Understanding the Reduction of Particulate Emissions in Biomass Cookstoves

Kathleen Lask[1,2], Cristian Birzer[3], Paul Medwell[3], Ashok Gadgil[1,2]

[1]University of California, Berkeley, [2]Lawrence Berkeley National Lab, [3]University of Adelaide, Australia

Background

Darfuri woman cooking on traditional fire[4]

3 billion people worldwide cook with biomass[1]

Inhalation of cooking smoke causes 4 million premature deaths per year[2]

Ultrafine particulates are especially detrimental to human health[3]

Efficient, low emission stoves are needed

Secondary air flow modifications can drastically reduce mass of particulates released from cookstoves[5]

Mechanisms behind these reductions are not well understood

Research Purpose

Study potential air flow modifications to identify mechanisms affecting particulate reduction, focusing on ultrafine particulates

Experimental Setup

Berkeley-Darfur Stove

Berkeley-Darfur Stove[4]

- Improved wood-burning cookstove
- Used as baseline
- Designed for Darfur
- Fuel efficient with good heat transfer to cooking pot[5]

1 Hz sampling of black carbon, CO, CO_2, fuel consumption, and particulate matter (5 nm - 20 μm)

4 air flow rates, spanning feasible range for air injection in the field

Straight Halo modification:
-- Copper ring manifold sits 50 mm above combustion chamber
-- Injects air inward and downward at 45° angle toward the flames

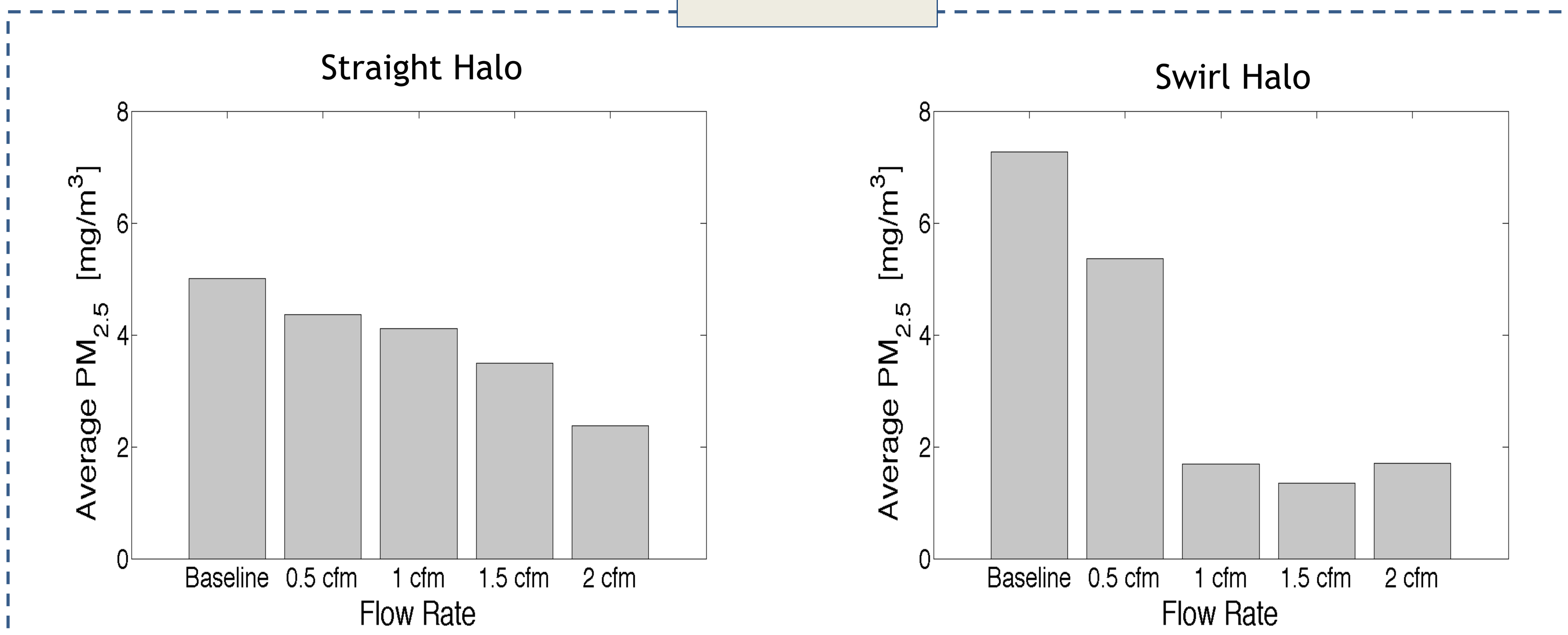
Swirl Halo modification:
-- Same as Straight Halo, but air holes are also angled horizontally at 30°
-- Angled holes force injected air to swirl in combustion chamber

Above: Halo in Berkeley-Darfur Stove

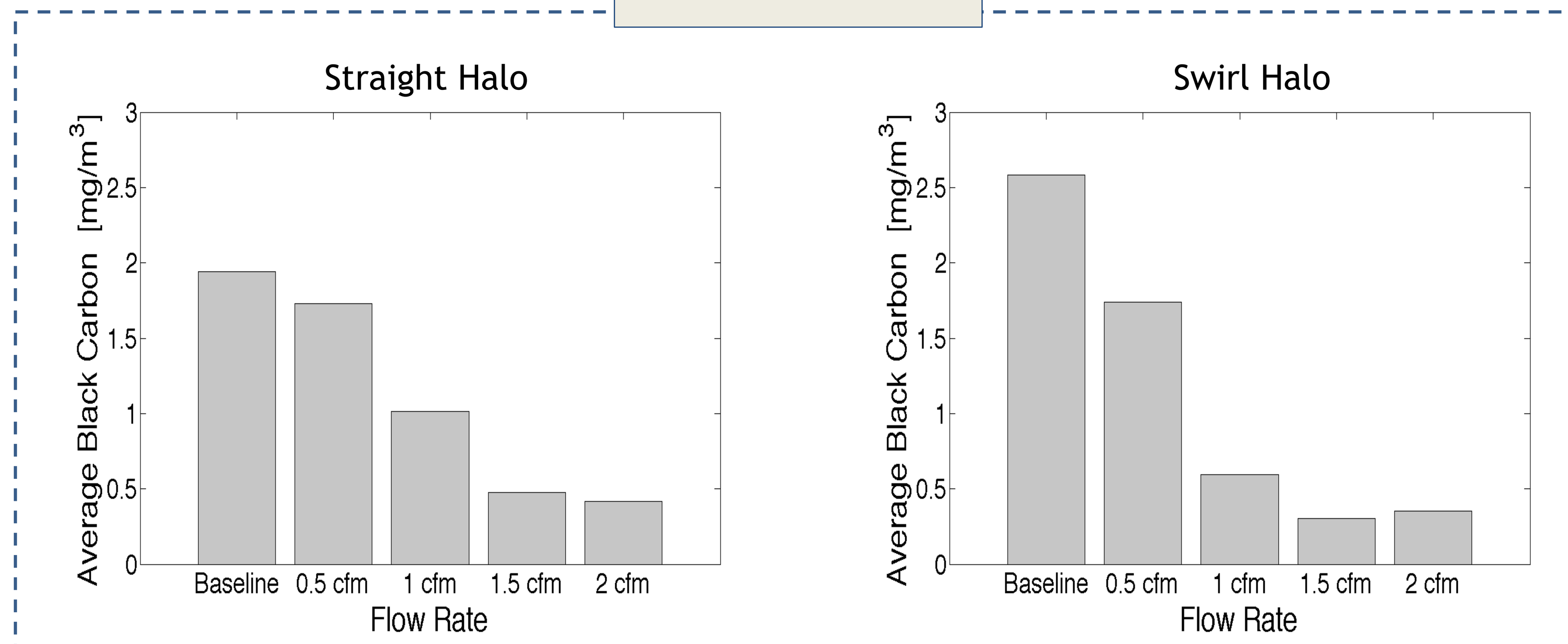
Above left: Underside of Swirl Halo

Preliminary Results

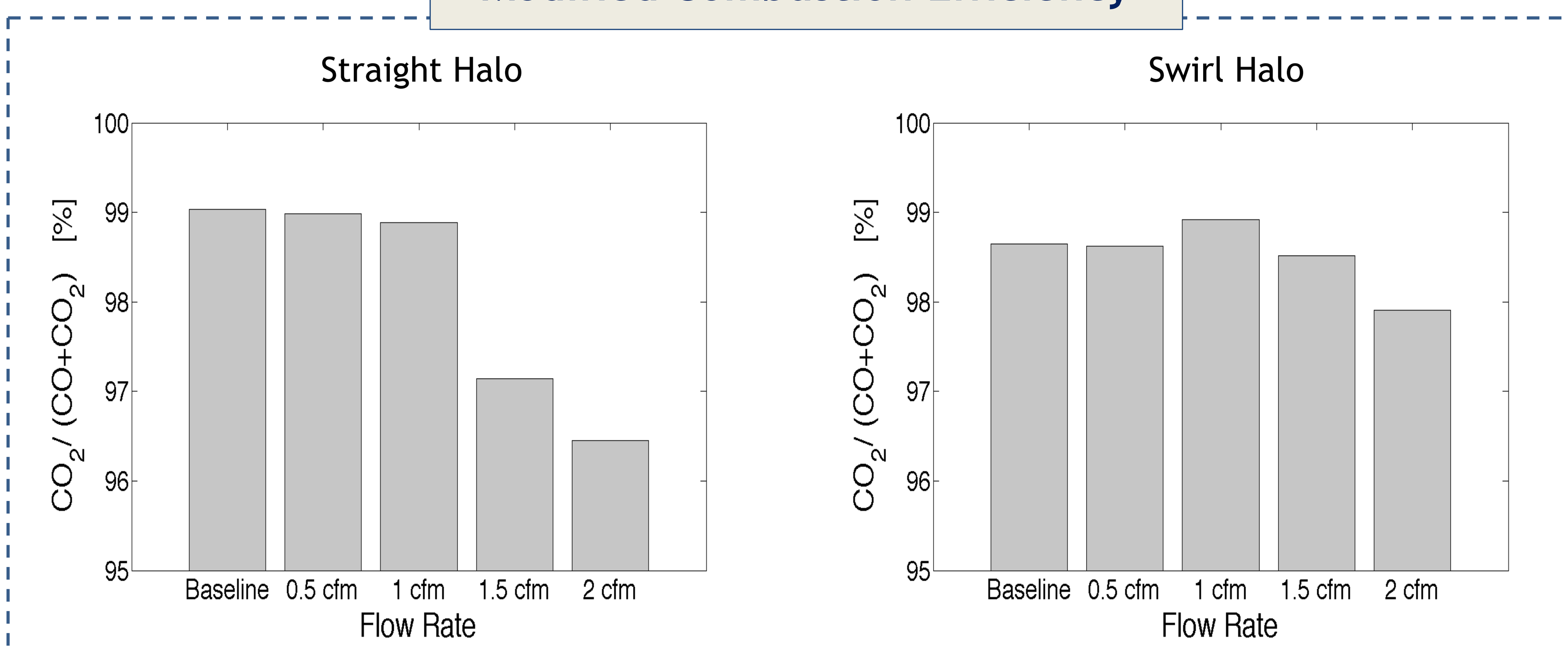
PM 2.5



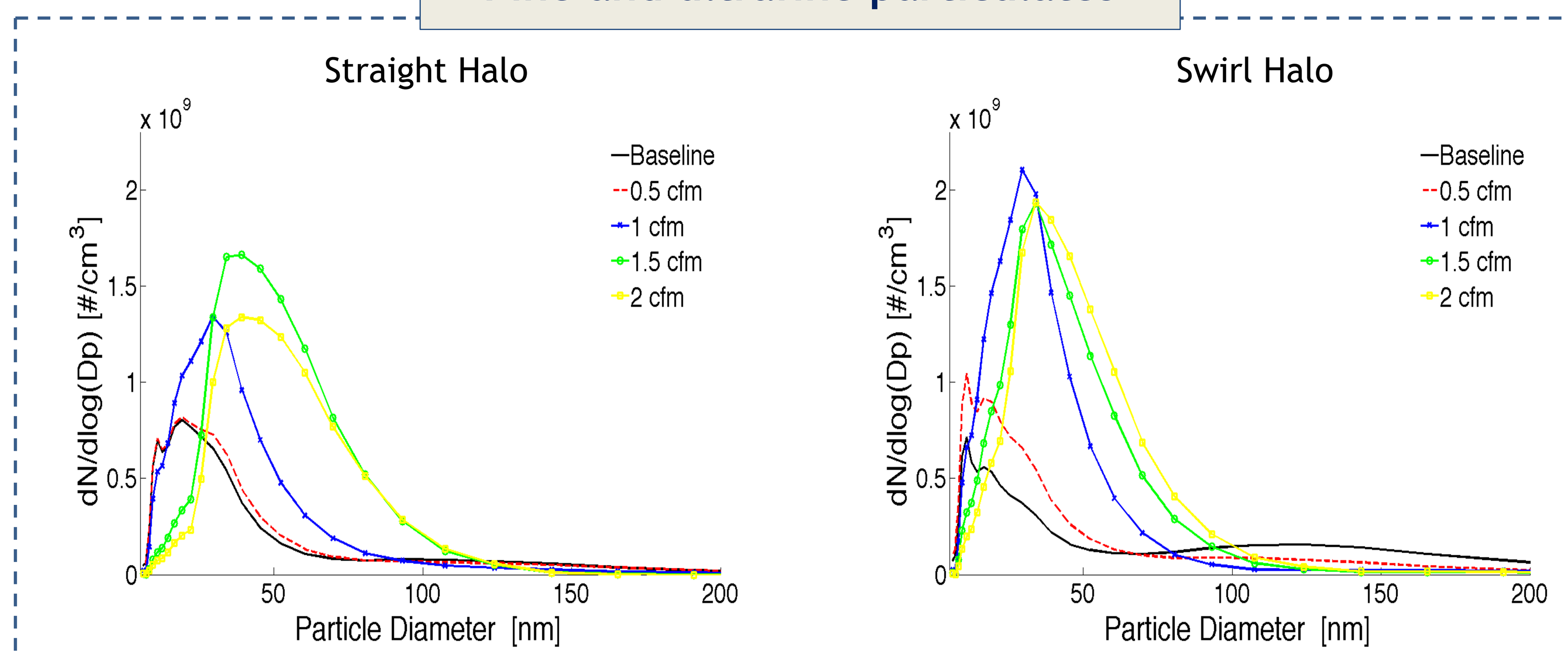
Black Carbon



Modified Combustion Efficiency



Fine and ultrafine particulates



Conclusions

- Both designs reduce black carbon and PM 2.5
- Straight Halo loses efficiency at higher flow rates
- Ultrafine particle size distribution concentrates and number density greatly increases as air flow rate increases
- Fine particles are greatly reduced as air flow rate increases

From the preliminary tests, 1 cfm Swirl Halo appears to be the best option of these designs and flow rates although it has an increased number of ultrafine particulates.

Future Work

Laser diagnostic techniques will be used to evaluate the effects of the air flow modifications

- Techniques will include PIV, LII, and OH-LIF
- Goal: Provide a better understanding of mechanisms behind particulate emissions and reductions
- Specifically, compare different air flow modifications to identify mechanisms increasing or reducing ultrafine particulates

[1] Smith, et al. (2004) WHO [2] Lim, et al. (2012) *Lancet* [3] Terzano, et al. (2010) *Eur Rev Med Pharmacol Sci*
[4] Courtesy of Potential Energy [5] Jetter, et al. (2012) *ES&T*

CONTACT: Kathleen Lask (kmlask@lbl.gov)
http://gadgillab.berkeley.edu/