A Study of the Effects of Crosswinds on Stoves

Dale Andreatta, Ph.D., P.E.

Mechanical Engineer

SEA, Ltd.

Adjunct Professor

The Ohio State University

(with some data provided by Christa Roth)

Natural Gas Flames to Simulate Wood Flames

- The big advantage is you can control and measure the fire power nearly perfectly.
- Gas is burned in a slow, non-premixed fashion that looks like a wood flame.
- Build a stove around the flame.
- Disadvantage is that no pile of coals is produced, so you don’t get much radiation.

Simulated Open Fire “Stove”

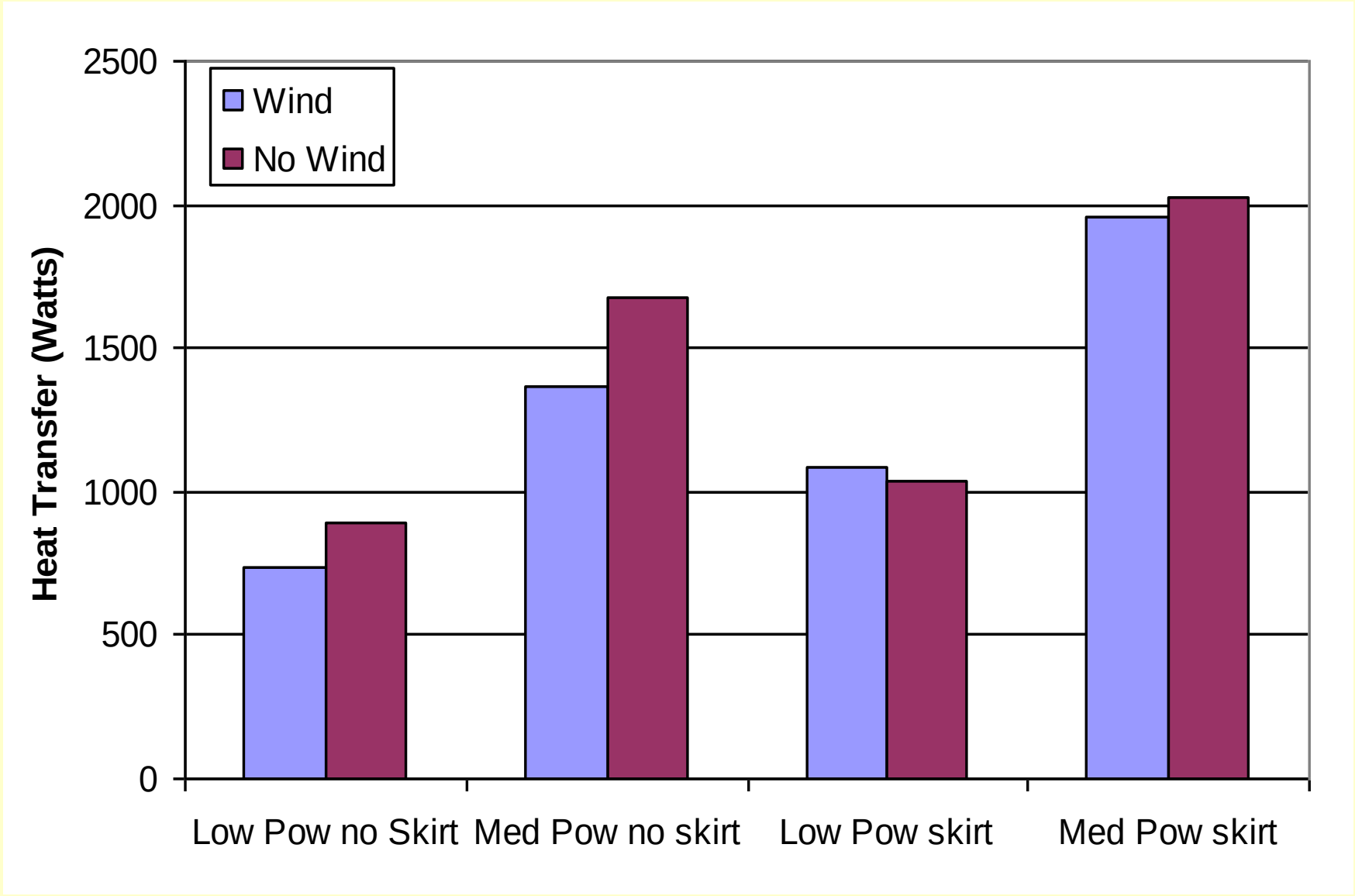
Simulated Generic Rocket Stove

Simulated Ceramic Rocket Stove (Stove-Tec)

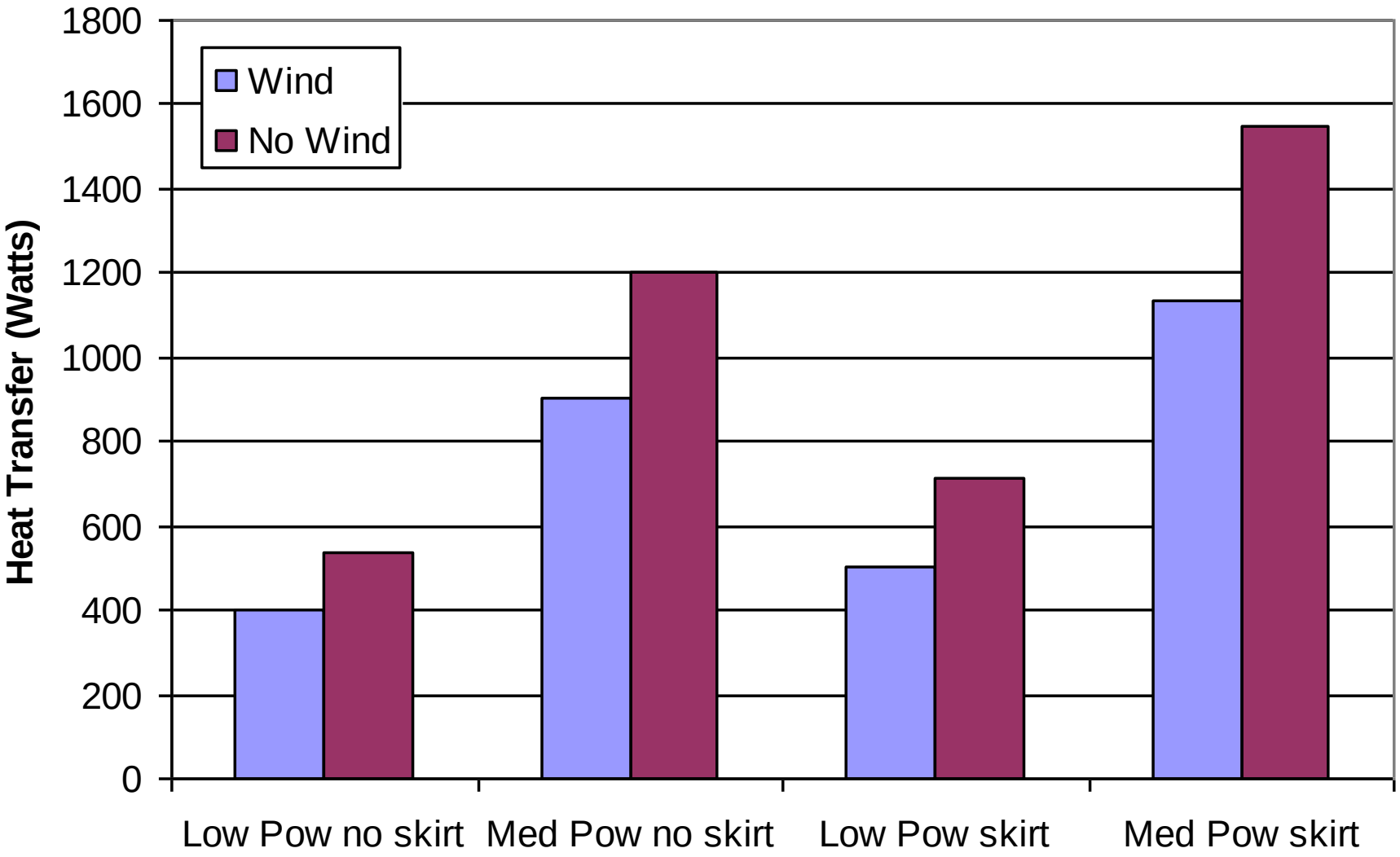
Test Details

- Fan provided cross wind of about 0.5 m/sec measured by anemometer.
- Each stove tested with and without skirt.
- Two or three power levels for each stove.

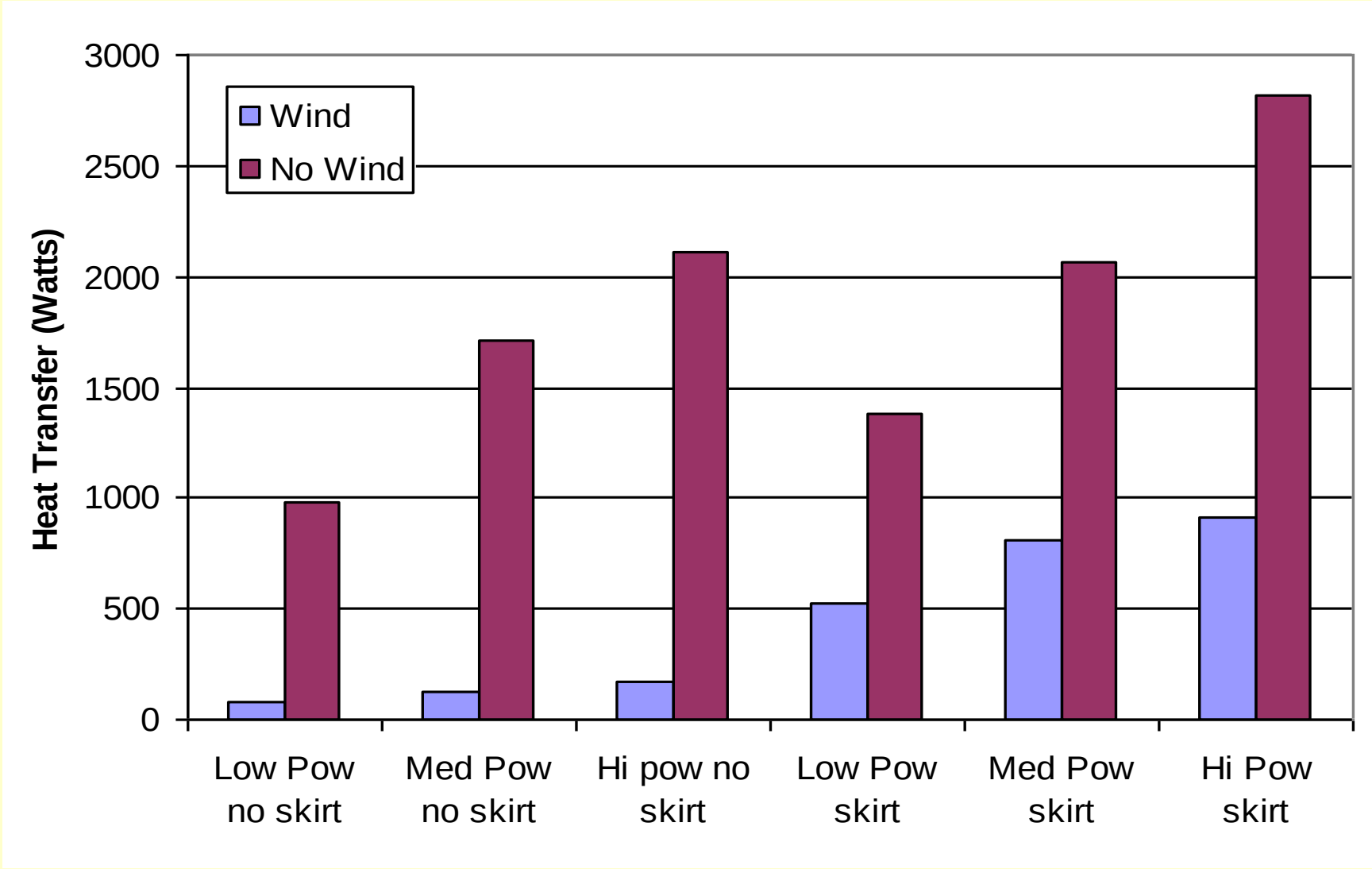
Results for Stove-Tec Stove



Results for Generic Rocket Stove



Results for Open Fire



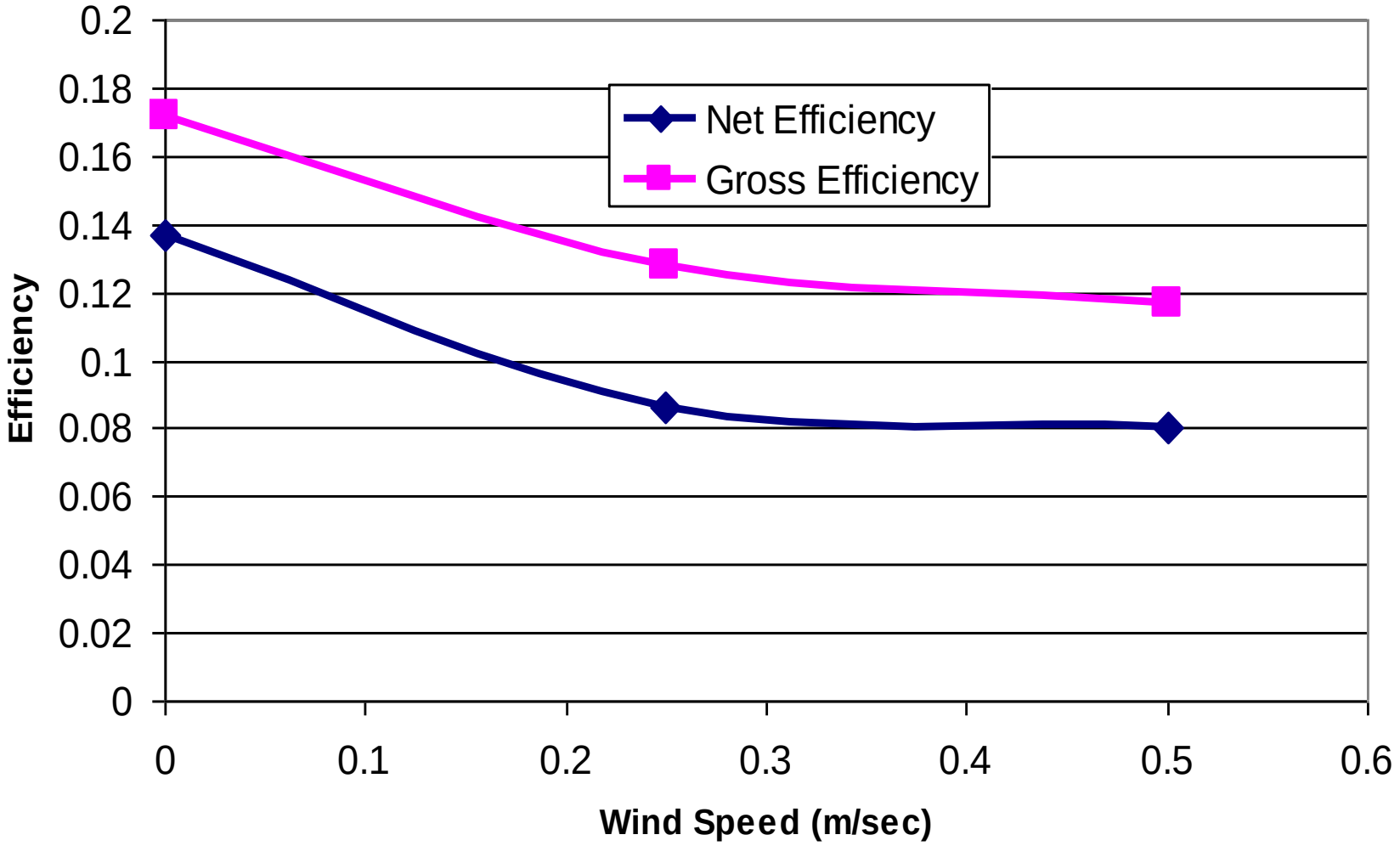
Preliminary test with infrared thermometer on coals

- 3-stone fire with real wood.
- Coal temperatures were 400-700°C, accounting for 160 to 700 W of heat transfer by radiation.
- Stones got hot too, but didn’t account for much heat transfer.

Actual Wood Tests of Open Fires in Crosswinds

- Similar situation with fan providing steady crosswind.
- Tests done with natural wood or cut lumber.
- Two different wind speeds, with speed estimated.
- Both speeds were low.

Results of Open Fire Tests with Wood



3 sets of tests done by Christa Roth on Madagascar

- 6 different stoves used for wood, 7 stoves for charcoal.
- Wood tests included water boiling tests and controlled cooking tests.
- Charcoal tests included controlled cooking, but not a lot of data, so only subjective results here.

Stove-Tec rocket

Charcoal Stove Tests by Christa Roth

- Controlled cooking tests with 7 stoves.
- Stove-Tec stove with and without skirt were 2 of the 7 stoves tested.
- Not a lot of information about the openness of the stoves.
- Results are mostly subjective.

Comments from Christa Roth

- The skirt really matters with the wind situation. The stoves that had the interface between the pot and the pot rests covered and protected from crosswinds came out well, the Pulumusa and the rocket stove with skirt. Without a skirt the rocket was worse than the traditional stove.

And further….

- The skirt does make a difference even in not windy conditions, but my observation is that the effect increases dramatically with wind.

Most open stove, a tripod

Open fire, mostly open

CNRIT, mostly enclosed

ALT stoves, original on left and Type 2 on right

Mud rocket (only riser is shown)

Interesting notes on the mud rocket

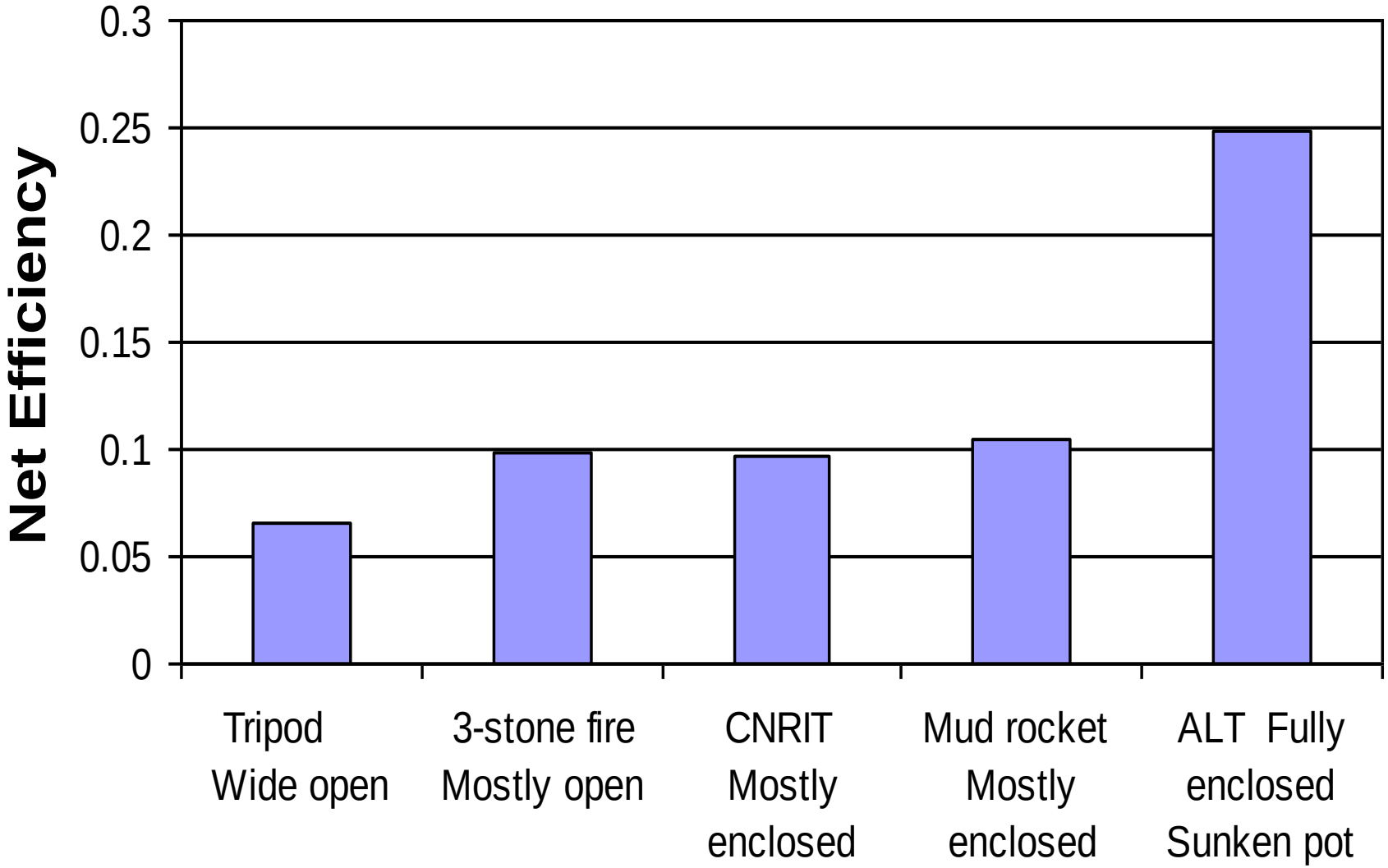
- Combustion chamber made of rock ring, with only the riser made of mud.
- “Mud” riser was made of “argile et bouse de vache”.
- “Bouse de vache?” Isn’t that……

Yes, it’s cow shit

- “Cow dung is a very common material to smoothen mud/clay/earthy substances in construction. Even the mud-houses get smeared with cow dung as part of the plaster, as it makes the mud stickier and adds coherence to the mud.”
- Quality of the mud wasn’t good, so stoves didn’t last long.
- Clearly, the cows aren’t getting the job done!

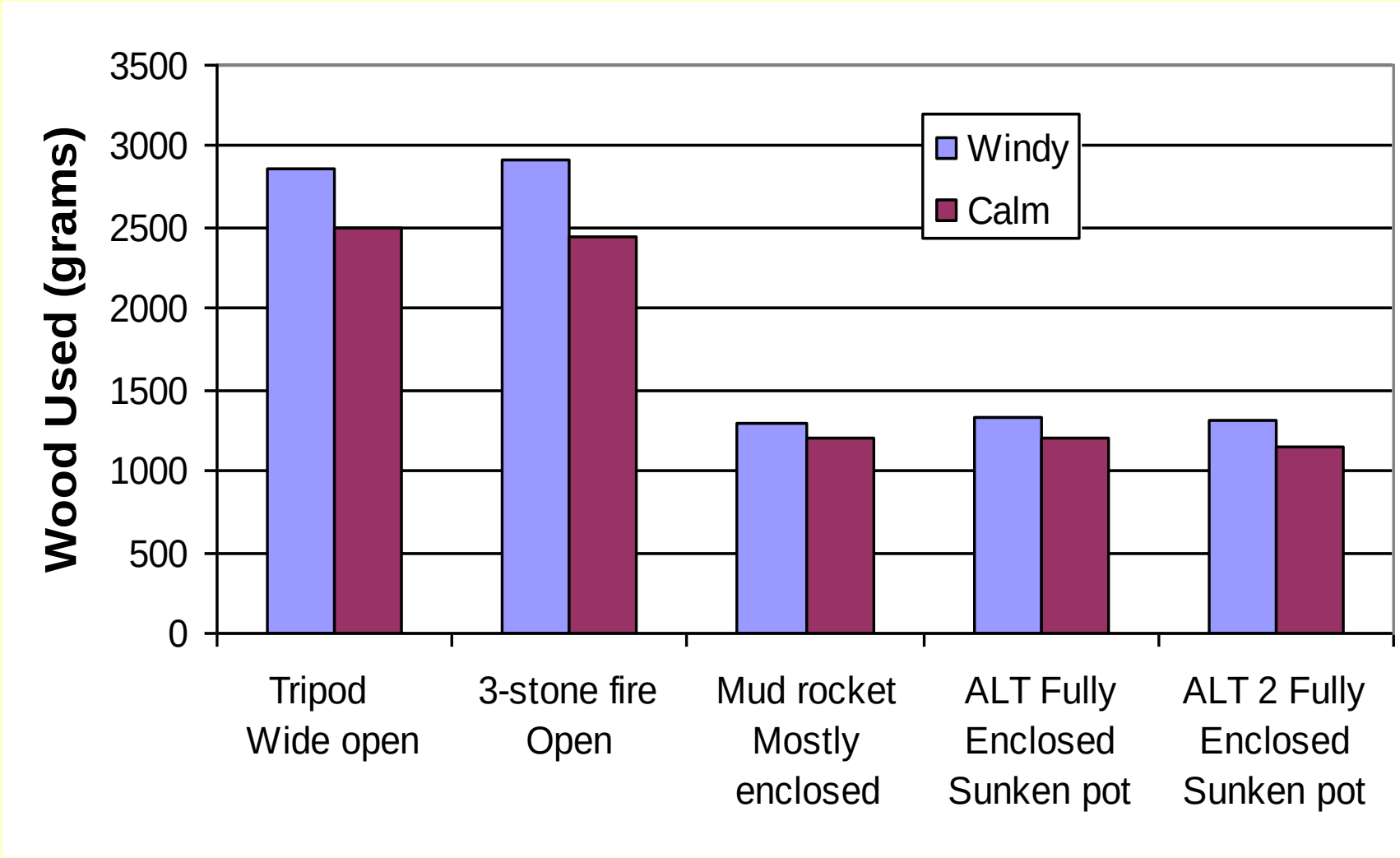
Water Boiling Tests by Christa Roth on Madagascar

- 5 wood stoves, range of openness.
- Stoves tested simultaneously in a very windy location.
- Not all stoves completed tests, so compare net efficiency.


Net Efficiency
0.3
0.25
0.2
0.15
0.1
0.05
0
Tripod
Wide open
3-stone fire
Mostly open
CNRIT
Mostly
enclosed
Mud rocket
Mostly
enclosed
ALT Fully
enclosed
Sunken pot

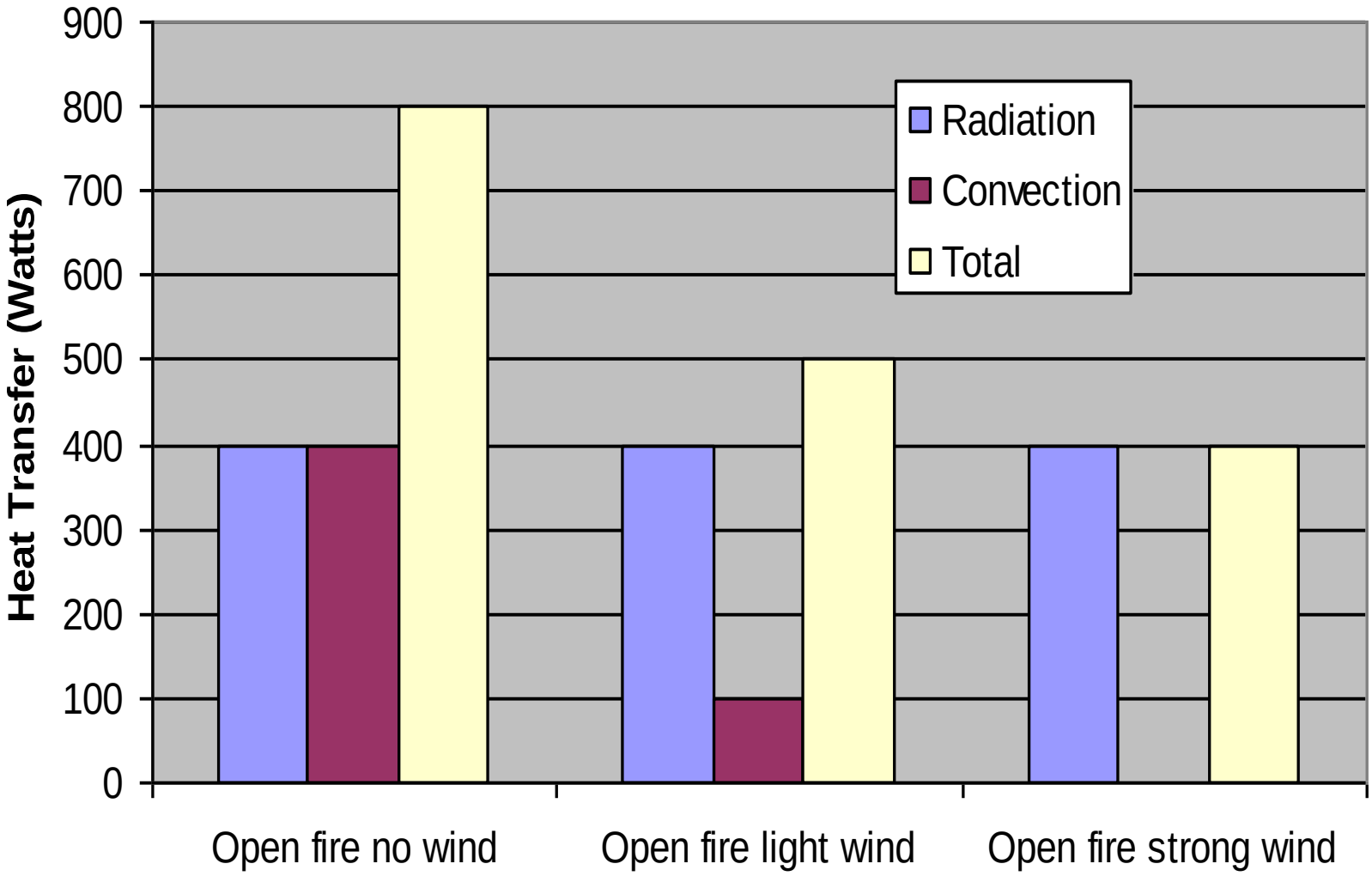
Controlled Cooking Tests by Christa Roth

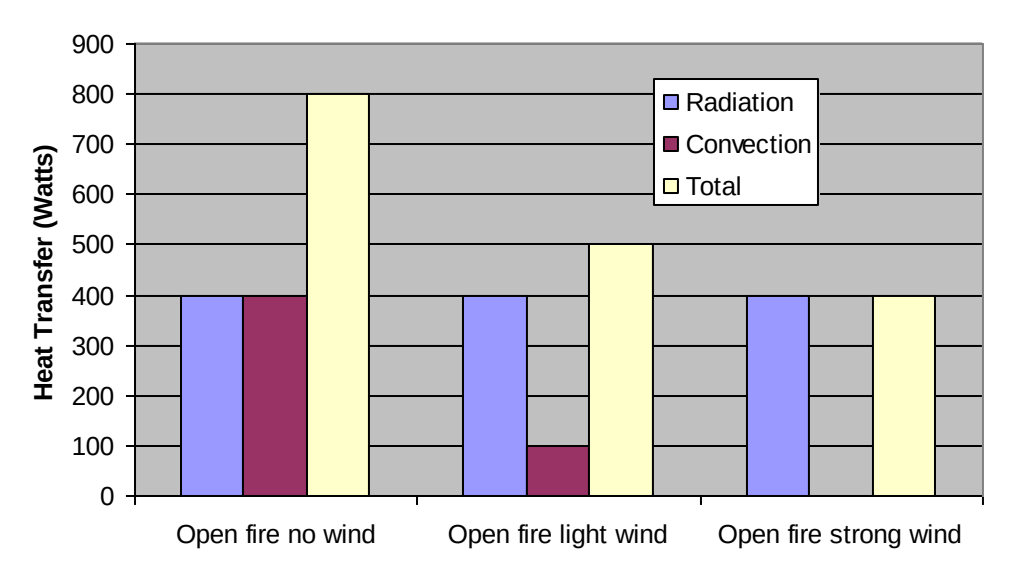
- 5 wood stoves, tested in windy and non-windy locations.
- Windy location was indoors, in a well ventilated kitchen, near the coast.
- Average wind speeds 1-2 m/sec in windy location, measured by anemometer.
- Calm location was in a less ventilated kitchen.

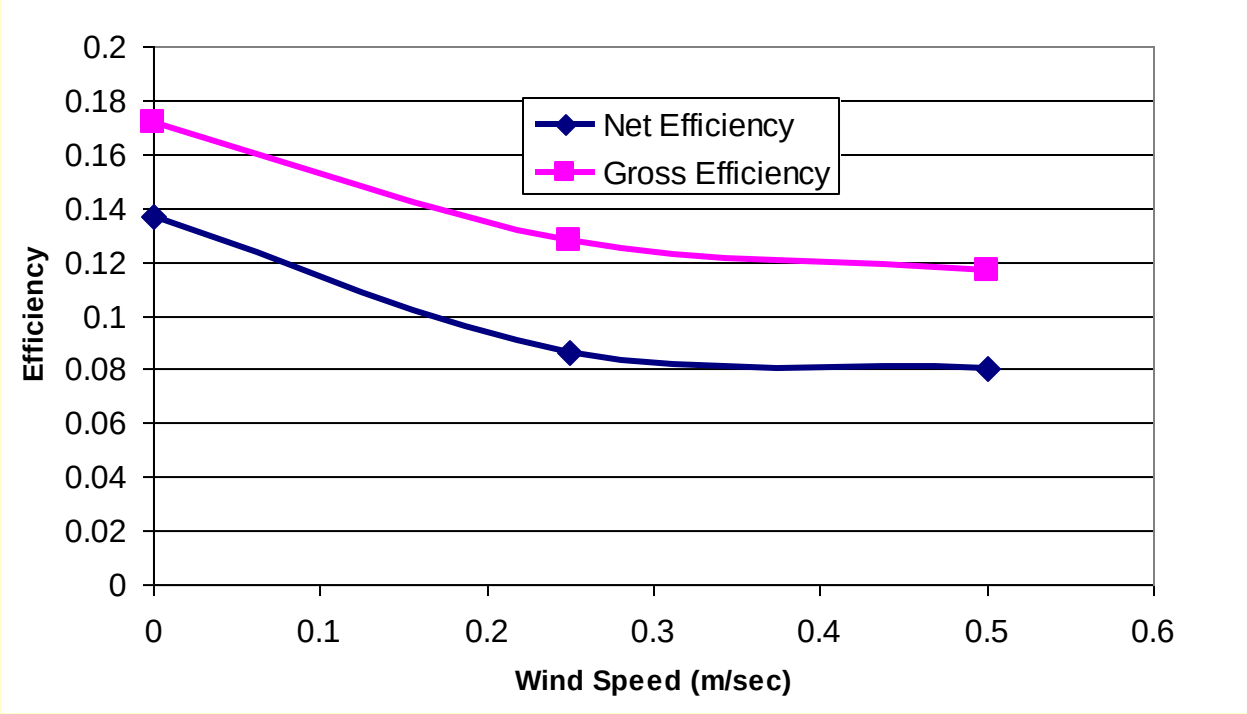

Wood Used (grams)
3500
3000
2500
2000
1500
1000
500
0
Windy
Calm
Tripod
Wide open
3-stone fire
Open
Mud rocket
Mostly
enclosed
ALT Fully
Enclosed
Sunken pot
ALT 2 Fully
Enclosed
Sunken pot

Hypothesis

- When the pot is close to the coals (tripod, 3-stone fire) you get a lot of heat transfer by radiation, much more than previously thought.
- If you have really low wind, then you get appreciable convection too, and good efficiency.
- But even a light wind blows away most of the convective heat transfer, so there is little difference between a strong wind and a light wind.

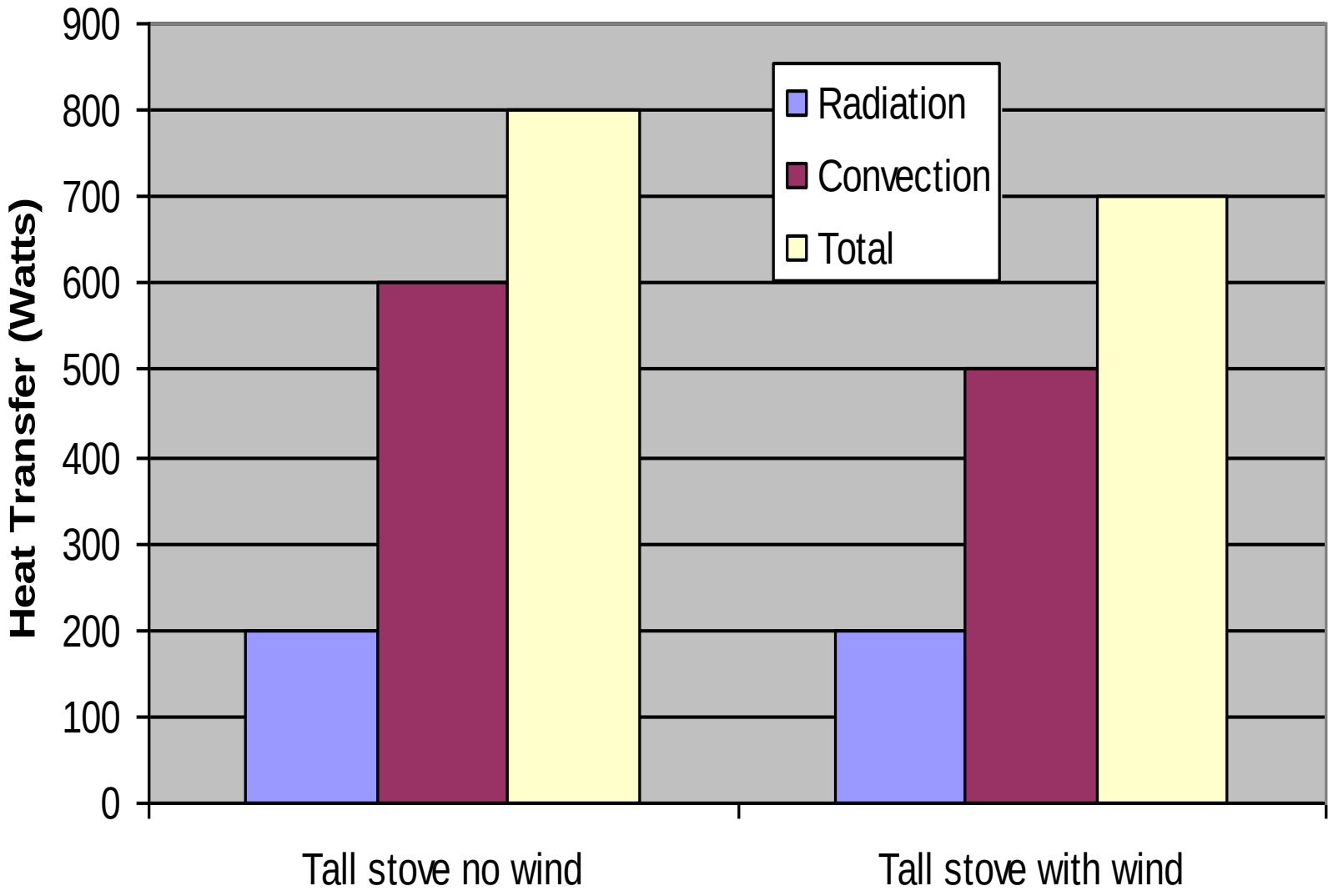

Heat Transfer (Watts)
900
800
700
600
500
400
300
200
100
0
Radiation
Convection
Total
Open fire no wind
Open fire light wind
Open fire strong wind


900
800
700
600
500
400
300
200
100
0
Heat Transfer (Watts)
Radiation
Convection
Total
Open fire no wind
Open fire light wind
Open fire strong wind


0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
Efficiency
Net Efficiency
Gross Efficiency
0
0.1
0.2
0.3
0.4
0.5
0.6
Wind Speed (m/sec)

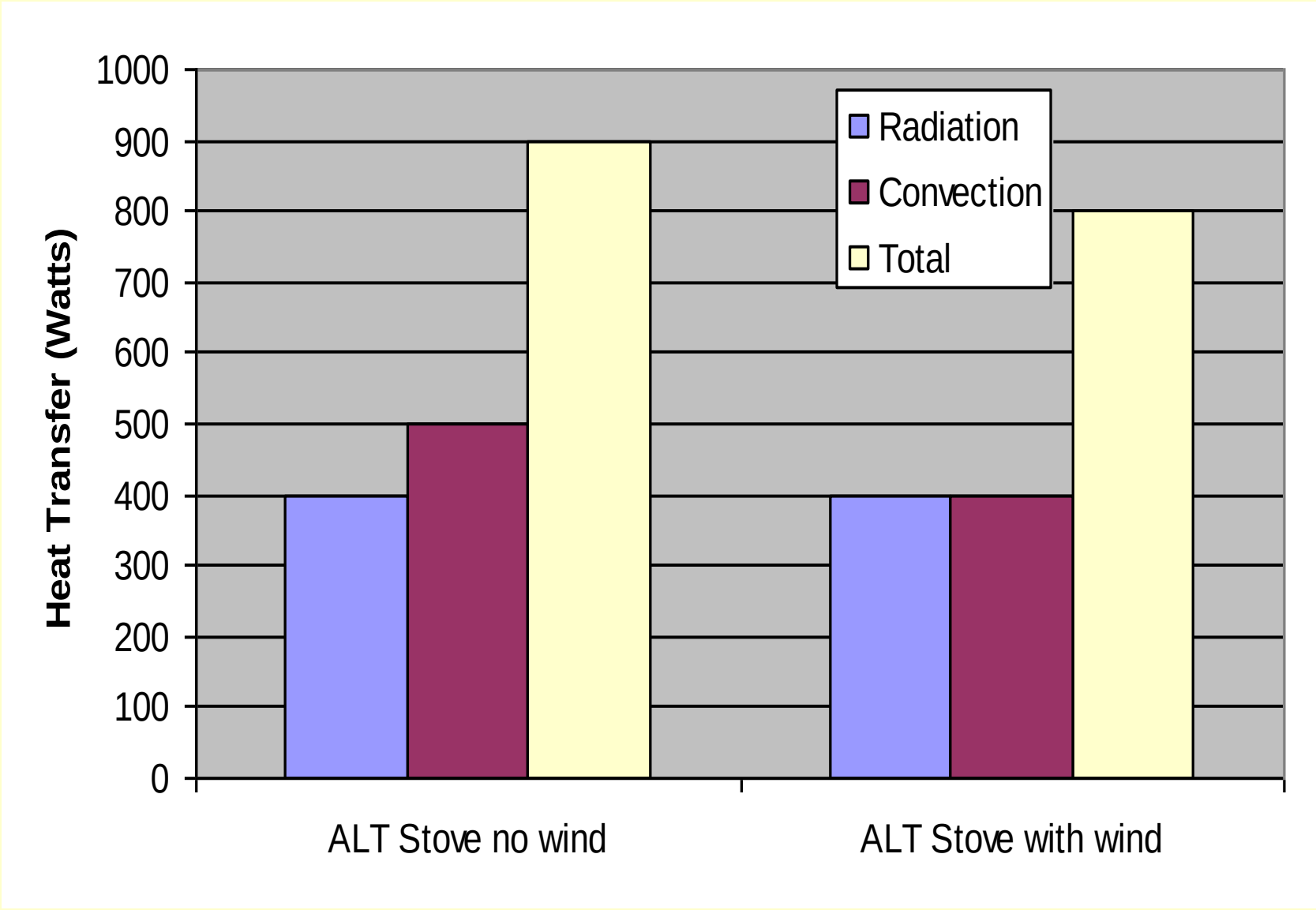
Hypothesis, cont.

- For a tall stove like a rocket, you get less radiation, but more convection.
- Flow path is enclosed, especially with a skirt, therefore you get good convection even in wind.
- Wind doesn’t make that big of a difference.


900
800
700
600
500
400
300
200
100
0
Heat Transfer (Watts)
Radiation
Convection
Total
Tall stove no wind
Tall stove with wind

Hypothesis, cont.

- Short enclosed stove, such as the ALT, has good radiation and convection, even in wind.
- Stove is little affected by wind and has high efficiency.


Heat Transfer (Watts)
1000
900
800
700
600
500
400
300
200
100
0
Radiation
Convection
Total
ALT Stove no wind
ALT Stove with wind

Conclusions

- Enclosed stoves, either short or tall, should do well in the wind.
- When the pot is close to the coals, with wood or charcoal, radiation is a very important mode of heat transfer.
- For an open stove, even a light wind blows away the convection. You still have the radiation, but you've lost the convection.

Question

- Is it possible that a simple wind screen around an open fire would do about as much good as a highly engineered stove?

Future Work

- 1a. Test this theory by building and testing a screened fire.
- 1b. Test several variations, under several conditions.
- 2. Do a study with direct measurement of radiation and convection.