I: INTRODUCTION AND SUMMARY

Household stoves, although individually small, are numerous and thus have the potential to contribute significantly to inventories of greenhouse gases (GHG), particularly in those many developing countries where household use is a significant fraction of total fuel use. In addition, the simple stoves in common use in such countries do not obtain high combustion efficiency, thereby emitting a substantial amount of fuel carbon as products of incomplete combustion (PIC) - such as carbon monoxide (CO), methane (CH_4), and total non-methane organic compounds (TNMOC) - as well as carbon dioxide (CO_2). This is true for fossil fuels, such as coal and kerosene, but is particularly important for unprocessed biomass fuels (animal dung, crop residues, and wood), which make up the bulk of household fuel use in developing countries.

Many greenhouse analyses of human fuel use assume that renewably harvested biomass fuels do not contribute to global warming, i.e., have no global warming commitment (GWC), because the released carbon is entirely recycled through photosynthesis in growing biomass that replaces the burned biomass. Even under renewable harvesting, however, the gases released as PIC contribute to global warming because of higher radiative forcing per carbon atom than CO_2 (Hayes and Smith, 1994). Thus, such fuels have the potential to produce net GWC even when grown renewably.

It is estimated that biomass combustion contributes as much as 20-50 percent of global GHG emissions (Crutzen and Andreae, 1990; IPCC 1990). Though the major fraction of the emissions is from large-scale open combustion associated with permanent deforestation, savannah fires, and crop residues, combustion in small-scale devices such as cookstoves and space-heating stoves also releases a significant amount of GHG. A more accurate estimation of emissions from biomass combustion would require an inventory for GHG from different types of biomass combustion as well as better estimates of amount of biomass burnt.

The emissions of non-CO_2 greenhouse gases from small-scale combustion of biomass are not well characterized (Levine 1996), but are known to be different from open large-scale combustion, such as forest and savannah burning, which have been the focus of more research. Emissions from other fuels as commonly used in developing-country households are also not well known. Therefore, extensive measurements of emission factors for GHG from a range of fuels and combustion devices would lead to removing some of the uncertainty in the estimates of total emissions from biomass combustion and also will provide a baseline database to understand the potential for reduction in GHG emissions due to various mitigation measures, such as fuel switching, in the household sector.

A pilot study was conducted in Manila, Philippines to measure the concentrations of a range of GHG from small-scale cookstoves burning biomass, charcoal, kerosene and liquefied petroleum gas (LPG) (Smith *et al.* 1992; 1993). The results indicate that the emission factors for CH_4, CO, and TNMOC from the combustion of wood and charcoal in cookstoves are high. In the case of wood combustion, the analysis also revealed that, the global warming commitment (GWC) of the non-CO_2 GHG - CO, CH_4 , and TNMOC - may in some circumstances rival or exceed that from CO_2 itself. In addition, the study seemed to indicate that in some instances substitution of

biomass by fossil fuels, such as kerosene and gas, could be considered as means to lower GWC, even when the biomass fuel is harvested renewably. If verified, these would have important implications in setting energy and global-warming policies.

To explore these tentative findings further, a series of more detailed measurements were undertaken in India. A total of 28 fuel/stove combinations in common Indian use were successfully tested for a range of GHG and other emissions while simultaneously being monitored for fuel, thermal efficiency, and other parameters.