warming Potential (GWP kg CO_2 eq)	0.573	0.039	**0.612**	**0.573**
Ozone layer depletion Potential (ODP kg CFC-11 eq)	4.238E-09	6.629E-09	**1.087E-08**	**4.238E-09**
Photochemical ozone creation Potential (POCP kg C_2H_4 eq)	9.160E-05	6.677E-06	**9.828E-05**	**9.160E-05**
Acidification Potential (AP kg SO_2 eq)	0.0021	0.0001	**0.0022**	**0.0021**
Eutrophication Potential (EP kg PO_4^{3-} eq)	0.0009	0.00004	**0.00094**	**0.00091**

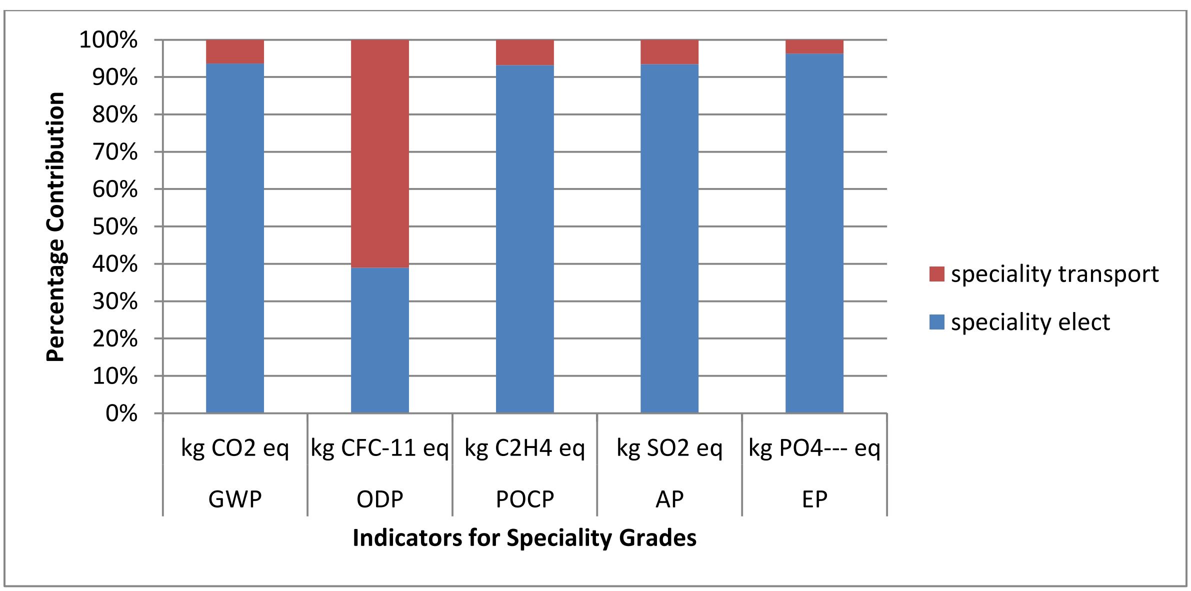

Figure 6- Contribution to midpoint indicator for Specialty Grades

Chapter 3

3.1 Interpretation

From the analysis we can compile the results as shown in Table 6 which shows the quantified amount of GWP indicator for the product system considered. These values are for the production of one kg of final product. It is observed that the GWP indicator is highest for manufacturing of one Kg of Extruded polystyrene (XPS) (1.964 Kg of CO_2 equivalent). From table 6 below it is observed that although the per Kg CO_2 emission is high for Extruded polystyrene (XPS), still the total CO_2 equivalent emission for total production of General Purpose Polystyrene (GPPS) is highest due to the higher production quantities. GWP can also be described as the Carbon Footprint of a product. As seen below, the Carbon Footprint from production of General Purpose Polystyrene (GPPS) is 391193.8 kg/day of CO_2 equivalent i.e. 391.193 MT of CO_2 per day.

Although GWP defined in terms of kg of CO_2 equivalent emission is a major concern in the current scenario, other factors such as Acidification Potential, Eutrophication Potential cannot be neglected. From Table 10 it is observed that Acidification, Eutrophication, Ozone Depletion and Photochemical ozone creation potentials are highest for production of one Kg of among the Extruded polystyrene (XPS) considered product system.

Table 7- GWP (kg CO_2 equivalent) indicator for all products

Sr. No.	Product	Kg CO_2 equi./Kg of product
1	1a. General Purpose Polystyrene (GPPS), High Impact Polystyrene (HIPS), Styrene Methyl Methacrylate (SMMA)	0.272
	1b. Acrylonitrile Butadiene Styrene (ABS), Styrene Acrylonitrile (SAN), Polymethyl Methacrylate (PMMA)	0.272
2	Expandable Polystyrene(EPS)	0.223
3	Extruded polystyrene (XPS)	1.964
4	Specialty Grades/Compounds/Master Batches of Thermoplastics & Elastomers	0.573

Table 8- GWP, AP, EP, ODP and POCP for all products (per Kg of product)

Midpoint Indicator	1a. General Purpose Polystyrene (GPPS), High Impact Polystyrene (HIPS), Styrene Methyl Methacrylate (SMMA)	1b. Acrylonitrile Butadiene Styrene (ABS), Styrene Acrylonitrile (SAN), Polymethyl Methacrylate (PMMA)	Expandable Polystyrene (EPS)	Extruded polystyrene (XPS)	Specialty Grades/Compounds/Master Batches of Thermoplastics & Elastomers
Global warming Potential (GWP kg CO_2 eq)	0.27	0.27	0.22	1.96	0.57
Ozone layer depletion Potential (ODP kg CFC-11 eq)	1.69663E-09	1.69663E-09	1.3334E-09	1.45289E-08	4.23761E-09
Photochemical ozone creation Potential (POCP kg C_2H_4 eq)	0.000047	4.72291E-05	0.000039	0.00031	0.00009
Acidification Potential (AP kg SO_2 eq)	0.001012	0.001012123	0.0008400	0.00708	0.00207
Eutrophication Potential (EP kg PO_4^{---} eq)	0.000379	0.000378960	0.0003100	0.00312	0.00091

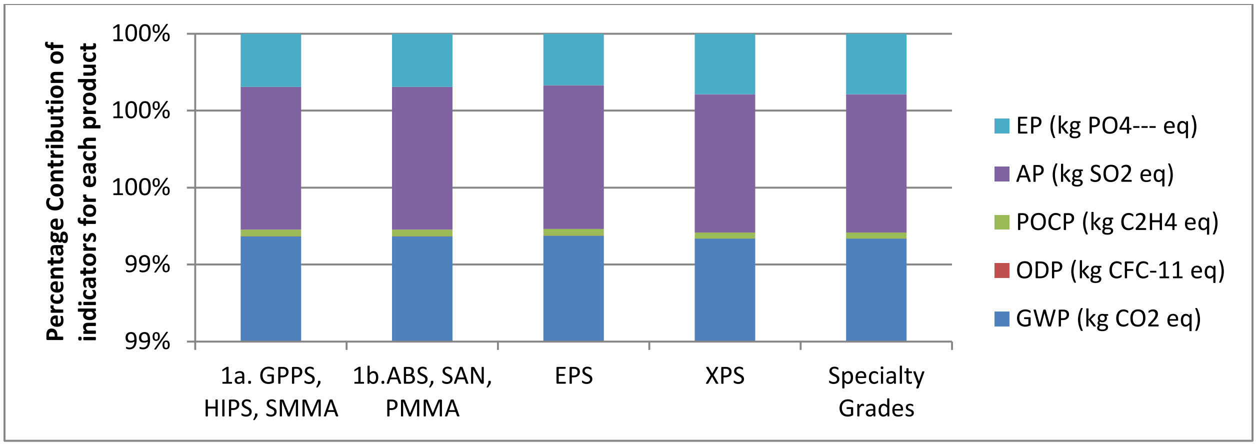

Figure 6- Contribution to midpoint indicator for all products (per Kg of product)

In Maharashtra state, nearly 75% electricity is generated by coal fired thermal power plants. Hence the CO_2 and other emissions for generation of 1 KWh of electricity have been considered in the software model. Another major part of the GWP identified in this study is due to electricity production from fossil fuels.

For the manufacturing of the products, the consumption of FO will be 48 TPD or 59932 Kl/Day of Natural Gas. This fuel usage can be translated into release of CO_2 which can be termed as primary emissions from the process due to fossil fuel use. By replacing the existing fossil fuel with cleaner fuels, this primary emission of CO_2 can be reduced.

Whether these indicator potentials for production of one Kg of product are high or low in a general sense, cannot be said as only the products in the defined system boundary can be compared with each other. The determination of impacts of these products as a comparison to a baseline impact already existing is not possible as the similar products manufactured by another competitor are not considered in this study. This LCA has quantified the various environment damaging potentials per Kg of various products manufactured by the proponent.

3.2 Mitigation Measures

A LCA is a holistic study of the product system to define environmental loads and determine the environmental damages occurring due to its production. The release of CO_2 in atmosphere is due to burning of fossil fuels for steam production and use of electricity. In Maharashtra state, nearly 75% electricity is generated by coal fired thermal power plants and hence reducing the electricity requirement for processing can help reduce the GWP index identified in the analysis. The Environment Management Plan should list the measures that the proponent will implement for reducing the environmental damage that has been identified in this study. Following mitigation measures have been suggested to the project proponent-

Use of Variable Frequency Drive- the processing techniques can be recalibrated to reduce the electricity consumption for manufacturing one Kg of product. Process recalibration can include simple changes like the use of Variable Frequency Drives (VFD) for stirrers and agitators which can reduce the electricity consumption by up to 20% which can reduce the fuel load and hence reduce the GWP potential arising due to these activities.

From operating load = 14956 kW from which 24479 kg of CO2 will be generated.

After 30% electricity reduction due to use of VFD & IE3 motors, operating load will be reduced to 10469.2 kW from which 17135 kg of CO2 will be generated.

Hence, reduction of CO2 emission will be= 24479-17135 = 7344 kg.

Carbon Offset measures-

A mature tree can absorb 20 kg of CO_2 per year, so it is important to increase the green cover for carbon emission mitigation. The proponent has already provided 33% green cover within the factory premises as per regulations. Proponent can undertake tree plantation and provide necessary infrastructure/logistics to become an active member of re-forestation efforts as a part of Corporate Environmental Responsibility (CER). Increasing the green cover not only offsets the CO_2 emissions but also increase the chances of rainfall due to the larger concentration of atmospheric water vapor in such a densely forested area [8].

Total existing Number of trees are 39490 nos.

CO2 absorb by tree is 39490 X 20 = 789800 Kg of CO2 Annually

i.e. 789800 /365 = 2164 Kg of CO2 per day

From existing production capacity, total CO2 generation is 162698 Kg per day out of which 2164 Kg is compensated through tree so total CO2 emission per day is 160534 Kg per day.

Since total no. of trees is 39490, **total CO2 absorbed by trees will be 2164 Kg/day**

Use of Non-renewables- 75% of electricity generated in Maharashtra comes from fossil fuels; the environmental impacts associated with production of 1 KWh of electricity are included in the LCA software database which has been considered for this study. Due to the database considered, the GWP related to electricity requirement of the manufacturing unit is high. Roof top solar electricity generation reduces the dependence on power supply grid and in turn reduces the use of fossil fuels for electricity generation. With the increased market share of solar power and greater number of suppliers, the capital costs for such a system have reduced which the proponent should take advantage of. Use of electricity generated by such means can reduce the Secondary CO_2 emissions related to electricity requirement of project site and help reduce the overall carbon footprint of the company thus helping the nation achieve its Carbon Reduction Goals.

From roof top area where Solar panel will installed it is estimated that 1000 KWp of energy will get generate.

Operating load= 14956 kW from which 24479 kg of CO_2 will be generated.

By using Solar power, 1000 kWp electricity will be generated. Hence operating load will be reduced to 13956 kW.

From 13956 kW = 22842 kg of CO_2 will be generated.

Hence, reduction of CO_2 emission will be 1637 kg.

Mitigation suggested for transportation:

1. To ensure whether transporter is using latest ratings of vehicles for transport.

2. Regular maintenance of transporting vehicles & this to be ensured by the proponent from transporter.

3. Ensure maintenance of emission standards by regular checkup through PUC.

4. If possible transportation of raw material in more quantity and in bigger capacity of trucks so as to reduce number of transporting trucks.

5. Search raw materials from nearby areas so as to reduce transportation distance.

Total Reduction in CO_2 emission after Expansion:-

Reduction in CO_2 emission due to use of VFD & IE3 + due to Green Belt+ due to renewable energy

Total Reduction in CO_2 emission = 7344 + 2164 + 1637= 11145 Kg/day

Carbon footprint without mitigations = 0.351 kg/kg (888232.3 kg CO2 per day/ 2530303.0kg per day production)

Carbon footprint with mitigations = 0.346 kg/kg (877087.3 kg CO2 per day/ 2530303.0 kg per day production)

References

1. ISO 14040:2006, Environmental management -- Life cycle assessment -- Principles and framework
2. ISO 14044:2006, Environmental management -- Life cycle assessment -- Requirements and guidelines
3. S S Muthu (2017), Evaluation of Sustainability in textile industry, Springer Nature Singapore Pte Ltd. 2017, Textile Science and Clothing Technology, DOI 10.1007/978-981-10-2639-3_2
4. Xingxue Zhang (2012), A New Metric-based LCA Method for Assessing the Sustainability Performance of Metallic Automotive Components, University of Kentucky
5. H. Scott Matthews, Chris T. Hendrickson and Deanna H. Matthews (2015), Life Cycle Assessment: Quantitative approaches for decisions that matter
6. Prof. Dr.-Ing. Norbert Reintjes, Fachhochschule Luebeck, Germany
7. Walter Klöpffer, Birgit Grahl (2014), Life Cycle Assessment (LCA): A Guide to Best Practice, ISBN: 978-3-527-32986-1
8. Douglas Sheil Daniel Murdiyarso, How Forests Attract Rain: An Examination of a New Hypothesis, *BioScience*, Volume 59, Issue 4, 1 April 2009, Pages 341–347.