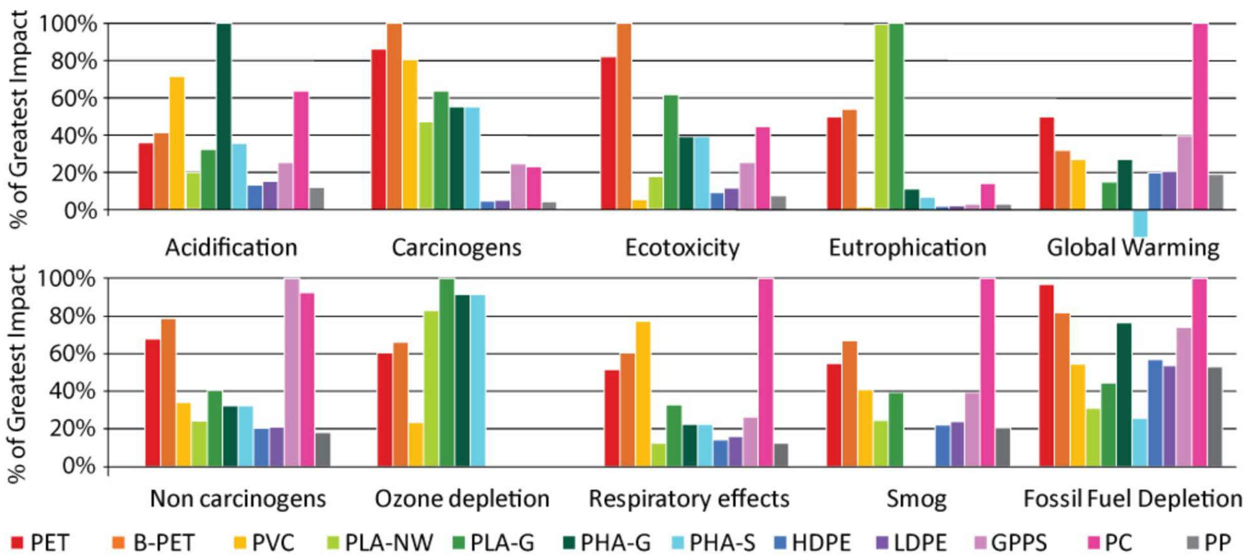
LIFE CYCLE ASSESSMENT AND GREEN DESIGN: AN ASSESSMENT OF GREEN DESIGN IN A CASE STUDY OF PLASTICS

Fig_3.2:



Here, In this case, a code has been written for the whole procedure. We should just send a CSV file containing the required LCA data of polymers as input. The code outputs all the ten category graphs. For this purpose, I have used python as a coding language, and I have used Pandas, NumPy, and Matplot libraries for specific operations.

Link for Code: Fig_3.2

Step to step procedure

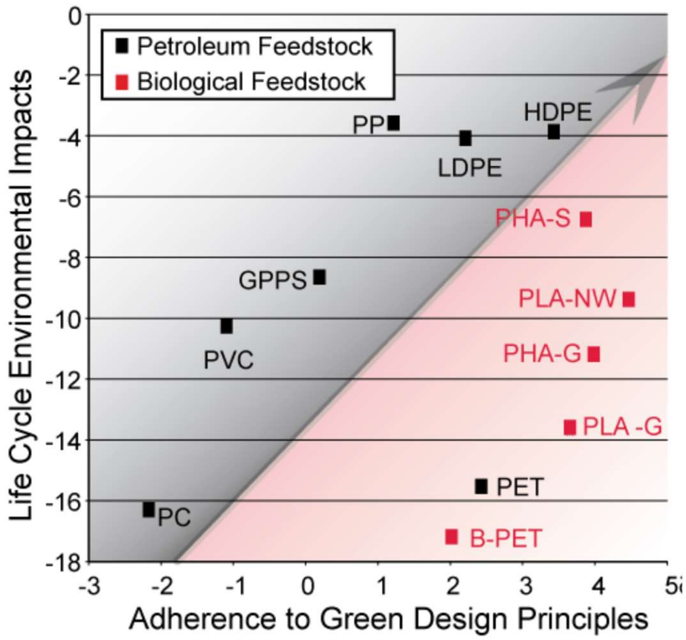
Step 1: A CSV file including the data of Acidification, Carcinogens, Ecotoxicity, Eutrophication, Global warming, Non-Carcinogens, Ozone Depletion, Respiratory Effects, Smog, Fossil Fuel Depletion for all the required polymers are taken as input using the PANDAS library.

Step 2: Using the original CSV, we make another CSV file that contains the data of solely required polymers. This helps us to make calculations more conveniently.

Step 3: Now, we find the maximum element of each category and divide all the respective category elements with that maximum value—this results in normalization by the greatest impact in each category.

Step 4: Now, using MATPLOT, we plot graphs for each category.

Fig_3.3:



For this Figure, we would calculate the Y-Axis values first.

For calculation of Life Cycle Environmental impacts of all the polymers,

<u>Step to step procedure</u>

Step 1: The data of acidification, carcinogenic human health hazards, ecotoxicity, eutrophication, global warming potential, non-carcinogenic human health hazards, ozone depletion, respiratory effects, smog, and Non-Renewable Energy Use (NREU) for each polymer should be taken from Simapro, TRACI, and ecoinvent databases.

Step 2: Now, the decision Matrix should be built using this data

<u>Process of building decision matrix:</u>

$$N_{ij} = \frac{V_{ij} * n}{\sum_i (V_{ij})} * \Psi_j$$

Nij is the normalized value for polymer i in metric/impact j, Vij is the value of polymer i in metric/impact j, n in the total number of polymers studied, and Ψj is a multiplication factor which is 1 for metrics/impacts in which higher values are more preferable and -1 for metrics/impacts in which lower values are more preferable.

Here in our case for Life Cycle Environmental impacts, we prefer lower values for all the impacts. So Ψj is -1 for all. N_{ij} is calculated for all the impacts individually, and all were added finally.

We would calculate X-Axis values now

For calculation of adherence to green design principles of all the polymers,

Step to step procedure

Step 1: Get the data of all the Green design metrics

1. Waste Prevention:

$$\text{Atom economy} = \frac{M_{product}}{M_{input}}$$

M_{Input} is the mass of chemical product input to all reactions, and $M_{product}$ is the mass of the chemical product.

2. Material Efficiency:

The ability of a material to promote efficient use is measured through its density, which is reflected in the volumetric as a functional unit for all assessments.

3. Avoid Hazardous Materials and Pollution:

The avoidance of hazardous materials and pollution is measured via an average of the normalized life-cycle impacts in TRACI categories of respiratory effects, human health cancer, human health non-cancer, and ecotoxicity.

4. Maximize Energy Efficiency:

Overall energy efficiency was measured by the cumulative life cycle energy-use found by the Cumulative Energy Demand LCIA method.

5. Use of Renewable Sources:

The use of renewable sources is measured by the percent of material from biological sources in the final product by mass.

6. Design products for recycling:

Adherence to these principles is measured through the percent recovery of a material in the U.S. municipal recycle stream (2008).

7. Design Biodegradable Products:

For quantitative purposes, non-biodegradable, biodegradable in an industrial facility, or biodegradable in typical backyard conditions are assigned values of 1, 2, and 3, respectively.

8. Use Local Sources:

categorical distances of international, national, and regional are assigned values of 1, 2, and 3.

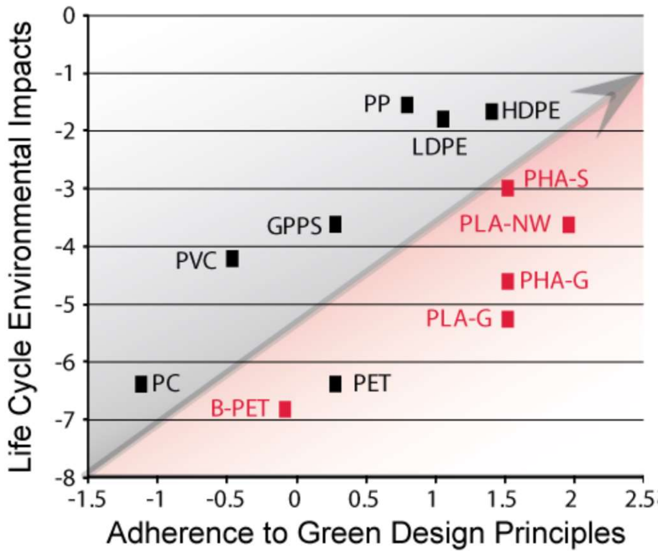
9. Cost Efficiency:

The cost-effectiveness of these polymers was measured via a median price per liter of the polymer, as reported by ICIS (2010).

Step 2: After calculating all these green design metrics, the decision matrix should be constructed similar to the one constructed for the above case.

After completing calculations of both the cases, the decision matrix values were plotted with X-Axis as adherence to green design principles and Y-Axis as Life Cycle Environmental impacts. This results in Fig-3.3.

Fig_S.3.4:



All the metric values for both the adherence to green design principles and Life Cycle Environmental impacts are the same as for Fig_3.3.

The only difference is the calculation of the decision matrix. The average value in the denominator gets replaced by the maximum value of the respective impact of all polymers.

The formulae become

$$N_{ij} = \frac{V_{ij}}{Max(V_{ij})} * \Psi_j$$

Nij is the normalized value for polymer i in metric/impact j, Vij is the value of polymer i in metric/impact j, n in the total number of polymers studied, and Ψj is a multiplication factor which is 1 for metrics/impacts in which higher values are more preferable and -1 for metrics/impacts in which lower values are more preferable.

After calculating the decision matrix, we plot a 2-d graph with X-Axis as adherence to green design principles and Y-Axis as Life Cycle Environmental impacts. This results in Fig-S.3.4.