STATISTICAL APPROACH TO HANDLING UNCERTAINTY IN LCA

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ABSTRACT

LCA has been widely used for assessment of environmental performance of product life cycles. Whenever LCA is used in environmental evaluation of alternatives, it is critical for target audience to know the uncertainties associated with reported impacts. This work aims at proposing approaches that companies can adopt to make statistically valid evaluation of alternatives. Another key objective is to conclude if universal "difference thresholds" can be set for claims. For instance, is 10% lower carbon footprint of a product against competitive product adequate for a statistically valid claim? Monte Carlo and Parametric bootstrapping techniques have been used for the proposed approaches. This study also concludes that setting universal "difference thresholds" may not be statistically valid all the time.

INTRODUCTION

LCA is a powerful environmental tool that is used in marketing, framing of policies, apart from use by leading companies in their external communication on sustainability. As its role is linked to functions of strategic significance (policies and regulations, company branding & communication, etc.,) accuracy and credibility of reported impacts become rather very important. This stresses on the criticality of awareness of the decision maker on the uncertainties in reported impacts.

There are three key sources of uncertainty in LCA, namely:

Model uncertainty: This arises due to uncertainties that are inherent when modeling of fate of substances in the environment.

Data uncertainty: This is related to statistical variations in life cycle inventory data.

Scenario uncertainty: This covers statistical variations of measured impacts due to various assumptions made during building of the LCA models.

METHODS

Few approaches to handle model, data and scenario uncertainties have been proposed by this work. Approaches proposed to deal with data uncertainty are described below:

Approach 1: Probability based paired sampling:

In this approach, "paired sampling" Monte Carlo simulation is carried out for alternative products being compared. This may provide user with the probability of a product having lower impacts than its alternative. However this approach may not apply well when a steel product is being compared to a plastic product, since they are inherently based on very different value chains and hence may be considered to be from independent populations from statistical perspective. To overcome this issue, approach 2 has been proposed below:

Approach 2: Confidence interval based approach

In this approach, Monte Carlo based probability distributions of the measured impact are generated separately for both product alternatives.

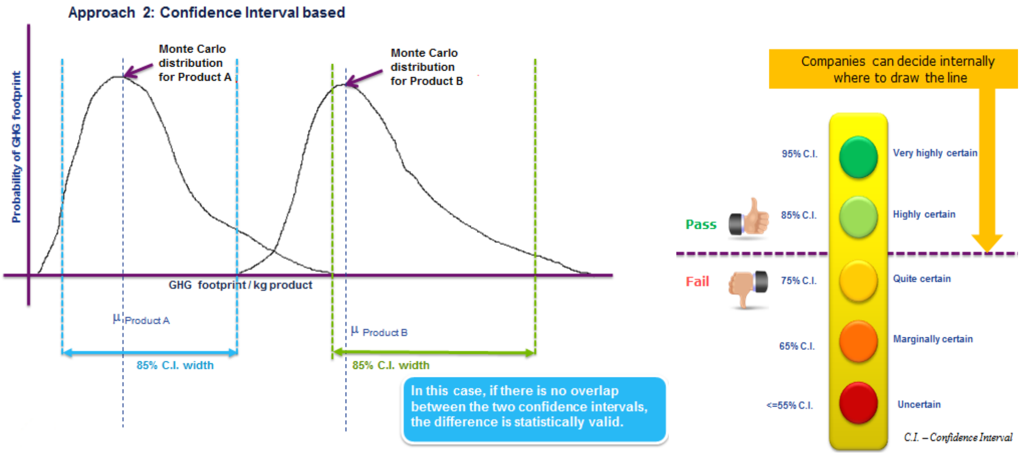

Figure 1: Monte Carlo based Confidence interval approach

By varying confidence interval of the probability distribution of both alternatives simultaneously from 95% down to 55% (in 5% decrements), user can look out for overlap of impact distribution of product alternatives. Overlap regions correspond to situations wherein the product alternatives may have comparable environmental performance. For instance, if the user observes overlap at 95% confidence level but no overlap at 90% then this is analogous to successful statistical hypothesis testing at 90% significance level. Such an approach can allow companies to set pass / fail criterion based on confidence intervals as shown in figure 1 above.

Approach 3: Parametric bootstrapping approach

Most environmental claims reported in public domain are based on deterministic or probabilistic mean of measured impacts. While this is a fair basis, it is also important for the target audience to be made aware of the likely range of variability of this reported value. To address this issue, approach 3 has been proposed.

Parametric bootstrapping technique can be used to generate detailed statistics on a population such as distribution of means, etc. This is a statistical sampling tool that carries out multiple resampling of the sample population so as to come up with a distribution of mean of the sampled population. This tool is available as part of Oracle Crystal Ball (add-on with Microsoft Excel). Process to be followed for performing parametric bootstrapping in Excel (using inputs from Monte Carlo simulation results) are not covered in this text. However the corresponding author can be contacted for further details.

Companies may resort to two different options for external communication based on outputs from Parametric Bootstrapping.

- *Option 1:* External communication on variability of mean of the estimated impacts. For instance, "mean carbon footprint for 1 kg of Product A may vary between 3.87 and 3.93 kgCO2 eq. For cases, wherein this variability is substantial, such communication can provide consumers with transparent information which in turn can enhance company branding.
- *Option 2:* Conservative approach for external communication on the product footprint. For instance, instead of claiming carbon footprint based on deterministic mean of 3.86 kgCO2 eq. for the product, company can claim a more conservative 3.88 kgCO2 eq. based on UCL mean (upper confidence interval mean). For cases where variability of mean may be higher, this can serve as a conservative estimate of the impact. This can ensure that environmental claims made by companies are both statistically sound and conservative.

RESULTS AND DISCUSSION

Another objective of this study was to conclude if a universal "difference threshold" can be set for making claims on a product's superior environmental performance over its alternatives. The below graph (figure 2) is plotted on confidence interval (x-axis) against percentage difference of impact of the company's product against its alternative (y-axis). For instance, if a company's Product 'A' has 12% lower carbon footprint when compared to its alternative, then its Y-coordinate takes a value of 12. Each data point on the graph refers to the confidence level at which a product passes the confidence interval test (as described under approach 2 earlier in text). As can be inferred from the figure below, while some products that have lower carbon footprint difference of around 15-20% pass the statistical test at higher confidence levels (products 6 & 8), few others pass only at lower confidence levels (product 3 as in graph below). This would imply that setting difference thresholds may not be considered to be statistically valid all the time.

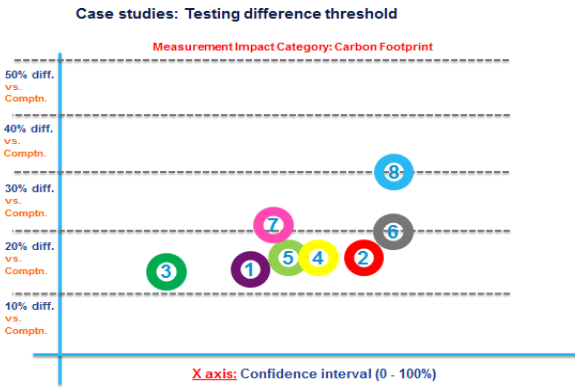

Figure 2: Testing difference threshold for claims

CONCLUSIONS

Based on the reviewed approaches, the following recommendations are made to approach data uncertainty in LCA:

Approach 1 proposed by this work (probability based approach) based on “paired sampling” may be used for comparison of product systems based of same or similar value chains. Approach 2 (confidence interval based) can be used as an effective statistical tool for external communication which allows for short-selection of product systems with superior environmental performance as compared to their alternatives. Based on this study, it can also be concluded that fixing a single universal threshold value of difference for external communication (for instance 10% difference on carbon footprint) is not a statistically valid approach. Approach 3 (robust means based on parametric bootstrapping) can be used for enhancing transparency and credibility in external communication by substantiation of variability of mean of reported environmental impacts. This can enable companies to set new standards for best practices. The proposed process for evaluation of data uncertainty (using approaches 2 or 3) can be easily built into a simple tool for LCA experts, the results of which can be converted into a standard template for use in business external communication.

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