SYSTEM BOUNDARIES AND METRICS FOR ANALYSIS OF CARBON MANAGEMENT TECHNOLOGIES

There is a multitude of technologies which could become part of a portfolio needed to manage greenhouse gas emissions. Obviously, there will be pros and cons to each of them, necessitating a systematic approach to the assessment of their performance.

Life cycle analysis (LCA) is increasingly used to evaluate systems. LCA is one tool with a focus on evaluating a product. If the evaluation of energy systems is to consider stewardship from a global perspective, there will also be need to consider metrics related to the service provided in addition to the product. Metrics related to economics, environment and equity are important. The metrics selected for an energy system are defined by the system boundaries. The boundaries or end-points of the systems being evaluated are critical if a consistent comparison of technologies is to be achieved.

Some of the issues involved in these definitions can be illustrated in the electric power sector.

EXAMPLE: Electric Power Sector

The electric power sector has typically been a major user of life cycle analysis in the decision processes associated with choosing between alternative power generation sources, customer-side measures, and other potential investments.

Historically, as a regulated industry, the decisions were largely based on an analysis of the present worth of all future revenue requirements. In this approach alternative investments were compared on the basis of their total life cycle costs, including construction, operations, maintenance, replacements, eventual decommissioning, salvage and fuel costs. The metric was annual revenue required to pay for the investment and deliver the desired service, reliable electricity to the customer or consumer.

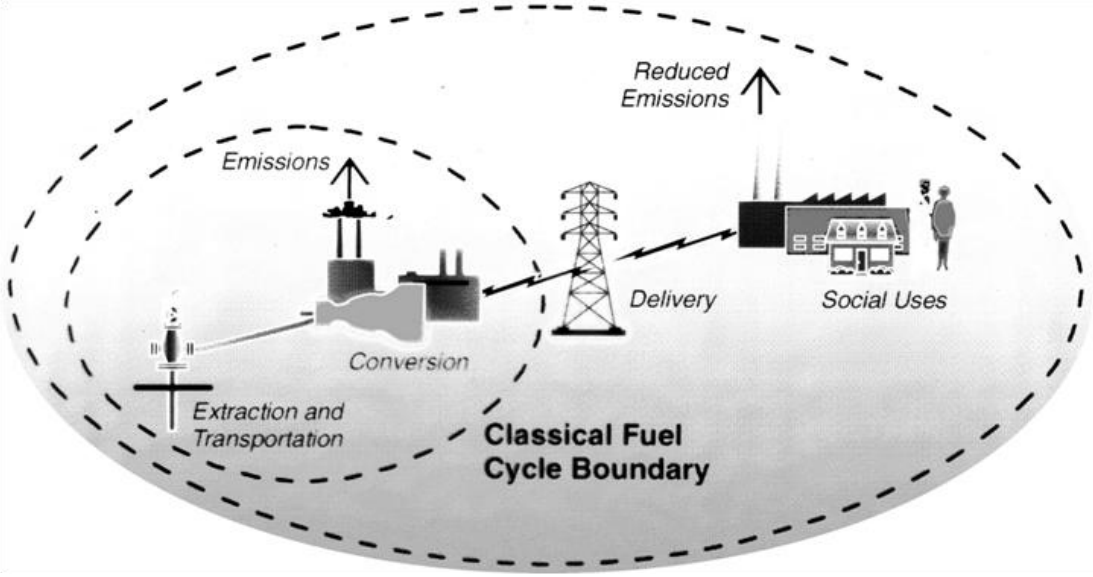
More recently, in the 90's, under pressure to pursue energy efficiency and demand response programs, the industry transitioned into Integrated Resource Planning. The process became more complicated with utility industry restructuring along with the emergence of Independent power producers, customer energy service providers, and aggregators. Concern about greenhouse gas emissions brought about the need to transition into Life Cycle Analysis (LCA), or cradle-to-grave analysis, before comparing various supply-demand alternatives. In turn, this necessitated a different (and more careful) definition of system boundaries.

System Boundaries

- Fuel Cycle System Boundary

The traditional system boundary for comparison of alternative power plants has been the power plant boundary. A more extended and complete analysis extends this boundary to include the resource extraction and processing elements. In the transportation sector this is referred to as a well to wheel analysis and in electric power it has sometimes been called a fuel cycle analysis. A complete fuel cycle analysis then extends the system boundaries to include all of the inputs and outputs from the resource to the delivery of electric power to the transmission line. This system boundary is generally sufficient for comparison of alternative generation scenarios.

Plant fence vs. end-use boundary



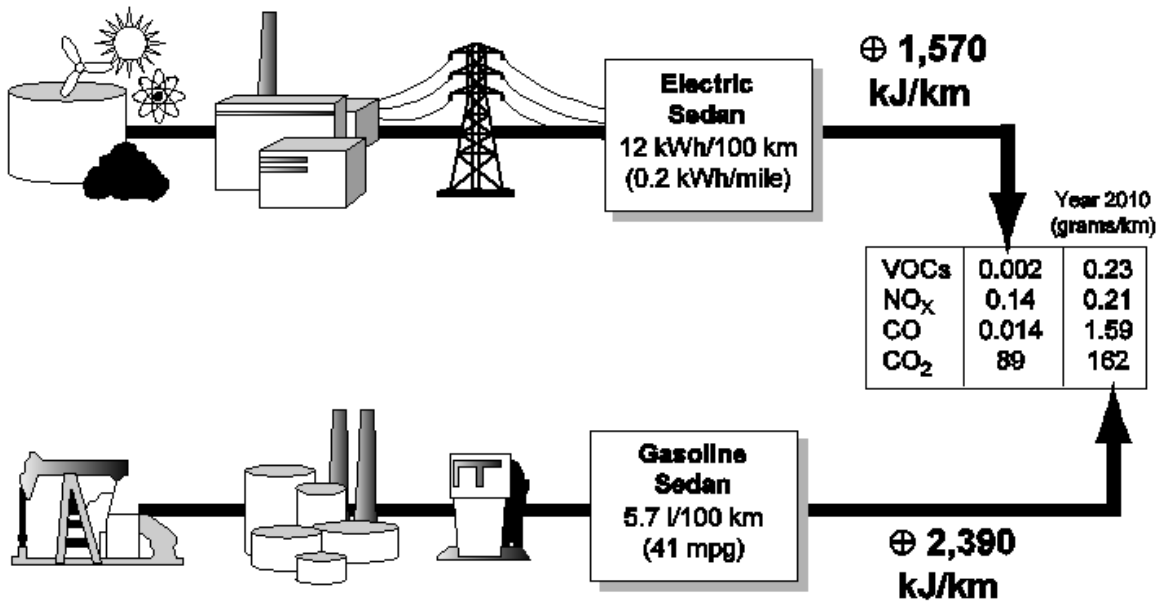
- Electricity Use Boundary

Because electricity is a new energy form, not a fuel, the complete understanding of various options (particularly a comparison of fuel- vs. electricity-driven alternatives) must include specifics on the service provided by the fuel or electricity to the consumers. The boundary then ranges from resource extraction and processing to customer-side systems.
Freeze concentration is an example of a high-efficiency electric technology for process industries. Using half the source energy of conventional gas-fired evaporation, electric freeze concentration can be used for many products, including concentrated milk or

juices. Conventional separation or concentration processes work by boiling off the volatile components in foods, which is typically water. In most cases and in all cases where water is the primary fluid being removed, achieving concentration through boiling incurs a higher energy penalty than freeze concentration, which removes the water at its freezing point instead of the boiling point. Emissions at the process site are reduced to nearly nothing, and total emissions, including those at the power plant, are a fraction of those of the gas-fired alternative.

Another example, the approach to comparing an electric to an ICE vehicle, is depicted in the diagram below. The specific performance and emission values are provided for illustrative purposes only.

Comparing Electric Transportation to Gasoline-driven Cars



– Distributed Generation and Combined Heat and Power

The comparison of central station and distributed generation creates additional complexity as does a comparison with combined heat and power (CHP) or cogeneration. In both of these cases the system boundary needs to again be extended. It needs to include application and utilization of the recovered heat, as well as the duty cycle. Resource extraction, processing and transport needs to be added for fuels which could deliver the same service directly.

Project Overview

One of the techniques for common-sense comparison of various technology options is a Scorecard, developed by the Carbon Management Project. While the technique is completely transparent and straightforward, here too care has to be taken to define consistent energy system boundaries for each set of technologies to be compared. However, the issue of system boundaries and metrics transcends the Scorecard requirement and needs to be addressed separately.

Objectives

The objective is to develop a methodology and/or criteria for a systematic approach to defining energy system boundaries and metrics. Specifically,

- Define issues associated with system boundary definitions and metrics
- Describe methodology for consistent definitions of boundaries and metrics
- Use energy systems with biomass to illustrate the approach

It is not the intent to include extensive computations and numerical comparisons in this work. However, we believe that a system which includes biomass would be a particularly challenging example to test the methodology. Biomass in energy systems can be difficult to analyze because the time span of the analysis and the mechanism of carbon absorption are so critical to the outcome

An example of the energy systems boundaries and metrics activity is the work that was initiated in 2010 in the area of biofuel metrics. This is an area where government agencies are developing a response to defining metrics for biofuel systems. Both EPA and NREL have engaged in initial discussions. Other agencies, such as NETL and USDA, are also working on the metrics problem for biofuels and outreach will be carried out to bring these entities to engage the technical expertise our societies in an efficient and streamlined fashion.

Some Considerations in System Boundaries

- Complete Energy Balance
- Disposal and/or management of effluents
- Land Use Changes

Potential Metrics

- Examples in NAS Report
- Metrics for Climate Change

- Carbon per Unit of GDP
- Carbon per Capita
- Not Just Carbon
- Other data needed for LCA analysis, e.g., fuels costs, discount rates, life times, and period of analysis. Data from EIA is often used as baseline.

Beyond the Dimensions of Monetized Metrics

- Quality of Life
- Life Span
- Biodiversity