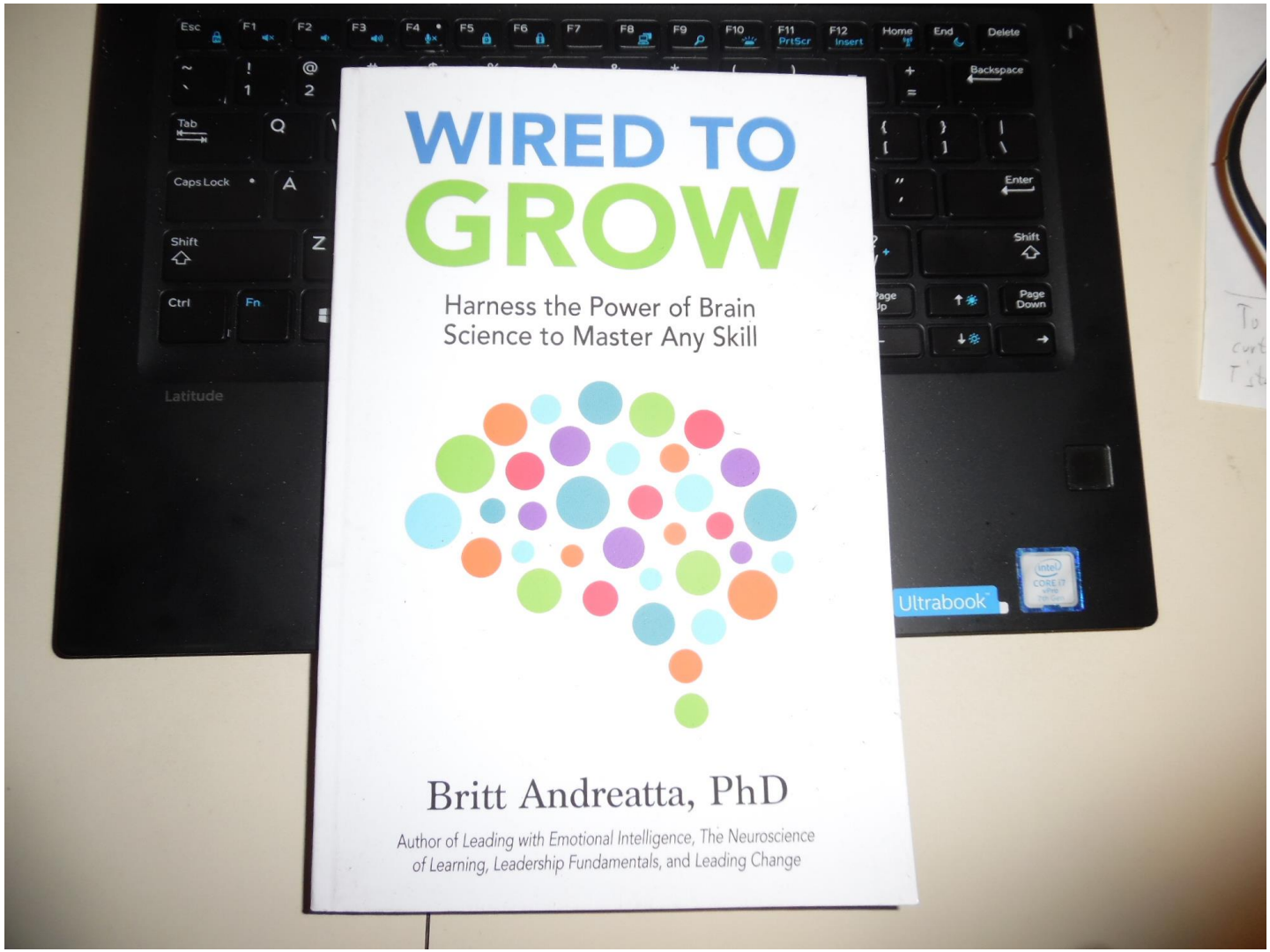
Stoves 101

Basic Stove Science for the
Non-scientist
(With Jokes)

Dale Andreatta,
Actual Scientist
(mechanical engineer, actually)

Britt Andreatta (no relation) says: Don’t max the hippo!



The Scientific Mindset

- The mindset of a scientist or engineer, as opposed to a normal person, is wrapped up in the question, “How much?”.
- Scientists/engineers are constantly asking this question, and then seeking to answer it.

Efficiency and Pollutants

- How do we measure these things so that we know how much?

Efficiency Measurement

- **Thermal Efficiency** is measured from the energy that goes into the pot, divided by the energy "contained" in the fuel that is burned.
- **Fuel use efficiency** is measured from the amount of fuel needed to do the job.
- **Cost Efficiency** is the cost to do the job.
- Increasing the fuel use or cost efficiency is the end we seek, increasing the thermal efficiency is a means to this end.

3 Types of Common Tests

- **Water Boiling Test (WBT)** is a lab test using water, and seeks to determine the stove performance in efficiency and pollution. Focus is on the stove. Variables are well controlled.
- **Controlled Cooking Test (CCT)** cooks some type of actual food, and measures the results. Focus is on the stove, and to some extent the user. Variables are less well controlled. There is also an Uncontrolled Cooking Test (UCT) which is similar but without measurements. It's still useful.
- **Kitchen Performance Test (KPT)** is done in an actual kitchen. Focus is on stove, user, and environment. Variables (such as ventilation) are not well controlled.

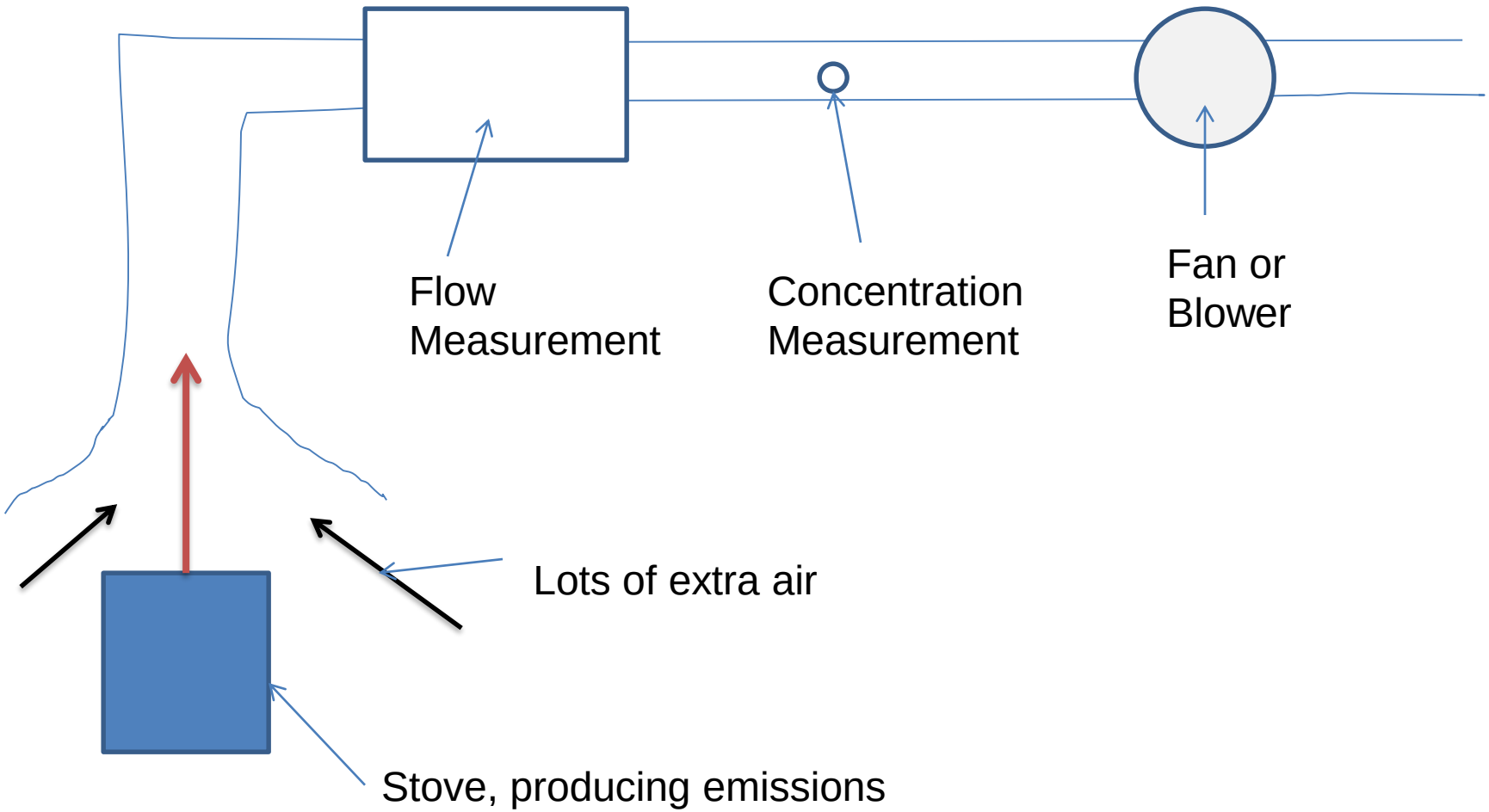
Pollutants-What are we measuring?

- Two pollutants of general interest, others of more specialized interest.
- Carbon monoxide **(CO)** measured in parts per million (ppm).
- Particulate matter **(PM)** also known as smoke, measured in milligrams per cubic meter.
- Sometimes **PM2.5**, particulate matter smaller or equal to 2.5 microns in size, small enough to get into your lungs and cause trouble.
- A stove may not be producing visible smoke, but may still be producing significant particles.

Particulates and Climate Change

- As a first cut, particles (smoke) come in 2 types, white and black.
- Both are harmful to health.
- Black particles produce significant climate warming.
- White particles produce significant climate cooling.
- Typically particles last about 7 days in the atmosphere before dropping out, but produce large effects during that time.

Standard Pollutant Measuring Method



Aprovecho Indoor Air Pollution Meter

Test shed

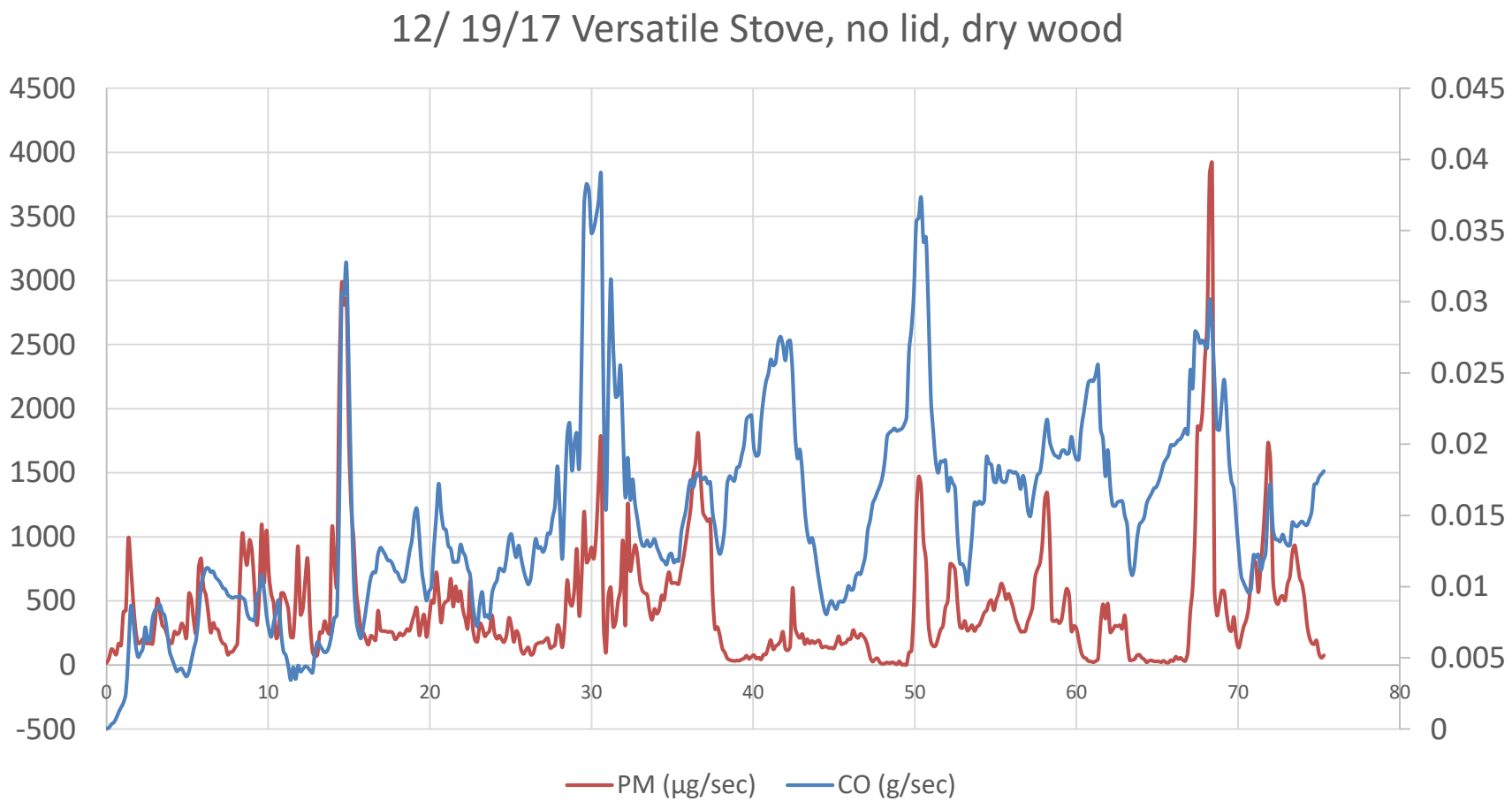
Burning Area

IAP meter goes inside box

Flow Grid-type flow meter with pressure measurement

Typical pollutant graph

(Pollutant production rate vs. Time



How to measure the pollutants

- Carbon monoxide, CO, is easy to measure with cheap instruments.
- Particulates are more difficult.
- You can measure approximately using light-based methods. Only approximate because different sizes of particles behave differently.
- Better methods are gravimetric methods, where you collect particles on a filter over a period of time, and weigh the filter before and after on a very accurate scale.

An example of light-based methods

How to measure pollutants, con'd

- Special techniques can allow only a range of sizes, such as less than 2.5 microns, to be studied with either method.
- Techniques are well worked out with Laboratory Emissions Measuring System (LEMS) and Portable Emissions Measuring System (PEMS).
- Other instruments measure the average color of the particles (black/white/gray).

Emissions vs. Exposure

- **Emissions** are what comes out of a stove, for example, 1.5 grams of particulates.
- **Exposure** is what people breathe, for example 100 parts per million **(ppm)** of carbon monoxide for 1 hour. Exposure is what relates to a person's health and there are guidelines for exposure.
- Exposure can be measured by instruments mounted on the wall, or attached to the subject in a backpack device.

Indoor Air Pollution (IAP)

- Exposure and **Indoor Air Pollution** are sort of the same thing, but…..
- If the cook goes in and out of the kitchen, maybe not the same thing.
- Reduced exposure is the end we seek, reducing emissions is a means to that end.

Ways to Reduce Exposure without Reducing Emissions

- Chimney to get the emissions out of the house.
- Good ventilation or cook outdoors.
- Having the cook leave the kitchen when possible.
- Don’t live in a city.
- High ceilings and/or short cooks

Exposure in the City (Nairobi)

Possible Newspaper Headline?

- PYGMY WOMEN SHOW GREATER RESISTANCE TO INDOOR AIR POLLUTION
- Scientists Baffled, Look for Genetic Clues

Stove Safety

- Can a stove be tipped easily?
- Does it have hot surfaces that can burn people, especially children?
- Does it have sharp edges that can cut or scratch?
- Do sparks fly out of the fire?
- Are people (and their clothing) directly exposed to flames.
- All these things can be measured and minimized.

Measuring Pot Stability

Final Note on Science

- We can use a lot of science to study stoves, and this is valuable but ……..
- Many factors that determine the success of a stove fall outside of what can be measured.

Appendix-Some additional notes on testing

Before testing take a step back and think about..

Which question do I want to have answered by the test? (stove peformance during development, performance potential with an experienced user, what can the stove do in a household energy system….)

What type of test do I need and in which level of detail?

Who is the recipient of the results (stove producer, user, donor, others…….)?

What is relevant for me, for the target group, for the donor?

What can I do myself (with a scale+thermometer) and where do I need expensive laboratory facilities (to test emissions)?

When should I test my stove? (in the prototype stage, after user feedback, …)

Who is going to do the test? (lab staff, experienced user, ..)

Where is the test going to be done? (CCT: lab, household,..)

CONTEXT MATTERS!!!

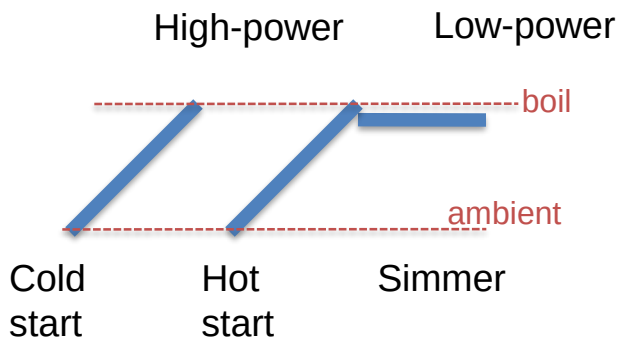
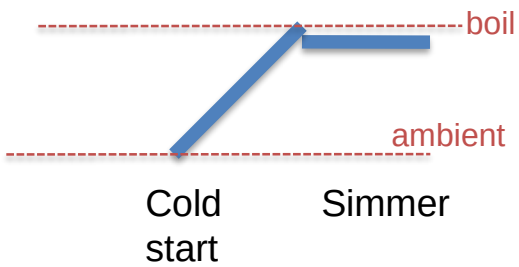
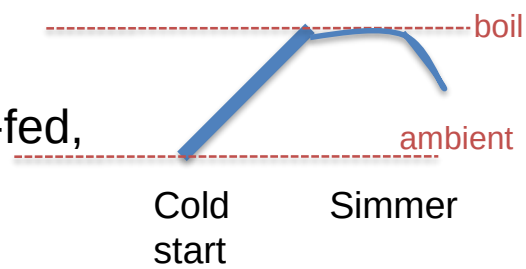
Remarks on the use of the WBT

1. The WBT was originally designed as an easy tool to design better continuously fed woodstoves by using simple devices like a scale, a thermometer and a timer.
2. The WBT was meant to determine **relative differences in the potential performance between two versions of a stove.** Thus it is important to follow the same procedure for each stove to be compared and keep all testing parameters constant.
3. Recently the testing procedures have been adapted for batch fed stoves like charcoal and rice husk stoves.
4. The WBT is useful to be applied in the phase of technology development to single out the impact of design changes between the versions of the stove model.
5. The performance parameters to be described were **fuel use, speed of cooking and turn-down (reduction of power for the simmering of the food)**.
6. The WBT was not meant to create absolute values of certain metrics in a laboratory upon which a single stove can be ‚evaluated‘ with worldwide validity.
7. The WBT has its limitations but it is a TOOL that is useful if applied appropriately. The ‚interpretation and evaluation of the resulting values is a different issue.
8. The WBT does not necessarily predict performance of a stove in the field. There are other tests that focus more on the users like the CCT (Controlled Cooking Test) and KPT (Kitchen Performance Test) j

Water boiling tests can also be used to…….

- Estimate effects of different variables such as wet wood vs. dry wood, or with wind vs. no wind.
- Compare stoves in terms of power, efficiency, pollutants and others, but the results are not universally applicable.
- Modified water boiling tests are also a possibility, for example, a test with limited tending of the stove.

Adaptations of tasks in WBT for batch feeding stoves

Type of WBT / stove	Power Phases / °C water	Procedure (main features)
Original WBT: for continuous feed **firewood** stoves		Task: bring 2 pots with 5 l cold water to boil 1x on cold stove, 1x on hot stove, Keep simmering for 45 min, Lid on pot: NO
Modified WBT: for batch-fed **charcoa**l stoves		Task: bring 1x appropriate size pot cold water to boil on cold stove, Keep simmering for 30 min, Lid on pot: YES
Modified WBT: for stoves used as batch-fed, non-refuelled e.g. **TLUD** gasifier stoves		Task: load to designed capacity or only with fuel assumed to be needed for the task, bring 1x appropriate size pot cold water to boil on cold stove, Keep simmering for 30 min or until fuel is consumed / burnt out Lid on pot: YES