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A life cycle approach to measuring sustainability

ABSTRACT

Achieving sustainability requires balancing economic, environmental and social aspects. The awareness of and interest in sustainability are growing but the main questions still remains unanswered: what economic and industrial activities could be considered sustainable and how could progress towards sustainability be measured? This paper looks into the subject of measuring sustainability using a life cycle approach. Three sectors are discussed – energy, transport and food – and various options within these sectors compared on the basis of their carbon footprints. The paper demonstrates how the results of sustainability measurement could help industry and consumers to identify more sustainable options.

SUSTAINABILITY

Achieving sustainability requires simultaneous satisfaction of social, environmental and economic aspects of sustainable development. This is illustrated graphically in Figure 1: industrial systems exist to provide goods and services to society; they can continue to do so only if their operations are economically viable. Providing goods and services to society improves quality of life but also requires environmental resources and results in emissions and wastes which are returned back into the environment. Thus the challenge of sustainable development is to continue providing goods and services to society in an economically viable way while at the same time minimising the impact on the environment. Only then can we hope to achieve the development that "meets the needs of the present without compromising the ability of future generations to meet their needs" (1).

This is by no means a trivial task as it requires action by all societal actors, including governments, industry and individuals. One of the challenges is that, even if there was a universal commitment to sustainable development, most actors are still looking for an answer to the fundamental question: what economic and industrial activities could be considered sustainable and how progress towards sustainability could be measured? Figure 2 shows some of the environmental, economic and social issues that would need to be translated into the appropriate indicators of sustainable development to assist in measuring sustainability (2).

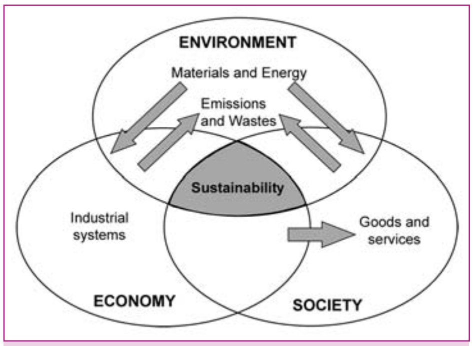

Figure 1. Achieving sustainability requires simultaneous satisfaction of economic, environmental and social goals.

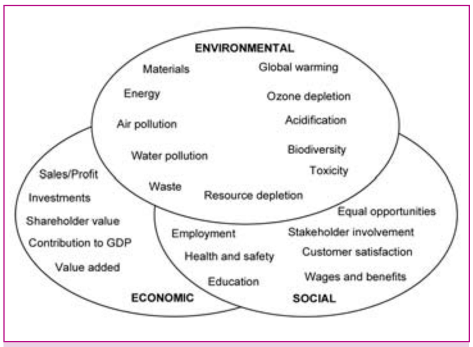

Figure 2. Example of sustainability issues that would need to be translated into sustainability indicators to measure sustainability.

This paper concentrates on one component of sustainable development the environment in an attempt to illustrate how environmentally sustainable products and activities can be identified. It is argued that a life cycle approach is essential for measuring sustainability as it enables us to obtain a full picture of the interactions between industry, human activities and the environment.

LIFE CYCLE APPROACH

As illustrated in Figure 3, taking a life cycle approach to measuring sustainability means drawing the system boundary from "cradle to grave" – or in other words, considering the whole life cycle of a product, process or activity from the extraction of raw materials, to production of the product or provision of a service, to the use and end of life stages. In some cases it is more appropriate to consider the system boundary from "cradle to gate" – i.e. up to the point where the product of interest leaves the production facility gate. This is the case, for example, with chemical commodities, which are used in a number of different products so that following their many life cycles would be impractical.

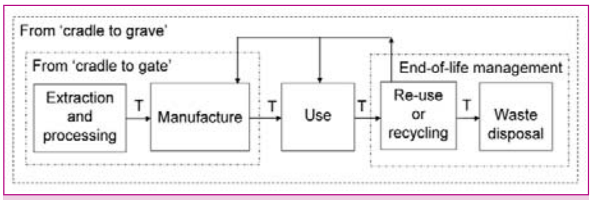

Figure 3. Life cycle approach to measuring sustainability: each stage in the life cycle of a product or activity is associated with certain environmental impacts which can be measured by using Life Cycle Assessment (LCA).
(T – transport).

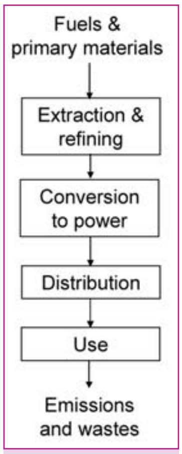

Figure 4. The life cycle of providing electricity.

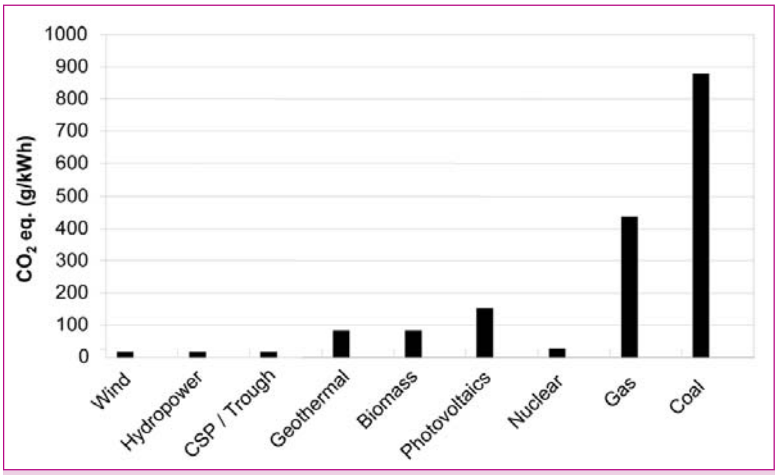

Figure 5. Life cycle comparison of the carbon footprint of various electricity generating technologies (5).

Life Cycle Assessment (LCA) is a tool that can help measure the environmental sustainability of products, processes or activities on a life cycle basis (3). By taking into account the whole life cycle of an activity along the supply chain, LCA enables identification of the most significant impacts and stages in the life cycle that need to be targeted for maximum improvements. This helps to avoid the shifting of environmental burdens from one stage to another, as could be the case if the system boundary is drawn too narrowly, e.g. just around the production facility.

MEASURING SUSTAINABILITY

This section illustrates how the environmental sustainability of different products and industrial supply chains can be measured using LCA. Due to space limitation, only one environmental impact – carbon footprint – is discussed.
Globally, the following three sectors are the largest contributors to the carbon footprint: energy, transport, and agriculture & food (4). Therefore, they have been chosen for the discussion here. Carbon footprint is defined here as the total emission of greenhouse gases (carbon dioxide, methane, nitrous oxide etc.) over the life cycle of a product, process or an activity; it is expressed as carbon dioxide equivalent (CO_2 eq)*.

Measuring carbon footprint in the energy sector

Energy supply contributes 26 percent to the global direct CO_2 eq. emissions (4); if the life cycle emissions are taken into account, this contribution would be much higher.
The life cycle of electricity provision is shown in Figure 4 and the life cycle carbon footprint of different electricity generating options is compared in Figure 5. As shown in the figure, of the options compared, electricity from coal has the highest carbon footprint of 875 g CO_2 eq. per kWh; electricity from gas generates half this amount of CO_2 eq.
The most sustainable options from the carbon footprint point of view are wind, hydropower, solar thermal and nuclear plants. Therefore, if we were only concerned with the carbon equivalent emissions from the life cycle of electricity generation, these four options would help us to become more sustainable. However, this is just one aspect of sustainability and other issues such as costs and social acceptability should also be considered.

Measuring carbon footprint in the transport sector

Transport is responsible for 13 percent of direct global CO_2 eq. emissions (4); the life cycle of the transport sector is shown in Figure 6. Comparison of the carbon footprints of different transport modes in Figure 7 suggests that travelling by train is the best option with 8 g CO_2 eq. per person and kilometre travelled. Car travel has the carbon footprint of 180 g CO_2 eq./person.km. Interestingly, travel by bus and long-distance flying have a comparable carbon footprint per km. Therefore, these results give an indication as to which transport options are more sustainable – however, as previously, other aspects would need to be taken into account, such as travel costs and availability of different transport options.

Identifying sustainable solutions demands considerations of a range of sustainability issues – focusing on a single issue at the time may lead to shifting the burden elsewhere.

It is also interesting to look at the carbon footprints of different biofuels, which have been hailed as a sustainable replacement for the fossil based fuels. As shown in Figure 8, bio ethanol from United Kingdom wheat offers a saving of about 28 percent of the carbon footprint compared to petrol. However, this comparison assumes 100 percent replacement of petrol by the biofuel – using only 10 percent as is currently the case results in only small savings of carbon.
The best performing bioethanol is from the Brazilian sugar cane which saves 70 percent of CO_2 eq. compared to petrol, while the bioethanol from US corn has 27 percent higher carbon footprint than petrol. In addition to the other issues such as competition with food production, these results further confirm that the first generation biofuels are

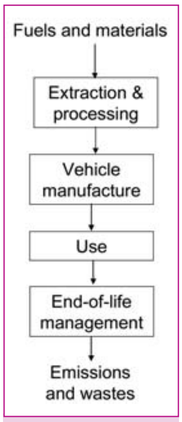

Figure 6. The life cycle of transport.

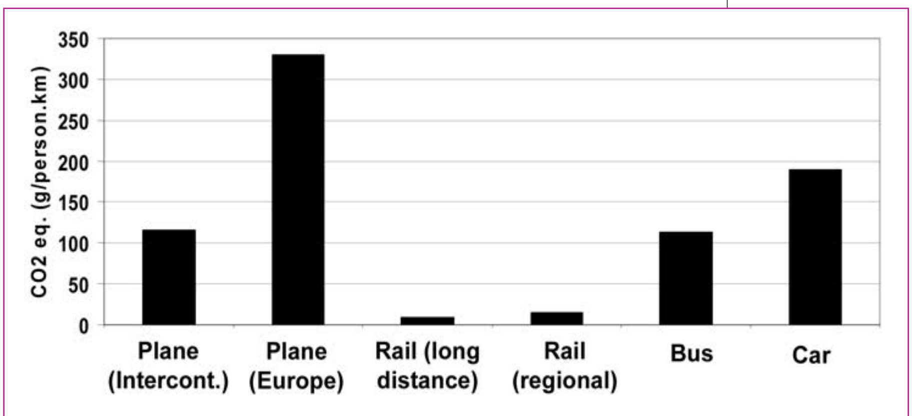

Figure 7. Life cycle comparison of the carbon footprint of various transport options (5).

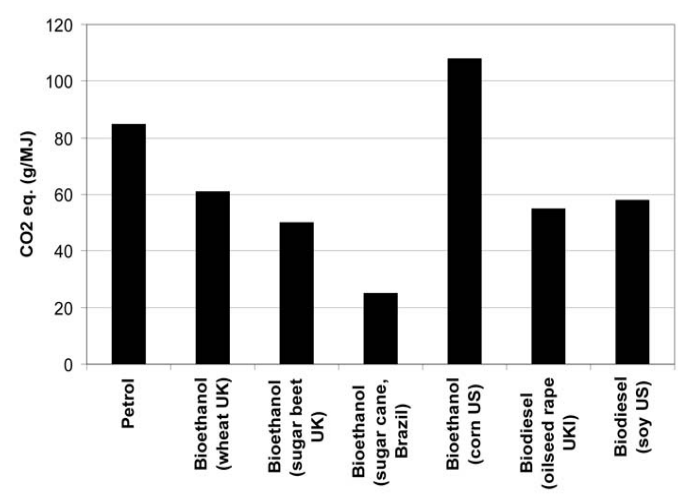

Figure 8. Comparison of the carbon footprint of different bio fuels with petrol (6).

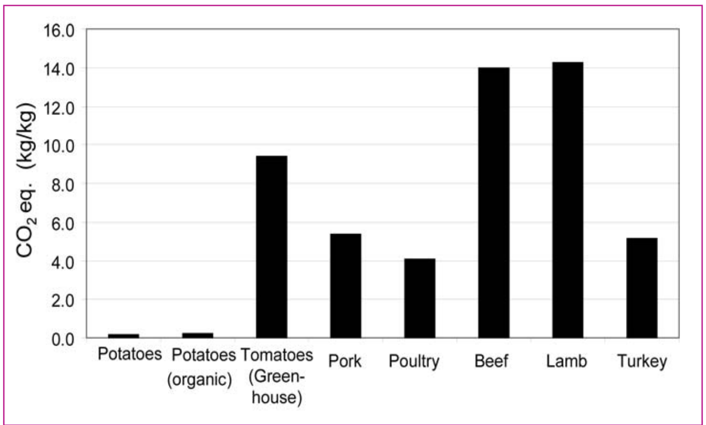

Figure 10. The carbon footprint of different foods from "cradle to farm gate" (7).

unsustainable and that we need to turn our attention towards the second generation of biofuels.

Measuring carbon footprint in the agricultural and food sectors

It is estimated that agriculture contributes 13.5 percent of direct global greenhouse emissions with the main contributors being fertilisers and livestock.

As shown in Figure 9, the life cycle of food provision includes cultivation, food production and preparation, and waste management. For illustration, the carbon footprint of several types of vegetables and meat is given in Figure 10. As can be seen in the figure, potato has a low carbon footprint compared to tomato (grown in a greenhouse).

In fact, the tomato from a greenhouse has a higher carbon footprint than pork and turkey. Beef and lamb have the footprint of 14 kg CO_2 eq. per kg of meat.

Therefore, this would suggest that a vegetarian diet is environmentally more sustainable than eating meat; however, other factors such as personal preferences will influence the choice of diet.

A life cycle approach is essential for measuring sustainability as it enables us to obtain a full picture of the interactions between industry, human activities and the environment.

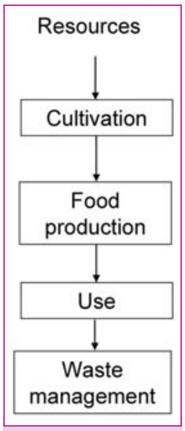

Figure 9. The life cycle of food provision.

CONCLUSIONS

This paper has illustrated via carbon footprinting how sustainability of different products and human activities could be measured. A life cycle approach has been used for these purposes. Three industrial sectors and supply chains have been discussed: energy, transport and food. The results presented demonstrate how this information could be used to compare and identify more sustainable options. Much more effort is needed in measuring sustainability of a wide range of products and human activities to help industry, consumers and policy makers identify more sustainable options. It should also be borne in mind that sustainable solutions can only be identified by considering a range of sustainability issues as focusing on single issues – such as carbon footprints – may lead to shifting the burden elsewhere.

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* CO_2 eq. is calculated by multiplying the emission of each greenhouse gas by its global warming potential and then summing across all the greenhouse gases. For example, the global warming potential of CO_2 is unity, or 1 kg CO_2 eq./kg CO_2. Methane (CH4) is 25 times more potent as a global warming agent than CO_2, hence its global warming potential is 25 kg CO_2 eq./kg CO_2.

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