RSC Sustainability

EDITORIAL

View Article Online
View Journal | View Issue

Check for updates

Cite this: *RSC Sustainability*, 2023, **1**, 1311

DOI: 10.1039/d3su90030d

rsc.li/rscsus

Fundamental tools for managing sustainability

Mike Sutton*

In 1987 the United Nations Brundtland Commission defined sustainability as "meeting the needs of the present without compromising the ability of future generations to meet their own needs". But great as that definition is, to be able to work with that requires tools to be able to measure it to allow for choices to be made to improve sustainability. There can be different tools in the environmental, social and governance areas. A balanced sustainable solution therefore considers the technoeconomic analysis, including the cost of implementation, in addition to the social and environmental impacts to come to a view of the benefits and drawbacks of any potential solution.

The foundational tool which underpins so much of the sustainability journey in the environmental area is Life Cycle Assessment (LCA). This can also be considered on the social and socioeconomic side of LCA (S-LCA) which allows for stakeholders "to move towards more social responsibility when assessing the life cycle of goods and services",[1] but is more often taken into account in the environmental area. LCA is a scientific method for assessing the environmental impacts associated with the life cycle of what is being analysed. It takes in the energy and material inputs into the different phases of raw materials, manufacturing, distribution use and end of life, considering the outputs in terms of emissions and waste. It is underpinned by ISO standards – ISO 14040 and ISO 14044, although there are specific ISO standards for other aspects such as product carbon footprint. What it allows is for analysis and understanding of the impacts for each of the phases, but also between different environmental impacts so we can understand potential burden shifting between different phases of the life cycle and also between multiple environmental impact categories (*e.g.* climate change, human health, eco systems, *etc.*). It is used to understand products, systems, companies and even a countries, impact, and allows comparison and assessment of competing opportunities.

Using LCA to measure company footprints

One application where the output data of LCA studies are used is the Greenhouse Gas Protocols **https://ghgprotocol.org**, where the definition of scope 1, 2 and 3 are built upon the foundation of LCA. One of the main uses of these definitions is in how companies define their goals, and so without the fundamental science of LCA, goal setting and driving towards these goals would not be possible. Many companies use these protocols to measure their carbon footprint from cradle to gate, which encompasses the direct and indirect scope 1 and 2 emissions and the upstream scope 3 emissions, which typically has scope 3, category 1 (purchased goods and services) as the most significant part. There is also an emergence of cradle to gate, plus end of life, but critically avoiding category 11; the use of sold products. The difficulty comes in how the LCA practitioner deals with some of the complexities with this category. For example, consider the application of commercial transport *via* a long-haul truck: it may be using 37 litres of diesel per 100 km of operation. It could typically complete 100 000 km in a year, so if a company came up with a product such as improved lubricants or tyres which saved 1% fuel efficiency then 370 litres of diesel could be saved. Ignoring the savings in CO_2 emissions in refining or transporting the fuel, that would equate to 1 tonne of CO_2 saving. The initial question is, who claims that saving; the operator, the truck manufacturer who allowed that on their vehicle, the supplier of the solution, or maybe their supplier who provided the raw material? The second issue is something which is how to account for Jevons' paradox, or in energy efficiency terms sometimes called the energy efficiency rebound effect. This is where the improvement in efficiency is offset by changes in behaviour which increase emissions elsewhere. These can be direct effects where the end user simply uses

Lubrizol, UK. E-mail: mike.sutton@lubrizol.com

more as the total price of their energy goes down, indirect effects where they take the saving and use that to increase demand for other goods, economy wide effects where lowering transport costs leads to costs of all goods reducing leading to increased demand, or even more complex effects where efficiency changes governmental regulation, for example. The net effect however, is how does the LCA practitioner account for these to feed the full scope 3 emissions back into the company carbon footprint? This highlights how it's great to have foundational tools, but you also need systems in place which allow for applications to give meaningful actions.

Utilising sustainability tools to compare technology options

Moving beyond footprint, consider how sustainability tools can be used in assessing potential competing technologies in an application. To illustrate this, we could consider the application of future passenger car transportation powertrains looking at environmental, social and economic implications from differing technologies.

Battery electric vehicles

Considering battery electric vehicles (BEVs), which are predominantly based on lithium-ion batteries, they are extremely efficient in round trip efficiencies, storing and then providing useful energy. Whilst coulombic efficiency is approaching 100% there are always losses due to heat dissipation through internal impedances. It is also affected by current differences where the efficiency drops as the current is increased and as such, figures in full production systems are typically quoted in the 85–90% region round trip efficiency. LCA considerations in particular need to consider the sourcing of raw materials in terms of environmental impacts for mineral extraction. There have been many in depth studies looking at the LCA of BEVs *vs.* other modes of transport, but perhaps one of the most comprehensive was the EU study published in 2020.[2] It is beyond this article to go into detail, but some pertinent thoughts relating to mineral extraction for BEVs would include cobalt extraction, where ~65% comes from the Democratic Republic of the Congo, where social, ethical and environmental concerns around its extraction have been identified. These include finding cobalt in blood and urine samples, leading to oxidative DNA degradation in the people living around artisanal cobalt mines.[3] Other elements needed within BEVs are the requirement for motors containing rare earth elements (REEs) within the permanent magnets of the motors. The mining of these require significant levels of energy and water in extraction.[4] As radioactive elements are part of the rock formations from which REEs are extracted, mines exposed to rainwater pollute the environment with radioactive and toxic substances, as do mine tailings which also contain additional chemicals from the flotation process involved.[5,6] There have been documented cases in China of severe pollution of soil and both underground and surface waters.[5]

Others have pointed to mineral sourcing from other sources, such as polymetallic nodules in the deep sea, however, the recent UN discussions in Kingston, Jamaica, during July on this topic, highlight that this is not without issues specifically around disturbing pristine environments at the bottom of the ocean. Previous LCA work has highlighted how comparative to land based mining, the mining of polymetallic nodules from the deep-sea leads to lower net CO_2 emissions than land based mining.[7] The authors use the impact data to which they have access, to best account for the impact of mining the nodules. However, scientists understand little of the deep-sea ecosystem as was eloquently pointed out recently,[8] so using the best available data in the LCA does not mean that the LCA conclusions can be relied upon, particularly when there is so little known of the long-term impact on this fragile ecosystem. Lacking quality fundamental science to underpin the LCA is one of the critical issues in utilising this tool.

Hydrogen vehicles

Considering hydrogen as a transportation fuel, the technoeconomic impact one must first consider is the energy losses in the generation of hydrogen, before looking at the efficiency of power generation. A kilogram of hydrogen contains 39.4 kW h of energy and typically requires around 50–55 kW h (~75% efficient) to generate as there are losses, predominantly from bubble accumulation on the electrode. Combining that with usage *via* a fuel cell which is quoted as approximately 60% efficient, means that the total round trip efficiency is in the order of 45%, so you would need approximately twice the energy to power a vehicle than a lithium-ion BEV. If you include compressing, storing and transporting the hydrogen this could be as high as three times the energy rather than just double. This is an important aspect to weigh in the sustainability balance, but additionally, from an LCA aspect it is worth noting that hydrogen is difficult to contain, for example current good quality leakage data is not available but has been approximated in the 1–3% range and that is expected to increase as more non-industrial usage is brought online, with approximations of 5–6% being discussed. Natural gas leakage was always considered low until the technology and systems were put in place to monitor this, highlighting just how much actually leaks, so putting this in place for hydrogen will be important. Hydrogen does not directly affect the climate, but its presence does increase the lifetime of methane, create changes in ozone, increase stratospheric water vapour and change the production of certain aerosols. Recent LCA studies on the global warming potential (GWP) of hydrogen give it a GWP100 of 11.6 CO_2e.[9] However, because it is so short lived in the atmosphere (current best estimate is 2.4 years) it has a GWP20 of 37.3 CO_2e. Projected hydrogen usage by 2050 by the International Energy Agency net zero scenario is production of 528 million tonnes of hydrogen.[10] If indeed the estimates being discussed are correct for leakage rates, this would give a GWP100 of over 360 million tonnes per annum which is not captured in the "zero emission vehicle" descriptions often ascribed to hydrogen vehicles. More worrying, by the mid-century with current levels of climate projections, the critical GWP20 comes into play and that would give close to 1.2 billion tonnes of CO_2e per annum. The LCA thinking highlights that the leakage rates must be discussed, measured, and specified in any hydrogen infrastructure or it would be difficult to determine the best sustainability balance between different technology types.

Sustainability needs robust science

What does all this show? Firstly, LCA is one of sustainability's foundational underpinning tools which allows for critical questions to be contemplated and answered. Secondly, this needs to be combined with other broader analysis methods to come to balanced sustainability views which can be entered into with eyes wide open. However, it also highlights how all of this relies on quality scientific studies which provide the data that underpin all LCA studies. As the well-known expression in computer science goes "garbage in, garbage out". Without great science leading to quality data that assess the impacts of all manner of human interaction with the biosphere, lithosphere, hydrosphere and atmosphere, humans are working off poor assumptions and taking decisions based upon flawed LCA inputs. Finally, it's worth stating that there is no perfect solution that does not have any impact. Sustainability is about finding an optimal balance as there will always be impacts. However, you cannot find that balance without good science underpinning the measurement tools for sustainability.

References

1 United Nations, Environment Programme, Guidelines for social life cycle assessment of products, United Nations, 2010.

2 European Commission, Determining the environmental impacts of conventional and alternatively fuelled vehicles through LCA: final report, Publications Office of the European Union, 2020.

3 C. Banza Lubaba Nkulu, *et al.*, Sustainability of artisanal mining of cobalt in DR Congo, *Nat. Sustain.*, 2018, **1**(9), 495–504.

4 N. T. Nassar, X. Du and T. E. Graedel, Criticality of the Rare Earth Elements, *J. Ind. Ecol.*, 2015, **19**(6), 1044–1054.

5 A. Golev, *et al.*, Rare earths supply chains: Current status, constraints and opportunities, *Resour. Policy*, 2014, **41**, 52–59.

6 D. Schüler, M. Buchert, R. Liu, S. Dittrich and C. Merz, Study on Rare Earths and Their Recycling, Öko-Institut e.V., 2011.

7 D. Paulikas, *et al.*, Life cycle climate change impacts of producing battery metals from land ores *versus* deep-sea polymetallic nodules, *J. Cleaner Prod.*, 2020, **275**, 123822.

8 B. N. Orcutt, Pause deep-sea mining to avoid irreperable harm, *Nature*, 2023, **619**, 673.

9 M. Sand, *et al.*, A multi-model assessment of the Global Warming Potential of hydrogen, *Commun. Earth Environ.*, 2023, **4**(1), 203.

10 International Energy Agency, Global Hydrogen Review 2021, IEA, Paris, 2021.