Reusable and Disposable Cups: An Energy-Based Evaluation

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ABSTRACT / A group of five different types of reusable and disposable hot drink cups have been analyzed in detail with respect to their overall energy costs during fabrication and use. Electricity generating methods and efficiencies have been found to be key factors in the primary energy consumption for the washing of reusable cups and a less important factor in cup fabrication. In Canada or the United States, over 500 or more use cycles, reusable cups are found to have about the same or slightly more energy consumption, use for use, as moulded polystyrene foam cups used once and then discarded. For the same area paper cups used once and discarded are found to consume less fossil fuel energy per use than any of the other cup types examined. Details of this analysis, which could facilitate the comparative assessment of other scenarios, are presented.

Conventional wisdom suggests that multiple uses of a reusable cup produce a lower overall environmental impact per use than a single use of a disposable cup. Disposable cups have a place in applications where breakages and losses of other types of cup are unacceptably high, or where washing and sanitizing of reusable cups is awkward, such as in hospitals, in the entertainment and transportation sectors, and for occasional use by large numbers of people. These circumstances make the convenience and the much lower unit cost of disposable cups attractive.

Our previously published study of the life cycle environmental impacts of paper and polystyrene foam cups (Hocking 1991a,b) evoked a lot of interest, most notably in its conclusion that adverse resource and pollution externalities of these cup types were at least similar. Some readers mistakenly interpreted these papers to be recommendations in favor of disposable over reusable cups, which was not the case. However, these misinterpretations, plus evidence of increasing concern about the overall environmental impact of cup selection (van Eijk and others 1992, Fenton 1992, Hocking 1991c, d, 1993) prompted the energy-based evaluation presented here.

The basic question is, considering the resource consumption and the total resulting waste stream during use, how many uses of a reusable cup are necessary before its overall impact per use is less than that of a disposable cup? Decision-making by food service operators, legislators, environmental groups, and the public would be served by the answer to this question.

KEY WORDS: China; Glass; Hard plastic; Paper; Polystyrene foam cups

This is not an easy question to answer because of the widely differing nature of the materials used and the conditions required to make reusable and disposable cups, e.g., pottery clays, glass, plastics, and paper. The fundamental property common to each of these cup types is the total energy required to produce the cup or mug ready for use, which is a well-established criterion for the comparison of disparate materials (e.g., Boustead and Hancock 1979, Kindler and Nikles 1979, 1980, Ringwald 1982). Available background information from previous studies of the merits of cup options are individually and collectively incomplete. The study carried out in the Netherlands did not consider polystyrene foam cups (van Eijk and others 1992), the Winnipeg Packaging Project did not examine ceramic (earthenware/stoneware) cups (Fenton 1992), and our own previous contribution did not review reusable cups (Hocking 1991b). Furthermore, the frameworks used in these assessments were sufficiently different to make it difficult for direct comparisons to be made between them.

This paper examines the fabrication energy for five of the common hot drink cup types applying the same methodology to each and tabulates the energy required for various widely used commercial washing and sanitizing methods employed for the reusable types. The combined information is then integrated to determine the energy requirements per use for various service scenarios of each cup type and to determine the break-even energy requirements for each of the reusable–disposable cup pairs. Brief consideration is given to the effects of various disposal options. Finally, a few tests are applied to determine the sensitivity of the energy requirements and break-even

points to alterations in the input data using the same methodology.

Methods

The boundaries taken for the detailed energy evaluation include: the total energy required for the extraction of crude oil on site to the final product for the plastic cup types; the total energy required to produce a finished paper cup from a standing forest; and all the processing energy required from raw materials in the ground to finished glass and ceramic cups. For the output side, the energy consumption during use for the cup life cycle is evaluated to the point of discard for both the cup types, disposable and reusable. For the reusable cups, account is taken of the total operating energy of various commercial dishwashers. No account is made of the energy or materials requirement to make a commercial dishwasher, because this energy component per cup use cycle over the life of the dishwasher will be small relative to the operating energy component.

The energy parameters of interest for each type of cup were compared on a common basis. The total energy consumption per use for each of the reusable cups was determined using equation 1. This reflects the usual practise to wash new cups of this type before use.

$$\text{Total energy consumption per use of reusable cup} = \frac{A + EB}{E} \quad (1)$$

where A is the energy required for the manufacture of one reusable cup, B is the energy required for one hygienic wash, and E is the number of single uses of the reusable cup followed by a wash.

To accommodate the influence of refills on the energy consumption per use requires the introduction of an additional term (equation 2). By way of example, for wash/use cycles WUWU, WUUWUU, and WUUUWUUU, E and F are assigned values of 2 and 0, 2 and 1, and 2 and 2, respectively. In the limiting case with no refills, $F = 0$, and equation 2 reduces to equation 1.

$$\text{Total energy consumption per use of reusable cup (accommodating refills)} = \frac{A + EB}{E + F} \quad (2)$$

where F is the number of refills of the reusable cup without intermediate washes.

The energy required per use of a disposable cup is the energy required to make the cup, C, divided by the number of uses before discard, D, as given by equation 3.

$$\text{Total energy consumption per use of disposable cup} = \frac{C}{D} \quad (3)$$

To determine the break-even number of uses of the reusable cup relative to the disposable cup from an energy consumption perspective is straightforward for single uses of the reusable cup between washes and only one use of the disposable cup before discard, determined by equation 4.

$$\frac{A + xB}{x} = C \qquad x = \frac{A}{C - B} \quad (4)$$

where x is the break-even number of uses of the reusable cup before the energy consumption per use equates to that required to manufacture the disposable cup.

Break-even evaluation becomes more complex when assuming more than one use before washing or discard of either cup type, as is common (equation 5). In the limiting case, when the number of uses of each cup type before washing or discard is 1 (i.e., $D = E = 1$, and $F = 0$), equation 5 reduces to equation 4.

$$\frac{A}{x} + \frac{B}{(E + F)} = \frac{C}{D} \qquad x = \frac{A}{\frac{C}{D} - \frac{B}{E + F}} \quad (5)$$

Finally, the break-even energetics of various disposal options for both cup types and accommodating a variety of usage scenarios were determined by equation 6.

$$x = \frac{(A - G)}{\frac{(C - H)}{D} - \frac{B}{(E + F)}} \quad (6)$$

where G is the energy recoverable from the reusable cup on discard and H is the energy recoverable from the disposable cup on discard.

Again in the limiting case, if no energy recovery is practiced for either cup type at the end of its useful life (i.e., $G = H = 0$), this equation reduces to equation 5.

The published energy requirements for each of the four cup technologies were collected without regard to their relevance to cups or to whether the reported value was for part of the process or for the whole process. Operating details were also obtained for several commercial dishwashers with particular refer-