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EDITORIAL

Measures for sustainability

Subhas Sikdar[1]

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Sustainability, conceptually, is an integrated descriptor of the conditions of the environment, society, and the economy. But it does not imply equal importance of these three domains in the integration. The current concept of sustainability emerged from concerns about environmental degradation, suggesting that of the three, the environment is by far the largest influencer. Though we cannot quite ascertain what the relative proportions of these three domains are, it is certain that the proportions will depend on the particular system under study and its scale. For instance, global sustainability these days is being almost wholly looked upon in terms of climate change caused by global warming due to accumulating greenhouse gases in the atmosphere. The other two conditions of economy and society at this scale are considered secondary. The thought forwarded on this point is that the possibility of global catastrophe caused by climate change renders the other two conditions irrelevant. But consideration of regional sustainability of a metropolis, on the other hand, cannot ignore the local air and water quality and the economic imbalance among citizens, both of which tend to destabilize civil society.

Merely claiming sustainability, or unsustainability for that matter, does not necessarily establish the truth. Ever since science distinguished itself from philosophy by insisting on quantification, measurement, and speaking with numbers, it has rapidly advanced our knowledge of the natural world. The same approach should be applied to the determination of sustainability. As to invoking scientific methods in sustainability claims, the following statement by Norbert Wiener is illustrative:

> Things do not, in general, run around with their measures stamped on them like the capacity of a freight car; it requires a certain amount of investigation to discover what their measures are.

Dr. Subhas Sikdar is the Editor-in-Chief.

✉ Subhas Sikdar
subhas.sikdar@gmail.com

1 Cincinnati, USA

Undoubtedly there have been various attempts to measure sustainability over the past couple of decades. A summary of these attempts is presented in a recent book (Sikdar et al. 2016). The core question on sustainability has not been what it is in absolute terms but how we can establish relative sustainability with numbers.

For more than 40 years or so, various concepts have been used to lessen the environmental impacts of anthropogenic activities and boost the attended resource conservation. These concepts, shown below, have led to the concept of sustainability: waste minimization, pollution prevention, design for environment, green chemistry/green engineering, recycle/reuse, industrial ecology, resiliency, and circular economy.

Three types of natural resources are important in sustainability discussions:

(1) Land use and extracted materials including biomass; (2) energy; and (3) water.

Measurements that have been developed to address environmental, societal, and economic (or cost) impacts are toxicity, health impacts, cost–benefit analysis, ecological footprints, emissions and discharges, and a host of other measures such as global warming potential and acidification potential. Comparative assessments using measurements of these types enable us to assert if we are making an improvement in one or more of the three main sustainability domains.

Most of the time, for sustainability in general, and for process sustainability in particular, the subject problem is multivariate. It is very hard to do experiments on such a problem to collect data for sustainability assessment. Modeling is the imperative alternative for looking into the future or a different condition of a chosen system. Modeling allows computer-based algorithms to keep proper track of complex relations of the many variables that affect a system whose sustainability is being assessed. In predictive endeavors such as modeling, the predictions will be as good as the assumptions made to jump-start the modeling. When the assumptions do not represent reality, we are subject to ugly surprises of the predictions missing the mark. The inherently hazardous feature of predictive modeling thus must be acknowledged by all involved in this venture. Innumerable modeling approaches have been established with beneficial effects on our understanding of comparative sustainability. The following is an illustrative list of techniques used:

Heat integration, mass integration, process modeling/process integration/process redesign, green process design and process synthesis, multi-objective optimization, ecosystem design, life cycle assessment, systems dynamics modeling, supply chain design, climate modeling, sustainability modeling, decision under uncertainty, etc.

Research on sustainability systems of global, regional, or technology scales essentially addresses the issue of resource use. Addressing the resource categories mentioned above has resulted in the phenomenon of dematerialization. On a regional scale, measurements show that the developed economies have successfully applied technological innovations to achieve a partial or complete decoupling of gross domestic product (GDP) from the resource use. This merely means that when GDP increases, resource use *does not have to* increase with it. The following data from McAfee (2019) illustrate this achievement for the USA. Other developed nations have reported similar records.

> Dematerialization, as expressed in reduced total use of the following resources, has been achieved in the face of increased overall GDP in the USA since about 2000. It is remarkable that even the CO_2 emissions and energy use show the same trend

- Aluminum, nickel, copper, steel, gold
- Fertilizer, water, crop acreage
- Stone, cement, sand and gravel, timber, paper
- Total energy consumption, CO_2 emissions

Measurement thus plays a central role in sustainability assessment. Any claim of sustainability should be supported by the results of measurement in order to gain credibility. This is particularly important when we make pronouncements of sustainable energy. All such claims, be it of wind, solar, nuclear, or biomass energy, should be predicated by the assumptions made in the assessments. Clear indications should be provided of what factors have been included, what ignored or excluded, so that the results can be interpreted either as work in progress or the ultimate truth. For instance, wind energy depends heavily on materials use. Some of the items must be extracted from the earth with measurable environmental impact. If these impacts are not properly discussed and accounted for in the context of wind energy sustainability, we have an incomplete picture and the sustainability claims will be questionable. So far, it seems that only the performance issues have been discussed at some length.

References

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