1 Introduction

Since 2003, a bloody and complicated war in the Darfur region of Sudan has resulted in the displacement of over 2.2 million Sudanese citizens. The displaced, known collectively as *Internally Displaced Persons* (IDPs) are living in dense camps scattered in arid areas with low fuelwood productivity. Unsustainable harvesting of fuelwood by the IDPs has created ever increasing zones of denudation, that now extend several kilometers in all directions from the camp boundaries. Leaving the safety of the camps to fetch fuelwood from farther and farther away imposes great hardship and risk on the IDP women.

In November of 2005, a group of scientists from LBNL, led by Dr. Ashok Gadgil and with logistical support of CHF International, travelled to Darfur to assess the potential of fuel-efficient stoves (FES) as a means to mitigate the fuelwood shortage. The LBNL team performed systematic informal surveys of IDP households in North and South Darfur to understand the household parameters related to family size, food, fuel, cooking habits, cooking pots, expenditure on fuel, and preferences for spending saved time and money if less fuel could be used. They also tested four pre-existing FES designs side-by-side with the current cooking technology - a three-stone fire. Three of these four FES designs were metal stoves transported to Darfur by the LBNL team, including the Indian-made *Tara* stove, and the fourth was an improved version of the ITDG mud-and-dung stove that was being locally produced and disseminated. Dr. Gadgil improved the design of the locally produced IDTG stove the best he could -- this improved version was named the *Avi* stove. The fuel efficiency tests were performed with IDP cooks, using their cookware, cooking methods, and food ingredients. The metal Tara stove was found to use 50% less fuelwood than the traditional three-stone fire, out performing other designs by large margins. A complete report of the field trip and findings is detailed in Galitsky et al, 2006.

While the Tara stove was clearly the most fuel-efficient of the tested options, the LBNL team made two recommendations for modifications to the Tara design before its dissemination in Darfur: (1) the stove must maintain fuel-efficient performance in the presence of wind and (2) the stove must not tip during the vigorous stirring employed by the IDPs in Darfur. The first recommendation was based on the rapid degradation in fuel efficiency observed during strong breezes. This was noted to probably be the result of using the round-bottomed pots of IDPs rather than the flat-bottomed pots of India for which the Tara stove was designed. The second recommendation stemmed from the experience of IDP cooks who had to use a second person to stabilize the stove while stirring during side-by-side tests. The use of two people to cook is an unreasonable requirement for busy IDP women who frequently cook alone.

In spring 2006, an interdisciplinary team of four UC Berkeley students - Susan Amrose (PhD student in physics), G. Theodore Kisch (Undergraduate senior in Environmental Sciences), Jesse Woo (masters student in Mechanical Engineering) and Charles Kirubi (masters student in the Energy and Resources Group) - took on the task of modifying the Tara stove according to the recommendations of the LBNL team. The modified stove, which came to be known as the Berkeley Darfur Stove, or "BDS", was subsequently tested against the Tara using a novel stove test designed specifically for conditions in Darfur. This work was performed as a group project for the spring 2006 course *Design for Sustainable Communities* (ER291-003) taught by Prof. Ashok Gadgil, who also acted as a mentor and guide to this team.

1.1 *Broad Objectives*

The broad objectives of the student team were to (1) modify the Tara stove according to the two recommendations of the LBNL group to create the Berkeley Darfur Stove (BDS), (2) come up with a reliable and reproducible test to compare the fuelwood use of any two stoves in conditions relevant to Darfur and (3) test the BDS performance to see that both recommendations of the LBNL group were adequately met. A corollary objective was to establish the expected annual fuelwood savings (considering both windy and non-windy conditions) between the BDS and the original three-stone-fire. This number was needed in order to estimate the impact that full-scale dissemination of the stoves could have on the Darfur fuelwood crisis.

1.2 *Specific Objectives*

(1) Design and fabricate the Berkeley Darfur Stove - a modified Tara stove that is stable during vigorous stirring and has minimal convective heat loss during breezy weather when using IDP pots to cook common IDP food.

(2) Establish a reproducible stove test protocol to compare the fuelwood usage of two stoves in conditions relevant to the IDPs of Darfur, including the cooking of common IDP food in IDP pots in both windy and non-windy conditions.

(3) Use the stove test protocol to compare the fuelwood usage of the original Tara stove to the Berkeley Darfur Stove (and by inference to the three-stone fire used in Darfur).

(4) Test the stability of the Berkeley Darfur Stove during vigorous stirring.

1.3 *Outline of the rest of the report*

The rest of the main report details the efforts and results of the student team, including the Tara stove modifications that ultimately lead to the design of the Berkeley Darfur Stove (BDS), the development of the Darfur Cooking Test protocol, and subsequent performance testing of the BDS. The structure of the report is as follows: Section 2 presents the design process of the BDS. Section 3 discusses fabrication of the first BDS prototype. Section 4 presents the development of the Darfur Cooking Test. Section 5 presents the performance testing of the BDS for fuelwood efficiency (using the Darfur Cooking Test) and stability. Finally, Section 6 presents our conclusions. Appendix 1 presents a detailed description of the Darfur Cooking Test protocol and Appendix 2 presents a worksheet intended to guide a user through the protocol.