Greenhouse gas emissions: A systems approach

Engineers have an important role to fulfil as the focus of climate change discussions shifts from policy to implementation. We need to promote rigorous, proven tools and methods that use a systems perspective.

by Kevin Brady, Duncan Noble, P.Eng. and Steven B. Young, PhD, P.Eng.

Climate change is here to stay. Business leaders at the 2000 World Economic Forum voted global climate change as the most pressing issue confronting the world's business community. The development of the Kyoto Protocol in 1997 signaled that climate change is firmly established on the public, government and business agenda. The political commitment of some countries (particularly the United States) to ratify the Protocol may be in doubt, but there is a strong commitment in all industrialized countries to reap the economic benefits of improved energy efficiency and reduced greenhouse gas (GHG) emissions.

Climate change is likely to create substantial risks and opportunities for businesses with assets and operations directly affected by the weather, for example insurance, agriculture, forest products, fisheries and tourism. However, the impact of climate change on almost all businesses is that, to meet international environmental commitments, governments are in the process of implementing policies and measures that will increase the price of fossil fuel-based energy and affect the entire structure of world energy markets. These climate change regulations will reduce the value of some assets (e.g. inefficient truck fleets and commercial buildings) and increase the value of others (e.g. energy-efficient technologies and products and replacements or substitutions for carbon-intensive energy sources).

Although the detailed rules for implementing the Kyoto Protocol are still being finalized, one clear need is for credibility and rigour in measuring, verifying and obtaining credit for GHG emission reductions. To manage the risk of climate change and to take advantage of the opportunities, accurate and credible reporting of emissions is crucial.

First is the need to understand whether national governments are meeting the emissions reduction targets agreed to in the Protocol. This process involves national inventories for six GHGs from 180 different sectors and subsectors of the economy.

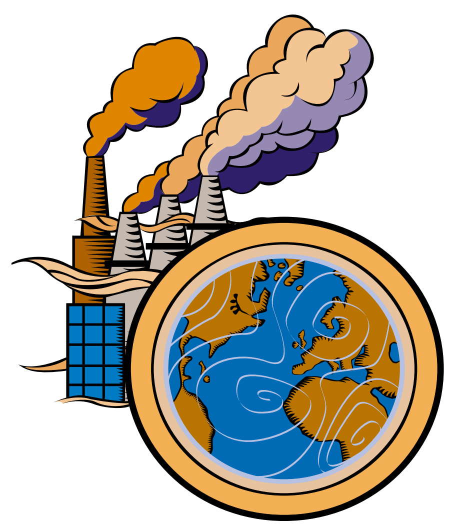
Secondly, within the Kyoto Protocol there are three "flexibility mechanisms" to enable countries to reduce their emissions. These mechanisms enable countries to achieve their targets through transferring or trading emission reductions. To be accepted by policy makers, and by the market for emissions trading, these mechanisms must be based on accurate and credible measurement of emission reductions.

Finally, as decision-makers in government and industry begin evaluating technology and policy options for GHG mitigation, there must be a credible means for evaluating their emission-reducing potential. For example, if a national government decided to provide tax subsidies to less carbon-intensive energy sources, a credible means of measuring emissions for the various alternatives would be needed.

National inventories are large complex data sets based on macro-level models of economic activity, but the latter two situations require more specific modeling and measurement of individual projects, technologies or actions. The systems analysis framework described in the international standard ISO 14040 and elaborated in the full series of ISO life-cycle-assessment standards proves an excellent starting point for supporting GHG measurement for these applications.

Why take a systems approach?

In addressing global climate change, it is essential that measurement tools and methodologies provide an accurate picture of whether GHGs are being reduced. Because the place of release for GHGs is not relevant to their potential impact, the measurement methodology must be capable of assessing system-wide implications of any action. For example, decision makers need to be assured that an improvement undertaken in a manufacturing plant does not result in upstream or downstream changes that will increase the overall release of GHGs. By tracking energy flows and GHG releases throughout all of the stages in the product life cycle, life cycle assessment (LCA) provides a system-wide perspective that enables decision makers to see and evaluate these trade-offs.



In the rush to reduce GHGs, it is important that we do not aggravate other environmental concerns, such as solid waste generation and the release of toxic substances. Therefore, measurement tools and methods must be holistic and not focus solely on GHGs. LCA satisfies this need, because it tracks energy and GHG releases and the consumption of such resources as water and materials, as well as multiple environmental releases. This holistic perspective helps decision makers understand the trade-offs inherent in any proposed change, as well as helping ensure that a reduction in GHGs does not result in other impacts such as increased release of toxic substances to the environment.

Another consideration in the choice of measurement tools is the need for globally accepted procedures and rules. The Kyoto Protocol's flexibility mechanisms involve partnerships among parties in different countries, different sectors and at different stages of economic development. To have confidence, a buyer of emissions reductions must have a means to evaluate the proposed project or reduction option against a credible internationally accepted standard. This confidence is required to ensure that the emission reduction is real and verifiable and to demonstrate to other stakeholders that the buyer has shown due diligence to ensure the emissions are real. For LCA, the International Organization for Standardization has developed such standards.

The ISO 14040 series of LCA standards provide direction on determining objectives, setting appropriate system boundaries, developing reliable data collection and handling procedures, evaluating and interpreting data and reporting in a transparent manner. They offer an excellent starting point for the development of measurement protocols for GHGs. This is particularly true if the LCA standards are considered together with an environmental management system that provides a framework for setting objectives and targets related to GHG emission reduction, and financial accounting standards and contract law procedures that provide protection for both the buyers and sellers.

In addition to international standards, there are thousands of completed LCA studies for electronics, automotive and many other products. Numerous software tools and databases have been developed to support these studies. These tools and databases represent a tremendous resource for modeling and measuring GHG emissions.

As climate change discussions shift from policy to implementation, the importance of measurement and verification will increase. Engineers have an important role to fulfil in ensuring rigorous, proven tools and methods, such as the ISO, LCA and EMS standards, are used and adapted to meet the evolving rules. In many ways, applying LCA to measuring energy systems and GHG emissions is bringing the tool back to its roots–extended product systems analysis began with energy systems analysis in the 1960s. Today, as we re-examine energy systems in the context of global climate change, we have the benefit of international standards for conducting and evaluating LCA studies; a large body of case examples that demonstrate the usefulness of this decision-making tool; and a choice of practical software applications that allow LCA studies to be completed in a reasonable time at a relatively modest cost.

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Upstream impacts of material selection

Lighter weight materials such as aluminum and magnesium are gaining market share over steel for structural applications in automobiles. These lighter weight materials offer higher strength-to-weight ratios and reduce vehicle weight–improving fuel economy, reducing cost of ownership and reducing GHG emissions–at least when the vehicle is being operated. A study by Opel, a division of General Motors, used a systems-analysis approach to analyze the full life-cycle impact of steel and magnesium as alternative materials for a typical automotive cross beam. Results showed that the lighter weight magnesium does not always result in GHG emission reductions. During metal smelting, volatile molten magnesium is protected from oxygen using a heavy cover gas–sulphur hexafluoride. Since this gas is a powerful GHG (about 23,900 times more potent than carbon dioxide), even small releases during magnesium production overwhelm GHG reductions due to weight reduction over the life of the vehicle. In response to these findings, Opel did not revert to a steel structural cross beam design. Instead, it used the results to leverage a new, more climate friendly cover gas for magnesium production.

Hydrogen fuel cells: the ultimate climate change solution?

According to their proponents, fuel cells are the "holy grail" of the automotive industry–they create no pollution and reduce the build-up of GHGs causing climate change. Similar to a battery, a fuel cell creates energy through an electrochemical process: Hydrogen and oxygen react to produce electricity and water vapour. During operation, the fuel cell does not produce any carbon dioxide, the basic combustion by-product of any carbon-based fuel such as gasoline.

But are fuel cells really pristine? It depends on several factors, including how the hydrogen is made, and what materials are used inside the fuel cell. A study by the Pembina Institute used a systems-analysis approach to determine the climate change benefits of using hydrogen from commercial-scale production in fuel cells. Depending on how the hydrogen is produced, life-cycle emission reductions of carbon dioxide can range from 5 per cent to 72 per cent compared to emissions from conventional internal combustion engines. The cleanest current commercial-scale source for hydrogen fuel is from natural gas reformed in a central plant.

Another challenge for fuel cells highlighted by taking a systems analysis approach is their dependence on precious metals such as platinum, rhodium and palladium. These metals are scarce, and significant GHG emissions occur during their mining and primary processing.

These results do not condemn the hydrogen fuel cell as a climate change solution. What they do indicate is a need to take a system-wide approach to determining the climate change benefits from fuel cells and other technologies. The results of this analysis can then be used to identify improvement opportunities and focus future research and technology development efforts.