Comparable Reference Flows for Lightweight Materials in Transportation Systems

Joyce Cooper
University of Washington Design for Environment Laboratory, cooperjs@u.washington.edu;

Bill Carberry
The Boeing Company

ISO 14040 defines the *functional unit* as a measure of the performance of the functional outputs of a product system. The purpose of the functional unit is to provide a reference to which the inventory data are related to ensure alternatives are compared on a common basis. For each product system or alternative being assessed, the amount of product necessary per functional unit is known as the *reference flow*. Definition of the reference flow must include the type and quantity of materials and energy linked to the functional unit and the number of times materials must be replaced during the analysis lifetime.

Because reference material and energy flows dictate up and downstream process alternatives, definition of the functional unit and reference flows are critical steps in LCA. In fact, in an ideal case, alternatives investigated in a study should provide the same service during their lifetime. In reality, definition of the functional unit and reference flows can be difficult due to issues related to lifetime (subject to customer habits and non-systematic variations), performance (subject to customer habits, the introduction of alternatives, and multifunctionality), and system dependencies (changes in the system design that result from changes in component design).

In this presentation, requirements for defining functional units and reference flows for comparative analyses in LCA are suggested and demonstrated. Requirements are grounded in a differentiation between the system and sub-system functions, functional units, and reference flows. Also, the requirements highlight the need to include data quality and uncertainty information and analysis of multifunctionalities needed in the interpretation phase of LCA.

A case study is presented that illustrates the use of the requirements in aircraft lightweight material selection. The subsystem of interest is a plate within the structure of an aircraft. Four materials are evaluated: a wrought aluminum alloy (the baseline), a cast aluminum alloy, an epoxy laminate carbon prepreg composite, and a titanium/silicon carbide composite. In addition to the lightweight materials used in the plates, use of the requirements led to the identification of interface materials (finishes and fastening materials) and wing and propulsion system enhancements that needed to be included in the reference flows to ensure comparability of alternatives. These additions were found to influence aircraft fuel use, the identity of up and downstream processes considered in the LCA, and related impacts.