State of Oregon
Department of Environmental Quality

Briefing Paper: Alternative Criteria for Measuring Environmental Impacts of Materials Management

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Many different environmental criteria can be measured for determining environmental impacts. This paper examines some of the more important criteria and examine how changes in materials management might affect those criteria.

Energy use. We use many types of energy. Non-renewable sources including fossil fuels (coal, petroleum and natural gas) and nuclear energy, and renewable energy sources such as biomass (wood, ethanol, methane from anaerobic decomposition), solar, wind, hydropower, tidal power and geothermal power. To a degree, different forms of energy can be used for the same purpose. Fossil fuels are of concern because their use generates substantial amounts of greenhouse gases and the potential for other environmental impacts, such as emissions of air pollutants and the potential for water pollution (e.g., from spills, mining, hydraulic fracturing, etc.). Fossil fuels are also not renewable, and so some types are becoming increasingly scarce and more expensive to obtain and use. Some renewable fuels and energy sources can also generate greenhouse gases when produced and when used, plus they frequently require large amounts of land to produce, and can degrade the environment and impact wildlife. Examples include the cropped lands used to grow biofuels that fragment habitats and replace natural ecosystems, and dams used for hydropower that affect fish spawning.

Greenhouse gases. Carbon dioxide, methane, and nitrous oxide are three of the most significant gases linked to global climate change. Many scientists have major concerns that as these gases continue to build-up in the atmosphere, climate patterns will change, with generally rising temperatures plus changes in the amount and distribution of rainfall and storm activity. There is also concern about acidification of oceans from increased carbon dioxide absorption, and the effects this can have on plankton, corals, mollusks and other marine life with calcareous structures, and on the larger marine environment. Carbon dioxide levels are commonly tied to the burning of fossil fuels, while nitrous oxide is tied to agriculture (fertilizer and manure), and methane to agriculture (enteric fermentation and manure) and landfills (anaerobic decomposition of organic materials).

Land use. There are two aspects to land use: the absolute quantity of land used for producing or managing materials, and the potential degradation of that land or suitability of that land for other simultaneous use. The ecological footprint system of evaluating environmental impacts is based primarily on land use.

Some materials, particularly food and wood products, require substantial amounts of land in order to produce materials. Metals, glass, petroleum products and other mineral resources require considerably less land (geographic space) to produce, although the production of these materials may involve substantial environmental damage such as is caused by mining overburden.

Land is available in only finite quantity, and land suited for high-valued uses such as agriculture is even more limited. As an example, there is increasing pressure to produce more biofuels as an alternative to fossil fuel use. Yet even if all Oregon land currently being used to grow grains, fruits and vegetable crops were converted to ethanol production using corn, it would still satisfy less than 25 percent of Oregon's annual use of gasoline,[i] indicating a lack of land to serve Oregon's energy needs using currently-available biofuel technology.

Ecological footprint. This measure models the direct amount of land needed to produce materials that are consumed (such as food and wood products) plus land needed to offset the carbon dioxide release through the burning of fuels or other sources. As such, it basically combines the effects of the land-use and energy measures above.

Freshwater depletion. Industrial processes (including paper recycling) and agriculture are major users of fresh water, and can divert water from other productive uses or degrade water to where it is not suitable for many other purposes.

Eutrophication. Nitrates, phosphates and other materials can overfertilize freshwater bodies and the ocean near river outfalls, causing algal and bacterial blooms and diminishing water quality. In the ocean near major river outfalls, this can lead to "dead zones" where oxygen levels are so depleted that much marine life cannot survive. Much of the nitrates and phosphates come from agricultural sources, but home detergents and industrial processes can also contribute.

Acid rain. Rainwater has become increasingly more acidic in recent years, primarily due to increased sulfates and nitrates in the air caused by the combustion of high-sulfur coal and some other fuels. Industrial processes using large amounts of electricity can potentially lead to higher acidity levels in rainwater. Rainwater acidity is particularly high on the U.S. East Coast, although energy production in the American West can lead to the production of acid rain that falls in the East.

Biodiversity. Land-use changes and many other factors affecting habitats can lead to local species extinctions and to increased abundance of some species at the expense of others. However, the interrelationships of many factors can complicate direct effects of materials management on biodiversity.

Soil fertility. This is normally considered just an agriculture issue, but with increasing interest in biomass as a source of energy, effects on soil fertility may come more into play in other materials management. Currently, much crop residue and logging slash is left in fields and on the ground, where it can help restore organic matter to the soil. To the extent that future conversion of biomass to energy uses that crop residue and logging slash, soils' long-term fertility may be reduced. Note that nitrates and phosphates that can lead to eutrophication can also bolster soil fertility if properly distributed on land and if there is enough organic matter or other suitable materials in the soil to absorb and hold on to these nutrients.

Resource depletion. Any resource that is potentially in limited supply can be affected by resource depletion. This includes energy sources, fresh water and land – already discussed above – but can also include many mineral resources.

Ozone depletion. Reduction of the stratospheric ozone layer has been caused by increased atmospheric emissions of gases such as chlorofluorocarbons. This leads to an increase in potentially harmful ultraviolet light reaching the Earth's surface.

Toxins: carcinogens. Changes in materials management can lead to increased or decreased quantities of carcinogenic chemical compounds in the environment, and to changed exposure of humans to these carcinogenic substances. Moving more to "green chemistry" production methods can reduce exposure to carcinogens.

Toxins: noncarcinogens. This measure refers to emissions of substances that contribute to human health impacts other than cancer.

Respiratory effects. Production of energy can produce small particulate matter that can have a negative effect on human respiration. This is often measured in terms of the pounds of material release that are smaller than a specific size, such as PM2.5 (smaller than 2.5 microns) or PM10 (smaller than 10 microns).

Smog. Chemical pollutants such as hydrocarbons can react with atmospheric gases to form harmful substances such as ozone and oxides of nitrogen. These gases can have an negative effect on human health and on ecosystems.

Ecosystem Toxicity. This is a measure of the potential of emissions to have harmful effects on ecosystems rather than human health. It is often measured in terms of the effects of specific herbicides on ecosystems.

Ranking and/or Combining the Impact Measures

Many criteria could be used to rank the importance of the various measures, including the following:

1) Effect on human health
2) Effect on natural animal and/or plant populations
3) Economic impact
4) Social equity impact

Because these criteria are so different, it may be difficult to reach consensus on their relative importance. For simplicity though, it would be ideal if the different impact measures could be combined into a single measure. In theory, one possibility is to determine the economic cost of mitigating each of the environmental impacts and use the sum of those costs as the overall measure. Such an approach has many potential problems though, including non-linearity of many of the impacts, lack of data and uncertainty of measurements. For example, data on releases of toxic chemicals over the life cycle of various materials is subject to high uncertainty and variability. Further, the impacts of such releases on human and environmental health are also subject to uncertainty, and so there may be insufficient data to judge the carcinogenic or non-carcinogenic potential of various chemicals relative to each other. Similarly, economists have generated wildly different estimates of the cost of greenhouse gas emissions (although many of the estimates tend to cluster in the same general area). Estimates of the "monetized" cost of other categories of pollutants are also variable.

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[i] In 2009, Oregon harvested about 1,300,000 acres of grains, vegetables, fruit, berries, nuts and other vegetative food crops, excluding hay and grass seed, according to the Oregon Agripedia Table 1. Data from Hill et al. (2006) indicate that an acre of corn grown on productive cropland in the corn belt states can yield 388 gallons of ethanol, which is equivalent to 260 gallons, or 6.18 barrels, of gasoline in energy value. Thus, if all this harvested land were used to grow corn for biofuel at yields similar to the corn-belt states, it would produce the energy equivalent of about 8.04 million barrels of gasoline. In 2009, Oregon consumed about 36.3 million barrels of automotive gasoline, according to the U.S. Energy Information Administration State Energy Data System. Thus, the 8.04 million barrels of gasoline-equivalent that could have been produced from corn ethanol on that land is about 22 percent of the total amount of automotive gasoline consumed in Oregon in 2009.