# Compiled Comments for WBT Version 4.1.2

(Comment period ending December 18, 2009)

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**1. Aga Khan Planning and Building Service, Pakistan, Submitted on 12/01/2009**

**First Name: Nahida**
**Last Name: Khudadad**

Comments:
1.1 Aga Khan Planning and Building Service, Pakistan (AKPBSP)SP has used Water Boil Test on many of our stoves, with the technical and financial Assistance from Partnership for Clean Indoor Air (PCIA) of USEPA. The water boil test is good for cook stoves, but it does not considers heating requirements. e.g. AKPBSP has cooking cum space heating stove. If some protocols are added how efficient the stove is to heat the space while cooking for cold regions. And also, if there is water warming facility attached to it, i.e. while cooking and heating, the stove can warm water with attached system. How will we test the efficiency of the stove with a water warming facility.

This important issue has been added to Appendix 8 (Remaining Challenges).

**2. Appropriate Rural Technology Institute, Pune, Submitted on 12/18/2009**

**First Name: Karabi**
**Last Name: Dutta**

Comments:
There are four points I wish to mention based on the observations made while conducting many WBT's in the laboratory and field:

2.1. During High Power for Continuous fed stoves it is mentioned in the protocol "you will not weigh the charcoal at this stage"- from the innumerable WBT's conducted by me it has been noticed there is a quite a difference between the charcoal remaining after cold and hot start in stoves which have high mass (cement and mud stoves) which affects the calculations for stove performance. So it is suggested that charcoal should be weighed at the end of hot start too. A tester can do it quite fast with practice.

It can be difficult for testers to weigh charcoal safely and quickly so that the water stays close to boiling temperature for the Low Power (Simmering) phase. This important issue has been added to Appendix 8 (Remaining Challenges) and a sidebar has been added

2.2. In case of Batch fed stoves it is mentioned that during hot start "Weigh the loaded stove plus fuel and Record zero for the weight of charcoal". However in the case of some gasifiers e.g Sampada developed by Appropriate Rural Technology Institute (ARTI)the stove burns the wood with double purpose- as a wood gasifier stove which leaves behind a considerable amount of charcoal during burning activity (cooking) and this is collected for use in other cooking devices . In such cases the amount of charcoal remaining is considerable. In such stoves the weight of charcoal cannot be ignored after hot start.

Instructions to separate and weigh charcoal in cold start phase. This important issue has been added to Appendix 8 (Remaining Challenges).

2.3. The third comment is about calculating stove efficiency: To calculate the stove efficiency the average thermal efficiency during high power may be mentioned separately (average of cold and hot start)in the result. This is because many stoves have low turn down ratio so the simmer phase becomes very difficult to control thus resulting in faulty testing. So may be a stove's thermal efficiency may be mentioned as thermal efficiency during high power and low power separately.

This issue is described in the Interpreting Results section. The Results worksheet in the Excel workbook lists thermal efficiency separately for the three phases of the WBT.

2.4. A suggestion, in case of light weight metal portable stoves which do not retain heat, the hot phase of the high power phase could probably be skipped as there is hardly any difference in performance between cold and hot phase.

A comment about this issue has been added to the Overview section that describes the three phases of the WBT.

**3. Asia Regional Cookstove Program (ARECOP), Submitted on 12/09/2009**

**First Name: Zakky**
**Last Name: Riza**

Submitted by Nordica MacCarty directly from Zakky Riza, trained testing technician for ARECOP, Indonesia.

Comments:
3.1. We have already tested several stoves with difference performances. I found that some stoves record unusually higher “thermal efficiency” if it has longer Time To Boil thus more “Evaporated Water”. I think we should also display “Evaporated Water” so as to be able to consider this factor when the thermal efficiency data are presented.

The current Results worksheet is designed to be streamlined, so that people with less experience will be able to interpret the results easily. Evaporated Water is shown in the worksheets for Test 1, Test 2, and Test 3. Evaporated water is also described in the Interpreting Results section.

3.2. Net change in char is also good sign of combustion quality. Stove with too much charcoal usually produces a lot of smoke. I think it’s useful to display Net change in char on ‘Results’ sheet.

Where noted? Maybe we should make a Useful Diagnostics

This important issue has been added to the Additional diagnostic measures in Appendix 8 (Remaining Challenges), to be reviewed in consultation with field testers.

3.3. For multipot hole stove, final temperature of 2nd or 3rd pot is also a good measurement of stove performance.

The multipot stove is discussed in Appendix 2 (Modifications to the WBT). This important issue has been added to the Additional diagnostic measures in Appendix 8 (Remaining Challenges), to be reviewed in consultation with field testers.

3.4. Talk about doing WBT, I find it useful to prepare wood and water for hotstart before testing (at the same time preparing for the cold start). Doing this make transition between cold start to hot start easier and faster. You don't need to be in hurry then. Usually we need 5 to 10 minutes to start the hot start phase.

Language has been added to the "Preparation for each Water Boiling Test" section to include this suggestion in situations when enough pots are available.

3.5. Maybe we have to record temperature progress. Because it shows how the test goes. If the temperature goes up and down, it's a sign that the test isn't well conducted. In addition, I find that water above 80°C evaporate. So, if water temperature is above 80° C for longer duration, it may result in more 'Evaporated Water' thus higher efficiency.

Instructions have been added to log temperature when equipment is available to do so.

**4. Berkeley Air Monitoring Group, Submitted on 12/19/2009**

**First Name: David**
**Last Name: Pennise**

Comments:
4.1. We fully support this effort to update the WBT protocol. Given that the test is designed to provide a standardized, lab-based efficacy measure to compare stoves under equivalent conditions all around the world, it is necessary to have one internationally accepted protocol. Additionally, as the cooking stoves field continues to grow and become more formalized, there is also a clear need for one internationally accepted lab test cycle to be the basis for future stove performance and emissions guidelines/standards.

Thank you for this comment and support.

4.2. The ability to discern statistical differences in the performance of different stoves in the WBT depends largely on the variability of the tests (e.g. standard deviation or coefficient of variation), which is influenced by the number of tests performed. While the protocol requires three tests of each stove, it would be valuable to include some basic sample size calculation information, so that testers can investigate the potential benefits of increasing the number of tests.

This would be a valuable addition to the WBT and suggestions for specific language or tables are welcome from any Alliance partners.

4.3. The protocol would benefit from a separate section on the importance of instrumentation calibration and calibration recommendations, including calibration standards, calibration intervals, etc. We

particularly noted a lack of direction on calibrating the scales for weighing. As more and more tests are performed over time, the ability to compare such tests depends on the standardization of methods and on accurate calibration of the instrumentation.

A discussion of calibration has been added to the "Preparing the Laboratory" section.

4.4. Does the Multi-Pot Stoves Appendix (2.2) include functionality that is not the heating of an additional pot, such as providing heat to an integrated water tank or jacket?

This important issue has been added to Appendix 8 (Remaining Challenges).

4.5. The following comment is not about the WBT protocol per se, but relates to standardization of the reporting of WBT results. If WBT results are to be reported as "final", used for marketing claims, or used for "certification/benchmarking", such results should be based on tests of the final or production version of the stove, not on tests of any prototype, specially modified, or otherwise atypical version of the stove. Ideally, the protocol would give some direction on randomly selecting a test stove from the production line for benchmark testing.

Appendix 9 has been added to discuss recent developments with interim international standards, including the impact on selecting stoves for testing.

**5. China Association of Rural Energy Industry (CAREI), Submitted on 11/28/2009**

**First Name: Xiaofu**
**Last Name: Chen**

Comments:
The main differences between The Water Boiling Test (Version 4.1.2) and the Thermal Performance Test Method for Household Firewood Stoves of China Standard (NY/T8-2006) are as follows, for your reference. Thanks.
5.1. The lid of the pot is sealed after the fuel is ignited. This has the effect of saving time and fuel during since no water is evaporated.
5.2. The lid is opened only after the water temperature has reached the boiling point.
5.3. The test is finished after the water temperature reaches two degrees below boiling point.
5.4. The remains of the unburned fuel do not need to be weighed because the thermal value of the unburned fuel is very low (the unburned wood is not really charcoal). In fact, if the operation is good, when the temperature reaches 2 degrees below boiling point, the fuel in the stove should be nearly burned out.

Thank you for these comments about the Thermal Performance Test Method for Household Firewood Stoves of China Standard (NY/T8-2006) and the results that you have observed.

5.5. We suggest that the WBT should be simple so that the users can understand and operate.

This version of the WBT has modifications intended to make the document easier to understand. The Global Alliance for Clean Cookstoves is seeking feedback on issues that remain unclear, and is seeking volunteers to help translate the WBT into additional languages. Please send suggestions for sections to simplify through the online **Community of Practice**.

**6. Chip Energy, and Biomass Energy Foundation**, **Submitted on 10/29/2009**

**First Name: Paul**
**Last Name: Anderson**

Comments:
6.1. On page 18, in the list of liquid fuels, you should also list "Alcohol" and its energy value.
Not just should. But must. There several alcohols stoves, and more can be expected.

This table of fuels has been updated with the calorific value for ethanol.

6.2. I have only seen "full testing" done at Stove Camp, but I have NOT seen the testing including the hot start. I think that many test results do not have the hot start data include (not even conducted). Therefore, I agree with Crispin's comment (in the last section about issues still to be addressed) that the sequence should be cold start -- simmer -- hot start (with the hot start perhaps being listed as "optional". Previous testing should be labeled as "included hot start" or "did not include hot start".

About that, one week of testing at Aprovecho should sufficiently clarify 1) if the sequence change really does make a difference, and 2) for which types of stoves, and 3) was actually including the hot start data in XX% of the testing already conducted.

We have "adjustment" that allow comparisons for when the tests are altered (such as with only 30 minutes of simmer, or for using 2.5 liters of water in the 3.5 liter pot). Equally reasonable "adjustments" should be possible for moving the hot start to the end, and possibly not even including the hot start in all of the tests (i.e., optional to conduct).

For those of us with low mass stoves (such as metal TLUDs), every start is essentially a cold start. And because my stoves (and some others) are primarily "air controlled" (with the fuel sitting still), they are disrupted with every time that fuels need to be weighed (which is much less of a problem for the primarily "fuel controlled," pushing sticks in and out).

Congratulations on nearly finishing some apparently excellent work!!!

A comment about this issue has been added to the Overview section that describes the three phases of the WBT. This important issue remains in Appendix 8 (Remaining Challenges) and additional studies and data will provide clarity and evidence.

**7. Developmental Association for Renewable Energies (DARE), Submitted on 11/10/2009**

**First Name: Habiba**
**Last Name: Ali**

Comments:
7.1. I think the new version is okay and would be easy to use even outside of a laboratory condition. Good work Partners

Thank you for your comment and support.

**8. Dian Desa Foundation – Indonesia, Submitted on 12/08/2009**

**First Name: m zakky**
**Last Name: faisal riza**

Comments:

8.1. Other than 'Equivalent Drywood Consumed' on all three phases and 'Water remaining at end - All Pots' on Simmer Test Phase, I find no changes on calculation.

Thank you for your comment.

8.2. However, on 'Specific Energy Consumption' for Cold Start and Hot Start, I think there's a mistype there. For example on 'Specific Energy Consumption' for Cold Start, the formula is '**=(W34/1000)*E18**' where W34 is 'Temp-corr sp consumption' and E18 is 'Fuel moisture content (wet basis)'. I think it should be written as '**=(W34/1000)*E20**'. So is on the hot start. And on 'Specific Energy Consumption' for Simmer Test, The formula is =**(AP33/1000)*E18,** where AP33 is Firepower and E18 is 'Fuel moisture content (wet basis)'. I think it should be written as '**=(AP32/1000)*E20**'.

This has been corrected.

8.3. We have already tested several stoves with difference performances. I found that some stoves record unusually higher "thermal efficiency" if it has longer Time To Boil thus more "Evaporated Water". I think we should also display "Evaporated Water" so as to be able to consider this factor when the thermal efficiency data are presented.

The current Results worksheet is designed to be streamlined, so that people with less experience will be able to interpret the results easily. Evaporated Water is shown in the worksheets for Test 1, Test 2, and Test 3. Evaporated water is also described in the Interpreting Results section.

8.4. Net change in char is also good sign of combustion quality. Stove with too much charcoal usually produces a lot of smoke. I think it's useful to display Net change in char on 'Results' sheet.

The current Results worksheet is designed to be streamlined, so that people with less experience will be able to interpret the results easily. Evaporated Water is shown in the worksheets for Test 1, Test 2, and Test 3. Evaporated water is also described in the Interpreting Results section.

8.5. For multipot hole stove, final temperature of 2$^{nd}$ or 3$^{rd}$ pot is also a good measurement of stove performance.

The multipot stove is discussed in Appendix 2 (Modifications to the WBT). This important issue has been added to the Additional diagnostic measures in Appendix 8 (Remaining Challenges), to be reviewed in consultation with field testers.

8.6. Talk about doing WBT, I find it useful to prepare wood and water for hotstart before testing (at the same time preparing for the cold start). Doing this make transition between cold start to hot start easier and faster. You don't need to be in hurry then. Usually we need 5 to 10 minutes to start the hot start phase.

Language has been added to the "Preparation for each Water Boiling Test" section to include this suggestion in situations when enough pots are available.

8.7. Maybe we have to record temperature progress. Because it shows how the test goes. If the temperature goes up and down, it's a sign that the test isn't well conducted. In addition, I find that water above 80°C evaporate. So, if water temperature is above 80° C for longer duration, it may result in more 'Evaporated Water' thus higher efficiency.

Instructions have been added to log temperature when equipment is available to do so.

**9. Eco Ltd, Submitted on 12/18/2009**

**First Name: Grant**
**Last Name: Ballard-Tremeer**

Comments:
The following comments are not intended as a comprehensive analysis of the proposed WBT, but highlights a few issues which I believe are of importance:

9.1. This version is a great improvement on earlier versions. Well done to Tami and the team.

Thank you for your comment and support.

9.2. The purpose of the WBT is to assess stove performance. Unless that performance relates to field performance in a predictable way then it does no assess performance reliably. Thus, to know if this methodology is valid, it should be validated by independent tests in a number of countries to answer whether it predicts field performance reliably. It is not sufficient to agree a WBT based on use of the WBT in the lab, theoretical analysis or where the primary data is not collected from independent sources.

The “Introduction and Background” section describes the scope of the WBT and that it should be used in combination with other available field tests.

9.3. Version 4 of the WBT is a big step forward, although not without certain risks... the main one, in my opinion, is that it further legitimizes a potentially false perception that the best stoves can be identified through an unvalidated lab test. We already see that Shell, PCIA and ESMAP are basing their funding decisions on these lab tests putting even more weight behind a questionable premise.

The “Introduction and Background” section describes the scope of the WBT and that it should be used in combination with other available field tests.

9.4. The introduction on the 'benefits and limitations of the WBT' in version 4 is really good at explaining these limitations, but I fear that most people including the funders won't take that into account. Page 15 is also good: "If laboratory tests are very different from real operation, then comparisons done in the laboratory may lead to incorrect conclusions about stoves in real operation." - however it implicitly assumed that the current WBT does match real operation - I have not yet seen independent test evidence of this. The same for the quote from VITA: "The standard should represent a compromise between the widest possible range of applications, and the closest possible fit with actual cooking practices." - however I haven't seen analysis of this compromise to date... it is more important to predict field performance than to allow international comparisons to be made, in my opinion. We can make compromises, but they should be based on experimental data.

This is an important issue and we will continue to support studies to gather data to compare the performance of stoves in laboratory testing with performance during actual cooking practices.

9.5. WBTv4 is a vast improvement - no longer for example stipulating the size and shape of wood to be used, and containing some great statements like: "The cooking system includes a stove, a fuel, a pot, and an operator. All four affect the performance of the system. You should use the same fuel and pot for each test if you wish to compare design changes. However, you should never use a fuel or pot for which a stove was not designed."

Thank you for your comment and support.

9.6. Point 4 on page 5: why is there a preference for the 7 litre pot? Why do we assume that most people boil 5 litres of water. In all my work I have never seen any rural family boiling 5 litres of water.

Language has been added to the “Preparing for Testing” section to provide more detail about selecting an appropriate pot size for the test, including to address the concerns raised in this comment.

9.7. Page 8: "While an excellent stove will perform well in all metrics," - it is unclear what 'well' is when it comes to firepower, burn rate, or time to boil.

The language was changed to provide a clearer explanation that each performance metric distinct information.

9.8. Sound experimental and statistical design says that repeated tests should be fully randomized. Thus repeating three identical tests one after another risks measuring changes in non-controlled variables. One example is that a tester gets better and better at lighting fires! If you are making design improvements and trying to identify changes, then a sound design would mean that repeated tests are made with and without the improvements in a fully randomized way. Otherwise you might just be measuring your own improvement in lighting the same stove...

The “Preparing for Testing” section describes how the tester should be familiar with using the stove prior to beginning the testing.

9.9 If variables aren't controlled they should be randomized. Thus wood should be selected from the pile in a randomized way or the pile fully mixed before each test, or the moisture content of each piece should be measured. If not, for example, the bottom of the pile may be damper than the top.

This would be a valuable addition to the WBT and suggestions for specific language or tables are welcome from any Alliance partners.

9.10. Page 10, step 4: "Note: There should NOT be a lid on the pot while conducting the WBT."

If you optimize a stove without pot lids, but most people use them in practice (and actually to save energy we should be encouraging people to use them) then the lab test favours stoves that may not perform well at low power (without pot lids, we never really test low power performance). The proposed WBT states: "While a lid helps to retain heat in the pot, and is often used for any actual cooking task, it does not affect the transfer of heat from the stove to the pot. Lids complicate the WBT by increasing the variability of the outcome and making it harder to compare results from different tests." While it may not affect the transfer of heat, it does affect the required firepower, which is a major determinant of stove performance.

Well if power level "does not affect the transfer of heat from the stove to the pot" then why do we test boiling and simmering? Shouldn't performance just be a constant? A pot lid does effect the stove performance because it is possible to carry out a cooking task at a much lower power with a lid. If the stove cannot operate at a sufficiently low power it will waste heat, and thus be less efficient.

It seems to me that the cart is pulling the horse. Rather than adjusting practice to suit the tests, we should adapt tests to suit practice.

One question to ask is 'where does the variability come from?' Is it that our measure of performance varies widely at low power, or is it that the stove performance varies widely at low power. If there former (which I think it is), then we should change our measure of performance. I think the variation comes from three things: differences in the 'goodness of fit' of the lid, our inability to judge 'simmering' consistently

when there is a pot lid, and the use of mass of water evaporated as the unit of energy during simmering. There are ways to address this I think, but it would need some experimental work.

This important issue has been added to Appendix 8 (Remaining Challenges).

9.11. It is great to see some statistical analysis introduced!

Thank you for your comment and support.

9.12. In the emissions testing section, in my opinion, the "Room method: Measure room concentration indoors and the air exchange rate in a room, then calculate the emission rate." should be removed. My PhD analysis showed that, even given the condition that there is perfect mixing, it also assumed constant emissions. If emission rates are not constant (they never are), then there is a significant bias depending on the emission profile. It is thus not fit for use.

These and other limitations of the room method, and other methods, have been updated in Appendix 6.

9.13. A simple method to ensure that hood extraction flow rate does not affect performance should be added. I think the "Must not affect flow through stove " caution on page 43 does not do justice to the importance of this factor.

As this is an important issue, the Global Alliance for Clean Cookstoves is seeking suggestions on methods to ensure that hood extraction flow rate does not affect air flow through stove, including guidance on minimal height requirements from the stove to the hood and limits for air velocity.

9.14. I think the outstanding issues in appendix 8 should be resolved according to the criteria: how do they contribute to ensuring the WBT reflects field performance better?

Language has been added to Appendix 8 to address how to resolve remaining challenges, including considering reflecting field performance, repeatability, and practicality.

Regards
Grant

**10. Energía Desarrollo y Vida (ENDEV)/GTZ Perú, Submitted on 12/18/2009**

**First Name: Miguel**
**Last Name: Tinajeros Salcedo**

Comments:
Dear PCIA Coordination Team,

Our comments regarding Boling Water Test Version 4 are:

10.1. You must design and build a team of indoor air pollution, low cost, real-time measurement, which is comparable with the gravimetric method and has a repeatability factor in laboratory and field less than 4% and 10% respectively.

10.2. Establish ranges that ensure the validity of the evaluation and its repetition, variables that cannot be controlled, such as wind speed, humidity, atmospheric pressure and air temperature, which generate errors due to fluctuations measurement.

10.3. Ensure that instruments measuring the variables that influence the evaluation, with a measurement range and accuracy to ensure the degree of repeated above.

Thank you for these three suggestions. Because they are related to equipment availability and development, no modifications of the WBT have been made.

10.4. What was the approach of using the thermocouple with an accuracy of 0.1 ° C?

The equipment list has been modified to include a digital thermometer accurate to 0.5°C. Data should be reported to a resolution of 0.1°C.

10.5. Review on page 24 the formula EHV (effective calorific value of the fuel)

10.6. Review on page 25 of ACfuel variable formula mchar, cold, produced (net change in char during the test)?

10.7. Review on Page 26 the variable mH2O, vap, cold (mass of water vaporized)?

Appendix 2 and 4 are currently being updated and will be released when finished.

10.8. It should look within the set of equipment necessary to ensure the safety and health evaluator breathing mask and eye protection.

A new section on laboratory safety has been added to the “Preparing for Testing” section.

10.9. In Peru people using improved stoves using firewood measures: 4 x 3 x 50 cm

Additional comments about fuel size have been made in the “Testing a New Stove” section.

Sincerely

Miguel Tinajeros
Proyecto Energia Desarrollo y Vida
Endev/GTZ

**11. Energy Institute, Cape Peninsula University, Submitted on 12/14/2009**

**First Name: Philip**
**Last Name: Lloyd**

Comments:
11.1. I have started my comments on the attached. I had gotten barely 20% of the way through WBT 4.1.2, and then gave up. I think you always have to think for whom you are writing. WBT 4.1.2 is not written for a non-English speaker in a remote area trying to carry out the tests you suggest - it is written with a Caltech undergrad in mind. I would do the job of translating it into usable English for you, but I think you would lose a valuable experience. Forgive me for telling you this, but I cannot think why no-one has told you earlier.
Kind regards

This version of the WBT has modifications intended to make the document easier to understand. The Global Alliance for Clean Cookstoves is seeking feedback on issues that remain unclear, and is seeking volunteers to help translate the WBT into additional languages. Please send suggestions for sections to simplify through the online **Community of Practice**.

The page nos. are the numbers from the front of the document, NOT the numbers on the pages!

11.2. p4 There need to be references to or hyperlinks to the Cooking Test and the Kitchen Performance Test

References and hyperlinks have been added.

11.3. p6 "1/10 of a degree" what kind of degree? C or F?

This suggested change has been made.

11.4. p6 "scale for weighing" what sort of scale? Accuracy?

This suggested change has been made.

11.5. p6 "Tape measure for measuring" Units? cm? Inches?
This suggested change has been made.

11.6. p6 "version number (4.1.2)." And when this is not the latest?
I am not certain who you are writing for. This needs to be debugged in actual trials, because I have a feeling you are writing for a relatively skilled investigator on the US West Coast. You may be intending it for a non-English-speaker in Burkina-Faso; you have failed!

The WBT will be revised as needed and the version numbers will continue to be updated. The "Obtain the calculation spreadsheet" section has been updated.

11.7. p7 "and must be avoided" I think you mean "and must be avoided as far as possible"
Modifications to this phrase have been made.

11.8. p7 "enough bundles of fuel" What constitutes a 'bundle'. I think you need a better definition
Modifications to this section have been made.

11.9. p8 "Determine moisture content of the fuel to be used during testing." I am concerned that this is illogical – the tester needs to do this FIRST.
This text appears in the section called "Daily Preparation" with instructions for steps that need to be done prior to testing, which includes a suggestion that these preparations may be done the day ahead.
Modifications to this section have been made to reduce the ambiguity of this phrase.

11.10. p9 "The tester should never perform a task that is unsafe." Agreed, but how is he/she to know?

A new section on laboratory safety has been added to the "Preparing for Testing" section.

11.11. p9 "This test was originally designed for stoves that burn wood, but has been adapted to accommodate other types of stoves and fuels". But you constantly refer to a bundle. Have you really thought this through?
Modifications to this section have been made.

11.12. p9 "important for stoves with high thermal mass" Do your testers understand what 'thermal mass" is? Are they likely to? Is it important? Should they not be told about it up front?
Modifications to this section have been made.

**12. Envirofit, Philips and Colorado State University, Submitted on 12/14/2009***

***** Additional comments/documents were too large to include in this compiled document. They have been attached separately.

**From: "Nathan Lorenz" <nathan.lorenz@envirofit.org>**

Envirofit, Philips and Colorado State University would like to submit the following comments for the WBT 4.0. You may already have some of the this data, but we wanted to include it all just to be sure.

As you know we have been working for the last year on systematically testing different parameters of the WBT 3.0 for areas of improvement.
Based on that testing we have created the Stoves Emissions & Performance Test Protocol (EPTP) to make improvements where we saw high levels of variability. I've attached three documents here in support of the comments. The first is the EPTP which incorporates these changes, the second is a draft

paper outlining the parametric testing that was done and the results of the testing. Lastly is a presentation that overviews the EPTP and includes some test data on the high variability that can be seen on different grades of test equipment.

To summarize the main points and recommendations:

12.1. Accurate emissions testing requires
   a. controlled hoods
   b. calibrated and accurate emissions equipment
   c. accurate exhaust flow measurement
   (these should all be specified rigidly in the protocol per established EPA or ISO test protocols)

12.2. To have reasonable confidence multiple test (6-8 minimum) are required

12.3. The addition of a foam to the top of the pot reduces vapor release variability and should be part of the standard test.

12.4. Keeping the same ΔT as WBT 3.0 but shifting the temperature range to prevent boiling reduces variability and should be part of the standard test.

12.5. Controlling wood dimensions and moisture content reduces variability

Thank you for these comments. These suggestions 12.1 – 3 and 12.5 have been added to the WBT as options for testers. Suggestion 12.4 has been included in Appendix 8 (Remaining challenges).

Thanks and Regards,

Nathan Lorenz

**13. EPA**, **Submitted on 12/18/2009***

***Additional comments were too large to include in this compiled document. They have been attached separately.

**First Name: Jim**
**Last Name: Jetter**

Comments:

13.1. Page 2, Appendix 4 not listed
This suggested change has been made.

13.2. Page 11, #8.f. "Batch: Weigh the loaded stove plus fuel and record that weight in the 'Weight of wood' location." If this procedure is specified for batch-operated stoves, why not use the same procedure for weighing remaining charcoal in continuous-operated stoves? It's much easier (if equipment is available to weigh the stove) than removing and weighing charcoal. This procedure can also be used to easily weigh the charcoal at the end of the hot start phase.
This suggested change has been made.

13.3. Page 11. Delete #9 because redundant with #8, or complete #9 by adding:
"Weight of wood remaining" and "Weight of charcoal remaining"
This suggested change has been made.

13.4. Page 11. "This completes the high power cold-start phase. Next, begin the high power-hot start ~~test~~ phase, immediately while the stove is still hot."

13.5. Page 11, end of page. "The pot of hot water may be temporarily covered with a lid and placed on a hot plate (if available) to keep the water temperature close to boiling during the following steps ~~a, b, and c~~. a., b., c., d., and e." (see top of Page 12)

This suggested change has been made.

13.6. Page 12, #10. "Weight ~~Amount~~ of wood remaining."

This section has been deleted to reduce redundancy.

13.7. Page 13, text box. I previously suggested adding: "The water temperature may be continuously recorded, if a device is available to do so. The average temperature during the test may then be calculated and documented." I think this is a very useful thing to do, and it's very easy to do when a data acquisition system is used for emissions monitoring. Continuous monitoring and recording of water temperature for all three phase of the WBT is useful for quality control and for diagnosing problems.

This suggested change has been made.

13.8. Page 15, figure. Diagram needs correction – TC probe not shown in correct position.

This suggested change has been made.

13.9. Page 19-20, table. Can't read two equations.

This suggested change has been made.

13.10. Page 26. I previously commented: "I think the stove should be at approximately the same temperature as the water at the beginning of the cold start test."

13.11. It is possible that a stove at ambient temperature may be tested in a cold climate with tap water (at a higher temperature). If the stove has a high thermal mass, it will take longer to warm up to steady-state operating temperature, and the correction for water temperature will not correct for the starting temperature of the stove.

- Also, it is possible that a stove at ambient temperature could be tested in a very hot climate with tap water (at a lower temperature). The stove may take a shorter time to warm up to steady-state operating temperature, and the correction for water temperature will not correct for the starting temperature of the stove.
- If the same stove is tested in two locations with very different ambient temperatures, results may vary.
- I suggest adding a statement: "Allow the water used in the pot to equilibrate to a temperature within 3 ºC of the starting temperature of the stove."

The issues raised in 13.10, 13.11, and 12.4 have been added to Appendix 8 (Remaining challenges).

13.12. Page 28, Variables that are calculated. In some equations, variables should have hot, not cold, subscripts

This suggested change has been made.

13.13. Page 35, Room Method, Disadvantages: add: “Exposes stove operator to air pollutants, unless special breathing equipment is available.”

This suggested change has been made.

**14. GRATIS FOUNDATION, Submitted on 12/14/2009**

**First Name: SABINA**
**Last Name: ANOKYE MENSAH**

Comments:
14.1. In hot climatic conditions it will have been good to know the time of the day that the stove is being tested and whether it is windy or not.

Start and end time, ambient air temperature and conditions are collected as part of the test.

**15. Grupo Interdisciplinario de Tecnologia Rural Apropiada (GIRA), A.C. (Patsari Project), Submitted on 12/18/2009**

**First Name: Victor**
**Last Name: Berrueta**

Comments:

**Comments and contributions to the Water Boiling Test**

**15.1. Including the energy contribution of the secondary pots during the low power phase.**

Considering many of the improved cookstoves versatility to heat up more than one pot at a time (like Patsari stoves, Onil, Lorena, Justa, Ecofogon), it is proposed to keep the water in the secondary pots during Phase 3 (boiling over a low flame or with low power).

This change will be reflected in the energy performance of the improved stove by increasing thermal efficiency and decreasing the specific fuel consumption. To count the amount of energy of the secondary pots during this phase it is needed to take their temperatures, as well as their weights, at the start and end points of the phase. The contribution of the secondary pot is obtained in the same way that high-power phases.

Recent measurements on the Patsari stove and other multi-pot stoves, show temperature increases between 10 and 20 ° C during the 45 minutes of Phase 3 in secondary pots, this energy contribution is not negligible and must be considered as part of the comprehensive performance evaluation of improved stoves. The procedure to quantify this contribution is simple.

Considering only the main pot, prevents a comprehensive understanding of a multi-pot improved stove performance, which leads to better indicators of this phase in traditional stoves or single pot stoves. If secondary pots were considered, results would be different when analyzing multi-pot stoves.

The multipot stove is discussed in Appendix 2 (Modifications to the WBT). This important issue has been added to the Additional diagnostic measures in Appendix 8 (Remaining Challenges), to be reviewed in consultation with field testers.

**15.2. Change in the calculation of the thermal efficiency of low-power phase.**

The numerator of the thermal efficiency has 2 parts, the first one is related to the energy transferred to the pot due to an increase of temperature (ΔT) that in high power phases is always positive (since the final temperature is greater than the initial), yet at the low power phase this ΔT is generally negative since the final temperature of the end of the phase is less than the local boiling temperature at which the phase is initiated.

It is proposed to omit this term in the calculation of the thermal efficiency of the Phase 3. We consider better to omit rather than subtract it of the "useful energy transferred to the pot".

$$h_c = \frac{\left[4.186 * \sum_{j=1}^{4} (Pj_{ci} - Pj) * (Tj_{cf} - Tj_{ci})\right] + 2260 * (w_{cv})}{f_{cd} * LHV}$$

Note: See left term of the numerator

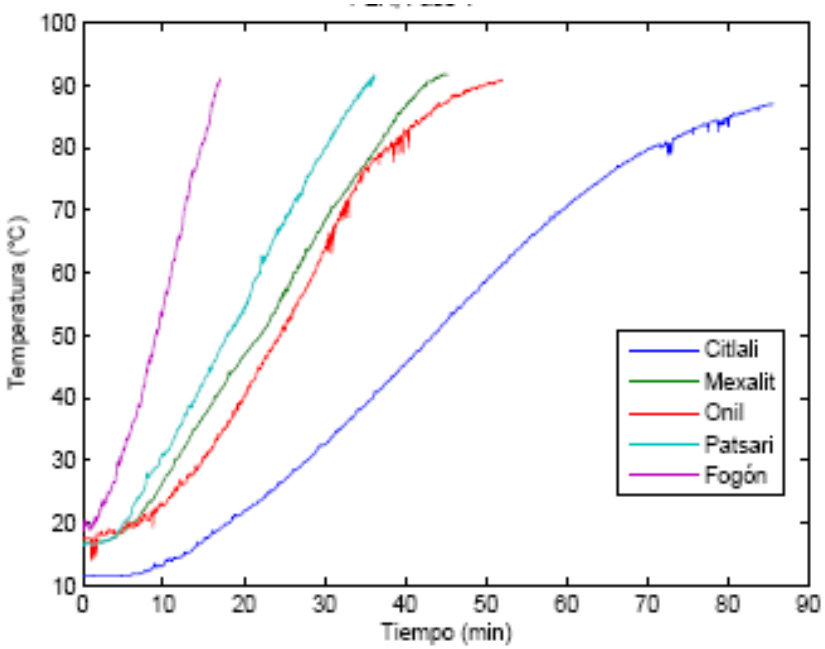
**15.3. Calculation of the energy transfer rate to water.**

It is proposed the calculation of a new indicator of energy performance that reflects the heat transfer to the pot, called: "**energy transfer rate to water**".

This indicator is the slope of the line that best approaches to the evolution of water temperature in the main pot during the phase, its units are ° C / min. It can be easily calculated from the temperature difference (ΔT) of the water in the main pot divided by the time (in minutes) the phase lasted.

This indicator allows to compare the heat transfer to the water between different types of stoves and between the 2 high power phases (cold start and hot start). This indicator considers time as an important variable for describing a dynamic system such as a wood stove, and it is an important measure considered by users.

As an example the picture below is shows some measurements of water temperature in the main pot during Phase 1 for different and traditional stoves




Pict 1. "Water temperature in the main pot against time (cold start) for different stoves"

This is important information that can be collected if equipment is available and for experienced testers. These comments will be made publicly available for testers.

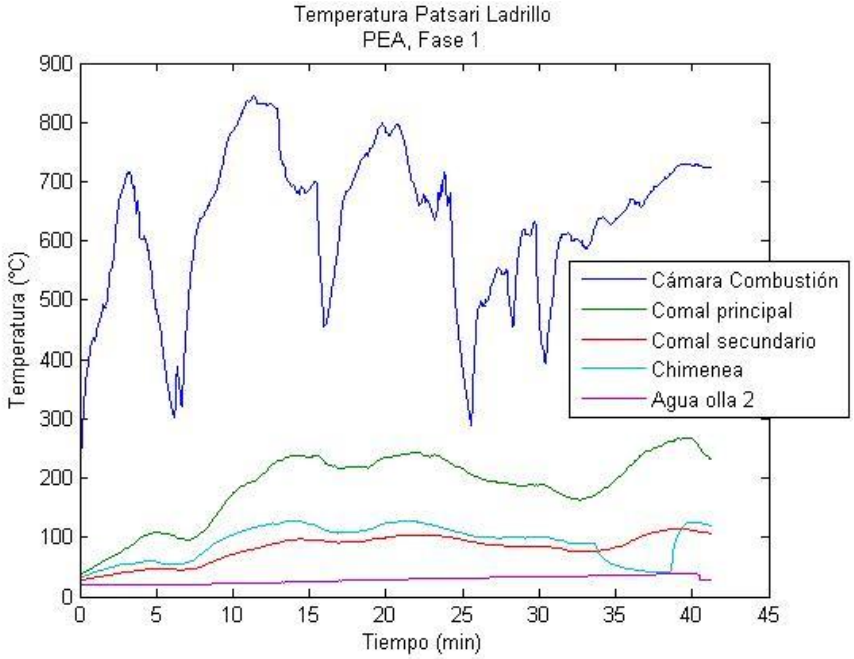
**15.4. Include in the evaluation of the stove's performance the temperature profile**

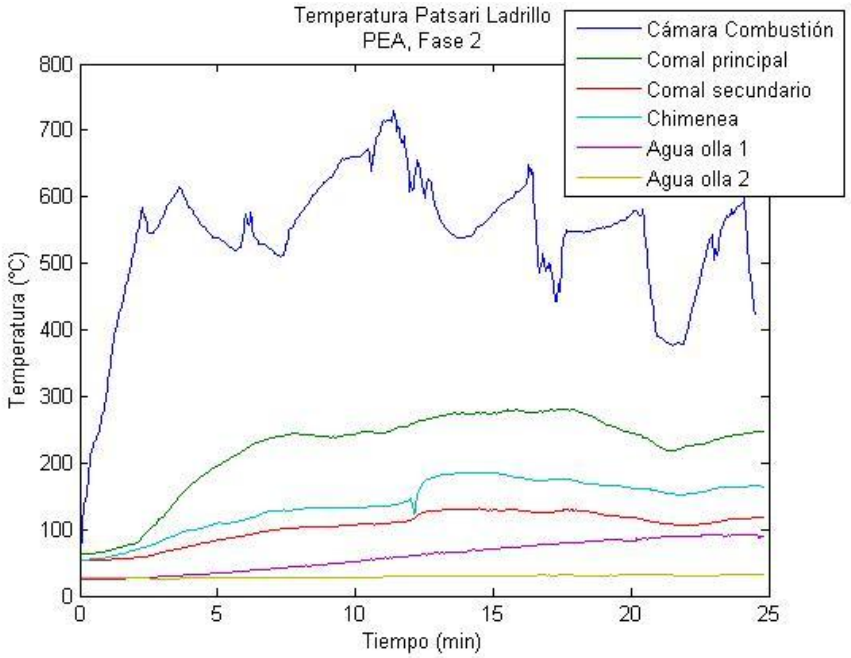
Is proposed to include as a complement of the test, the analysis, minute by minute, of the temperature profile in each phase. These measurements will be simultaneously taken with efficiency and emissions measurements. It consists on placing a thermocouple in, at least, 5 specific points on the stove:

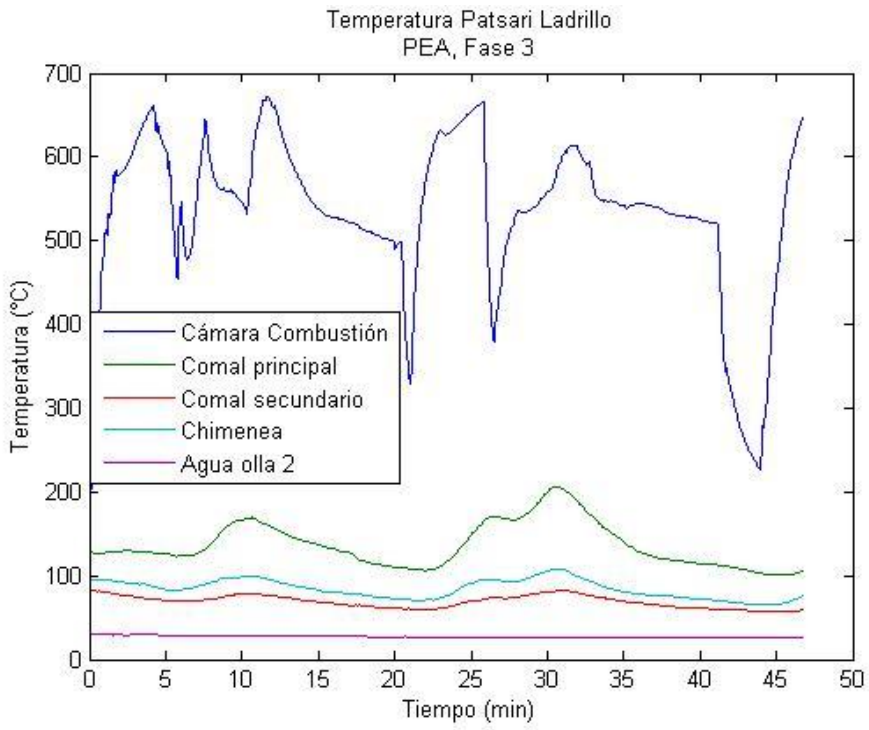
**1) Combustion chamber,**
**2) Contact surface ("comal" or pot base),**
**3) Water in the main pot,**
**4) Secondary contact surface (secondary "comales" or secondary pots place, if applicable),**
**5) Gas temperature in the chimney (if applicable)**

The temperature profile complements a comprehensive approach of the stove's performance and provides indicators of the energy transfer at different points on the stove, so designs can be improved without compromising the overall performance of the stove.

As an example, the graphic below shows the temperature profile of the Patsari stove.


Temperatura Patsari Ladrillo
PEA, Fase 1
Temperatura (°C)
Tiempo (min)
Cámara Combustión
Comal principal
Comal secundario
Chimenea
Agua olla 2


Temperatura Patsari Ladrillo
PEA, Fase 2
Temperatura (°C)
Tiempo (min)
Cámara Combustión
Comal principal
Comal secundario
Chimenea
Agua olla 1
Agua olla 2




This is important information that can be collected if equipment is available and for experienced testers. These comments will be made publicly available for testers.

Dr Víctor M. Berrueta Soriano,
Coordinador del Programa de Energía Rural, GIRA, A.C

**16. GTZ, Submitted on 12/15/2009**

**First Name: Alemayehu Z.**
**Last Name: Tufa**

Comments:
16.1. It would be nice if we include biogas datas in the list. There are a lot of stoves developed in different places with different performance.
Regards
Alemayehu

Biogas is included in the list of fuel options.

**17. GTZ – BOLIVIA, Submitted on 12/09/2009***
***Additional comments were too large to include in this compiled document. They have been attached separately.

**First Name: GABRIELA**
**Last Name: DUARTE**

Comments (translated to English, original Spanish below):
17.1. In the theoretical part: It doesn't include the description or the formulas of Pitot-Delta P Hood Flow Rate. All the theory is very long and redundant. Some formulas and graphics are not configured. The new names of the formulas are very long and all are similar. They should keep their original names like "Cc" instead of "mchar,cold,prod."

Appendix 2 and 4 are currently being updated and will be released when finished.

17.2. In the Excel spreadsheet, the increase in pages to fill out such as the description of work appears to me to be too much because people lose more time filling these out when there is a lot of work. I have attached an Excel sheet with comments on the formulas.

This version and the Excel workbook have been updated with changes to make filling in data clearer.

17.3. In general it seems like doing the emissions test together with the WBT complicates the work because, for example, if we have to start the Hot Start in approximately 5 minutes, controlling the starting and stopping of the emissions equipment will delay this step and we could lose valuable data about efficiency.

The emissions test is optional for the WBT. Appendix 6 (Emission Measurement) has been modified to encourage testers to become familiar with using the emissions testing protocol and equipment before conducting the test.

17.1. EN LA PARTE TEORICA: NO INCLUYE LA DESCRIPCION NI FORMULAS DE PITOT-DELTA P , HOOD FLOW RATE. TODA LA TEORIA ES MUY LARGA Y REDUNDANTE. ALGUNAS FORMULAS Y GRAFICOS ESTAN DESCONFIGURADOS. LOS NUEVOS NOMBRES DE LAS FORMULAS SON MUY LARGAS Y TODAS SE PARECEN DEBERIAN MANTENER SUS NOMBRES ORIGINALES COMO SER Cc EN LUGAR DE mchar,cold,prod.
17.2. EN LA HOJA EXCEL: EL AUMENTO DE HOJAS DE LLENADO COMO DESCRIPCION DEL TRABAJO ME PARECE Q ESTA DEMAS PORQUE SE PIERDE MAS TIEMPO LLENANDO ESO CUANDO HAY MUCHO TRABAJO. ADJUNTO HOJA EXCEL CON COMENTARIOS DE LAS FORMULAS.
17.3. EN GENERAL ME PARECE QUE HACER LA PRUEBA DE EMISIONES JUNTO CON EL WBT COMPLICA EL TRABAJO PORQ POR EJEMPLO SI DEBEMOS EMPEZAR EL HOT START EN 5 MINUTOS APROX. CONTROLAR EL ENCENDIDO Y APAGADO DEL EQUIPO DE EMISIONES TARDARA MAS ESTE PASO Y PODRIAMOS PERDER DATOS VALIOSOS DE EFICIENCIA.

Attach Comments: **http://www.pciaonline.org/files/webform/wbt_comments/WBT_data-calculatio...**

**18. GTZ-Bolivia, Submitted on 12/16/2009**

**First Name: Ricardo**
**Last Name: Villarroel Camacho**

Comments (translated to English, original Spanish comments below):
18.1. On page 7, the Overview doesn't take into consideration that there are stoves that heat up the surrounding environment significantly, owing to the fact that the construction is made of metal. In the first test the surrounding environment will be cold, but for the second Hot Start test, the environment will be hot (there is surely a change in temperature), which would be interesting to take into consideration in the graphic since temperature is not constant.

This important issue has been added to Appendix 8 (Remaining Challenges).

18.2. In the Cold and Cold and Hot Start tests, the tests refer to the first pot boiled, and it is for that reason that many stove builders focus their efficiency on the first pot that boils and not the second. It would be interesting to take into account the time of boiling both pots, since the users need a stove that boils 2 pots at least, and not just one. Since these are laboratory tests, they should consider this point.

The multipot stove is discussed in Appendix 2 (Modifications to the WBT). This important issue has been added to the Additional diagnostic measures in Appendix 8 (Remaining Challenges), to be reviewed in consultation with field testers.

18.3. For the tests on metal stoves, I suggest more specifics with respect to the durability, safety, efficiency, since metal that is exposed to heat acquires elevated temperatures, and tends to become deformed and cannot be returned to its original state, causing cracks and making the stove dangerous.

The need for protocols for durability and safety is discussed in Appendix 8 (Remaining Challenges).

18.4. With respect to the Excel Spreadsheet on page 1, this is a lot of data to fill out, and the questions should all be closed rather than open ended, for easier tabulation of data.

For relevant data with a limited set of options, the spreadsheet has a drop-down list of items to select.

18.5. What is "Pitot"? How do you calculate it and what is its interpretation?

Brief definitions and how to calculate these values have been added to Appendix 6 (Emission Measurement). In the Excel workbook, if emissions measurements are not being made, Pitot delta-P and Hood flow rate (m3/hr) do not need to be entered.

18.1. En la Pág. 7. Overview no se toma encuenta que existen cocinas que calientan el ambiente bastante, debido a que la construcción es de metal, en la primera prueba el ambiente se encuentra frío pero para la segunda prueba en caliente el ambiente ya se encuentra caliente seguramente existe una variación de temperatura, esto seria interesante tomar encuenta en el grafico ya que no es constante.
18.2. En las pruebas de Cold an Cold and Hot start, las pruebas se toman respecto a la primera olla de hervido, es por esta razon que muchos constructores de cocinas enfocan su eficiencia a la primera olla que hierve y no a la segunda, seria interesante tomar encuenta el tiempo de hervido de ambas ollas ya que los usuarios necesitan una cocina que hierva 2 ornallas por lo menos y no sola una, como son

pruebas de laboratorio deberia tomarse encuenta este punto.
18.3. Las pruebas en cocinas metalicas sugiero mas especificas respecto a la durabilidad, seguridad, eficiencia puesto que el metal al ser expuesto al calor adquiere temperaturas muy elevadas y tiende a deformarse y estas a la vez ya no pueden volver a su estado inicial provocando grietas haciendo que la cocina sea peligrosa.
18.4. Respecto a la hoja excel en la Pág. 1.- muchos datos para llenar, las preguntas debian ser cerradas y no abiertas para una facil tabulacion de datos.
18.5. ¿Que es Pitot?, como se calcula y cual es su interpretación

**19. HED Consulting, UK, Submitted on 12/18/2009***

***Additional comments were too large to include in this compiled document. They have been attached separately.**

**First Name: Jonathan**
**Last Name: Rouse**

Comments:
Thanks for putting this out for comments.

19.1. I have not used the WBT much at all, so am able to read it as a novice, and have pointed out a few bits (marked on the pdf attached) which I think could trip people up.

19.2. Overall, however, I think it's very clear, and I also appreciate the appendices which provide back ground info from history to techy. I also think linking to online - and updatabale - resources for data sheets etc is great.

Thank you for your comments and support.

Hope these are useful. You know where I am if you need any clarification.

Best wishes, Jonathan

Attach Comments:
**http://www.pciaonline.org/files/webform/wbt_comments/WBT%20JRRouse%20Com...**

**20. Huys Advies, Submitted on 11/01/2009**

**First Name: Sjoerd**
**Last Name: Nienhuys**

Comments:
20.1. It should be clearly indicated that all measurements are to be metric. e.g. in "Preparing the Laboratory" the temperature should be Celsius.

This suggested change has been made.

20.2. In daily preparation, the definition of air-dried fuel should be provided earlier in paper (e.g. 15% humidity + or - 5%).

The description of air-drying fuel has been expanded. The “Changes to Testing Conditions to Improve Repeatability” section describes suggestions for air dried fuel.

20.3. Preparation for each set... Guidance. Provide a cross section drawing of the stove with dimensions. Please note that the outside picture does not tell much about its functioning, but is useful for overall reference.

This suggestion has been added.

20.4. Tests should be performed at nearly sea level, otherwise the boiling point varies too much. The same stove will have different values at different altitude levels. Comparing stoves efficiency will be difficult. By obliging almost sea level, the document and calculation will be simpler.

Because of the diverse locations of cookstove testing centers and other cookstoves activities, a requirement for conducting tests at sea level is not possible. The results are corrected for the based on the local boiling point that is provided by testers, which correlates with altitude.

20.5. The boiling point should be described as "fully bubbling and bubbles reach all water surface".

A definition and description for boiling point is provided in Appendix 1, Section 1.2.

20.6. On page 15, the small block above diagramme is unclear. In the diagramme, above the water, the bend line is not clear. In other part of document it is suggested to keep the thermometer in the center of the pot.

This diagram has been corrected.

20.7. 2.2. The formula for Water vaporized and SC Tc are garbled.
For non-mathematicians explain how to calculate/find the 4 Z j-1 (sum) formula.

Appendix 2 and 4 are currently being updated and will be released when finished.

20.8. Stoves can be labeled with a WBT412 figure for reference of quality. The labeling method should be clarified.

Appendix 9 (Standards) has been added to discuss issues related to standards and possible applications for certification and labeling.

20.9. Many stove manufacturers will not be able to perform the WBT412 test, yet it would be beneficial if they can provide an indication on the stove performance. A simpler test (or the older) may be considered, providing the stove maker with the option to give the instrument a labeling with another code.

The Global Alliance for Clean Cookstoves is focused on activities to enhance global testing capacity so that manufacturers will be able to work with testing centers and standards organizations to test their stoves.

20.10. The field testing (in houses by the user) gives different results. These different results depend much on the cooking habit, but the minimum and maximum differences from the WBT412 will vary with the stove design. Please see attached one of the survey forms we used for measuring consumption in the field.

The section of the Introduction that describes other tests that are designed to measure in-field performance of stoves has been modified to adjust this comment.

Attach Comments:
**http://www.pciaonline.org/files/webform/wbt_comments/firewood%20data%20c...**

**Registration form: Firewood consumption for cooking per household.**

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Name TOP-ICS owner:** | | | | | | | | | **measure 0.1 kg precision** | | | |
| **Village:** | | | | | **Number of adults:** | | | | A. Total kg of firewood at the start of the week | B.Total kg of firewood added during the week | C.Rest amount of firewood at the end of the week | D.Total firewood used during week. D=A+B-C |
| **House:** | | | | | **Children under 6:** | | | | | | | |
| | **Number of meals/day (child < 6 yrs= 1/2 meal)** | | | | | | | **Total number of meals** | | | | |
| Days | **Monday** | **Tuesday** | **Wednesday** | **Thursday** | **Friday** | **Saturday** | **Sunday** | | | | | |
| WEEK 1 Breakfast | | | | | | | | | | | | |
| WEEK 1 Lunch | | | | | | | | | | | | |
| WEEK 1 Dinners | | | | | | | | | | | | |
| Totals | | | | | | | | | | | | |
| Average use of firewood per meal = Total D divided by total number of meals | | | | | | | | | | | | |
| | | | | | | | | Total tea | | | | |
| WEEK 1 Tea | | | | | | | | | | | | Incl. Tea |
| Average use of firewood / meal + tea = Total D divided by total number of meals | | | | | | | | | | | | |
| Name of record collector: | | | | | | | | | Date: | | | |

**21. KRISTOMS BAKERY, Submitted on 11/25/2009**

**First Name: Sam**
**Last Name: Simbwa**

Comments:
21.1. In my view this is one of the best method of Water Boiling Test and I would suggest that since most of the Third World Countries treat drinking water by boiling then an enlarged testing method may be applied to look more attractive.

Thank you for your comment and support.

**22. Mfaminyen Conservation Society, Submitted on 12/16/2009**

**First Name: Linus**
**Last Name: Ita**

Comments:
22.1. Water Boiling Test is the best. In actual fact, after every test that we have conducted even questionnaires in different communities in Cross River State Nigeria, none had come up with a perfect result like WBT. Our plan in January 2010 is to organise a training on that in the communities we have worked.

Thank you for your comment and support.

**23. Moi University, Kenya, Submitted on 12/15/2009**

**First Name: Jacob Onjwaya**
**Last Name: Mbego**

Comments:
23.1. Initial standard temperature of water at which timing start before boiling point is reached e.g 30 degrees centigrade need to be set.

This important issue has been added to Appendix 8 (Remaining challenges).

23.2. For long cooking tasks, there is need for determining duration of maximum water temperature and cooling graph back to room temperature per given quantity of fuel need to be included in the testing procedure(this will determine heat transfer efficiency).

Because this comment discusses long cooking tasks, it does not address the tasks in the WBT.

23.3. Fuel combustion rate need to me measured. A stove need to be permanently mounted on a weighing balance during testing period and weight reduction trend due to fuel combustion determined. Such a weighing balance need to be developed and used.

The WBT calculates fuel combustion rate (fuel burned divided by number of minutes, burning rate/fire power) both reported. A scale that large cannot be required, but this suggestion has been added to the procedure as an option if equipment is available.

23.4. Cheap equipments for emission testing need to be developed and used to meet all situations in all different countries.

Work is ongoing to develop affordable equipment that can be used in different situations.

**24. Pro Peru, Submitted on 12/18/2009**

**First Name: Javier**
**Last Name: Saldivar**

Comments:
Our comments are in Spanish and English

24.1. One suggestion is that the size of the pot used throughout the testing process should be related to the size of the burner on the stove and not the size of the entire stove.

> El tamaño de olla debe tener una relación directa con el diámetro de la hornilla y no con el tamaño de la cocina.

This comment has been addressed in the expanded section to describe pot selection.

24.2. What considerations should we take into account for the Pro Peru clean burning stove: does not solely use firewood, but other fuels as well; our model can accommodate different sizes of pots; and the pots can be receded into the burner or sitting on top of it.

> Que debe considerarse con una cocina que se adapta a diferentes condiciones como: utilizar diferentes tipos de combustibles, diferentes tamaños de ollas, posición de a olla (por fuera o introducida).

24.3. We also need to consider the material of the pots, because in some cases we use cerarmic pots.

> Consideramos que se debe indicar el material de la olla, muchas veces en nuestra zona utilizan ollas de cerámica.

24.4. Our stove model has a combustion chamber that does not necessarily need to be filled to capacity with fuel, because the goal of the stove is to use the least amount of fuel as possible. We also need to control the convection with the use of a damper in the chimney.

Nuestra cocina tiene un área de combustión, que no precisamente debe llenarse completamente con combustible, consideramos necesario utilizar siempre lo menos posible de combustible, acompañado de controlar la salida de humo con el uso del diafragma para la chimenea.

Comments 24.2 – 24.4 are asking for suggestions which have been sent to the group submitting these comments. If other groups have suggestions, please send them to this commenter.

**25. Rahman Renewable Energy Co., Submitted on 12/18/2009**

**First Name: Redwanoor**
**Last Name: Rahman(BulBul)**

Comments:
Rahman Renewable Energy Co. thinks under below:

25.1. Water Boiling Test (WBT): WBT is a laboratory test-this stove performance completing a standard task controlled environment to investigate the heat transfer and combustion efficiency.

These suggestions have been incorporated into the updated introduction.

25.2. Controlled Cooking Test (CCT): CCT is field test that measures stove performance to traditional cooking methods when a cook prepares a local food. CCT perspective performance controlled setting using local fuels, pots. Households understand actually achieved by households during daily food cooking.

These suggestions have been incorporated into the updated introduction.

25.3. Kitchen Performance Test (KPT): KPT is a field test - stove performance of consumption. This system actual impacts on household fuel saving. KPT actual dissemination effort with real populations cooking normally, and succession the best indication.

These suggestions have been incorporated into the updated introduction.

**26. Resource Efficient Agricultural Production (REAP-CANADA)**, **Submitted on 12/18/2009**

**First Name: Roger**
**Last Name: Samson**

Comments:
26.1. My comments relate to the type of fuel used in the studies. It is evident that if we use barkless, processed dry sticks it is not representative of the fuel used in most developing countries and ultimately creates a bias that creates a low emission profile for the 3 stove fire baseline and all wood stoves. A favourable wood fuel selection thus would create a bias for low emissions for all wood stoves that would not be representative of the actual emission situation in developing countries. Furthermore it would create bias against non- wood, biogas and solar stoves and not fairly demonstrate their emission reduction

potentials vs wood fuel burning systems. Thus the description below is inadequate and favours wood stoves (eg. no pitch, high heat value). It would be best of the wood used was much more descriptive and representative of the actual wood in use. The description could be branch wood be utilized that is 3 cm to 8 cm in diameter. Wood should be split such that at least 1/4 of the outside of the fuel stick is covered in bark material. It could be we could recommend acacia species be used because these species are available throughout much of the developing world. In the event acacia species are not available locally the study coordinator can justify why another local hardwood species was used as the replacement fuel. It would need to be similar in quality and prepared in a similar manner. I do not know if 1.5 cm is unrealistic as a wood fuel size. This possibly could be used as a starter but it seems again a fuel resource that would be unrepresentative of what people are burning in the field. Perhaps it should read not less than 2 cm in cross section.

1. Fuel
a. Type: Wood with high heat content (between 20-21 MJ/kg), and without excessive pitch content, should be used for all tests. Choose one wood which is used widely in the region.
b. Dimensions: Different sizes of solid fuels have different burning characteristics. Some laboratories have used wood with cross-sectional dimensions of 1.5 cm x 1.5 cm.

These suggestions have been incorporated into an expanded section describing fuel selection.

**27. Rozis, Jean-François (Independent), Submitted on 11/08/2009**

**First Name: Jean-François**
**Last Name: Rozis**

Comments:
Dear PCIA members, I passed sometimes in reviewing your paper, so please give me some feedbacks..
Thanks
JFRozis

Dear PCIA members and WBT version 4 developers,
So I had a look on the paper, huge work done, not easy because of regrouping different actors, never easy..

**Concerning the content:**

27.1 **Introduction**: perfect, just to **underline very strongly this test is not to be used for CDM or any tentative to prove real fuel savings in the field!!** You will make a strong progress if it's clearly mentioned because I saw, and see misuse of this test (CDM with SAVE 80 by instance, use only of high power phase to prove better performance, and so on..)

The text has been updated based on these comments.

27.2 **In introduction mention** which combustion technology is adapted, for some technology like T-

LUD or other we are working on, it's not relevant (access to remaining biomass, stop and restart combustion)

The WBT can be used for TLUD stoves and instructions specific to these and other batch stoves are separated from instructions for continuously fed stoves. However, there are issues relating to weighing charcoal and unburned fuel that are discussed in Appendix 8 (Remaining Challenges).

27.3 I saw no information on **accuracy of the result** (error in measure, in calculating energy content, ..), just mention of Cov to be under 10% to complete more test if above up to complete this recommendation. That is very important, please mention more clearly in the text, just to refer to appendix to have more details on calculations for cov and so on**, but three test if representative only..**

These issues are discussed in Appendix 5 (Statistics) and in Appendix 8 (Remaining Issues).

27.4 For me important to recommend strongly use of extraction hood (basic one if no emission test) to ensure repeatability (less external influence, wind and so on..) and avoid any IAP risk for testers

The disadvantages of the room method have been expanded. A new section on safety has also been added to address this issue.

27.5 Mention more clearly HOT power Hot pot interest because it's an addition from Vita WBT, if I understand well, it's for calculating useful energy or efficiency at permanent phase, without any thermal inertia influence..if it's the way, in some stove you need to wait at least one hour..so explain better the interest..also the pot to be hot!!

27.6 What's the debate on calculation of efficiency or useful energy in simmering phase, I remember remark on the risk to give advantage to a stove at this stage making more vapour than real cooking?? I think difficult to provide other equation..

Specific consumption is a more useful measure during simmering, than thermal efficiency.

27.7 What about debate on energy content of remaining charcoal (real fixed carbon content), wood (torrefied part)?? Any idea of error level made in the calculation??

Instructions to separate and weigh charcoal in cold start phase. This important issue has been added to Appendix 8 (Remaining Challenges).

27.8 page 14, c. just mention low value of moisture (stabilized with ambient air after long time storage), so it's around sometimes 15% on a wet basis

These suggestions have been incorporated into an expanded section describing fuel selection.

27.9 in my pdf version, some equations not readable (Wcv, SCTc, ..)

Appendix 2 and 4 are currently being updated and will be released when finished.

27.10 in you stat example, please, try to present another example, I saw in certain country people analysing only the WBT for high power phase (to avoid manip..)using only high power phase, so a stove has to be compare with a certain cooking phase so at end of it. In your example, stove 2 can be more efficient, but we have to see globally, useful energy used during the test time (or global efficiency) to say this parameter give better result, or this design.. can you give a better example of analysis of WBT..

This comment has been addressed in Appendix 5 (Statistics).

**Concerning your WBT:**

So can we have a real debate on this affair. The problem of Vita WBT, it has been developed for laboratories, not for stove developers or quality control at producer level. So the main defaults are:

27.11 loss of accuracy with the stop and start process after boiling phase

27.12 necessity to adapt to local conditions, so difficulty to compare internationally (and for which interest??)

27.13 so the current contradiction between necessity to standardize the test (25 °C room temp, 5 liters, extraction hood, high accuracy measures, moisture content, ..) to try to have something internationally comparable (but for why??), and the separation more and more deeper with the field context and the capacity of local NGO, producers to conduct such test..

27.14 a bit more difficult than before, so more risks for errors

This version includes suggestions to improve the tester's ability to conduct the test quickly and in a repeatable way. In addition, this version include suggestions for reflecting local conditions or being international comparable.

**Constructive proposition**

27.15. Could we have two test to avoid all those contradictions and error risks.

**- a standard WBT** , based on your WBT, but clearly oriented for labs with emissions possibilities (strongly recommended), maybe 100 lab maxi in the world able to complete it nicely but sufficient. Very restrictive, a real standard, oven dried wood, 25° room, certain humidity, certain wood, ….so every one can exchange and for a certain stove, can find the best design, or underline influence level of certain parameter..pure academic work..

**- a local & comparative WBT** test for developers, local NGO, producers to apply local standards in production chain, improve their design. We developed one test on this way, we enjoyed it a lot, and I recommend since some years in SE Asia and North & West Africa.

In this test, we start to identify clearly for a representative family in our area, a representative cooking task for which the stove is designed. So we fix the pot specifications, the qty of litres, the ideal time to boil, the time for simmering, the fuel qty. .and we conduct always in same time two stoves in test (same wood, same external conditions, same operator, ).

In that way we obtain a much more accurate test with basic equipments (a common kitchen scale is sufficient).

We stopped to play with remaining wood and charcoal (I definitively don't like it), the objective is to use totally the fuel load. we calculate the useful energy used and choose the design, the parameters improving this results (we can make the same for emissions of course, but at this time only with a stove at once, two expensive to purchase two PEMS..)
High correspondence between field and lab is obtained, but as mentioned in the standard WBT, we follow always a field test to prove real savings (a specific test also simplified and more accurate than standard, but other time to tell about).
Other, we can adapt the test to different technologies of combustion, different stove designs. We limit a lot errors of interpretations, variability, and so on..**we learn maybe less info, but the essential ones are more accurate and easy too obtain!!**

This revision is an attempt to make this the WBT easier to use. There are benefits to having one version of the test, as other commenters have mentioned. The CCT can be used to test for representative local cooking tasks.

Attach Comments:

**http://www.pciaonline.org/files/webform/wbt_comments/PCIA%20WBT_JFR%20co...**

**28. Soil Control Lab, Submitted on 12/14/2009**

**First Name: Frank**
**Last Name: Shields**

Comments:
A good test as-is but there will always be limiting factors that we must work on to improve in the future.
28.1. Characterizing the fuel used should include; moisture, ash, resident matter(450 deg.C in a pipe), size and shape, type, particle and packing density. These are easy tests.

This important issue has been added to Appendix 8 (Remaining Challenges).

28.2. One fuel will work great while another fuel will fail in the same stove so we cannot make a comparison of different stoves if we do not compare using the same fuel - if that is the intent of the test. If the intent is to find the best stove for the fuel in a region we need to use data on stoves using the fuel they will use. Otherwise the results are mean little.

These suggestions have been incorporated into an expanded section describing fuel selection.

28.3. We need more work on easy measures for un-burned organics in emissions and better tests for the left wood/char. I suggest research on an after-burner to determine the unburned gases and, perhaps (a) density/ash determination on the left over fuel or (b) resident/mobile/ash fractions on the unburned fuel. Both compared to the starting material.

This important issue has been added to Appendix 8 (Remaining Challenges).

Thanks
Frank Shields

**29. Solar Connect Association, Submitted on 11/03/2009**

**First Name: Kawesa**
**Last Name: Mukasa**

Comments:
29.1. Real WBT should be done by end users themselves at the grassroot level in a normal set up without the usual user knowing that she is doing WBT, putting into consideration types of firewood. WBT in places like Germany or USA cannot reflect what happens in the kitchen in the Ugandan village of Kikokwa- Isingiro District where I work with women.

The goals in this comment can be addressed by conducting CCTs. The results of the WBT can be compared to results of the CCTs.

**30. Sustainable Energy Technology Testing and Research Centre (SeTAR Centre), Submitted 12/18/2009**

**First Name: Crispin**
**Last Name: Pemberton-Pigott**

Comments on the Water Boiling Test Protocol
(WBT Version 4.1.2)

Sustainable Energy Technology Testing and Research Centre (SeTAR Centre),
Department of Geography, Environmental Management and Energy Studies, University of Johannesburg,

These comments are submitted in response to the Technical Committee in response to an invitation to comment on the "*Water Boiling Test: Cookstove Emissions and Efficiency in a Controlled Laboratory Setting - Version 4.1.2*", issued on October 1, 2009.

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The Water Boiling Test (WBT) is a simplified simulation of the cooking process. It is intended to help stove designers measure ***how efficiently a stove uses fuel to heat water in a cooking pot*** and the ***quantity of harmful emissions produced while cooking***.

30.1. The WBT4 should not be used to test several stove types, including biomass gasifiers, biomass pellet stoves, ethanol gel stoves, paraffin stoves, coal stoves and most batch loaded stoves as the protocol is inappropriate. Gasifiers and pellet stoves can often be tested with a '*burn-out test*' devised by C Pemberton-Pigott. This latter test has approximately one third of the intrinsic errors, giving performance evaluations accurate to ~15%, in contrast to an accuracy of only ~50% for the WBT4 (Penn Taylor, 2008, 2009).

Specific instructions are provided for batch fed stoves. Some issues relevant for these types of stoves are addressed in Appendix 8 (Remaining Challenges)

30.2. The WBT should be a *product design and testing tool,* to rate the performance of a stove using the range of pots and fuels with which it is intended to operate.

The Introduction and Background section has been modified to reflect this comment.

30.3. Fuel efficiency is not necessarily indicated by the performance of a single task (though choosing a task is often useful). The performance of any thermal appliance such as a flame based cooking stove necessarily requires that the appliance be tested over the intended power range, and with the pots and containers that are expected to be found in the user's home. Further, fuel variations including size, moisture content and heat content, can produce wide variations in emissions and in performance measures such as maximum power, combustion efficiency and the turn-down ratio. Evaluation of a device should be based on a test using the fuel for which it was designed or is likely to be used.

The explanatory language reflects the challenges raised in this comment to balance the goal of having comparable and repeatable testing results and reflecting use in the home. Testers using the WBT may find this comment useful and this comment has been made publically available to accompany the WBT.

30.4. There are three variables which need to be accommodated in order to construct a set of performance curves for a stove: (i) fuel and fuel moisture; (ii) the pot or container; and (iii) the power level at which the stove is operated. A **heterogeneous** approach to testing is needed. It requires that the stove be operated at a variety of power levels while fixing the fuel moisture and the pot sizes. Work conducted at the SeTAR Centre in 2009 shows that a heterogeneous testing protocol can reveal both promising stove designs and severe operational problems, depending on the product and the fuel. These issues are not likely to reveal themselves when testing in a homogeneous fashion wherein all variables are constrained in order to test the stove at a single power, with a single pot and a single pot load, and pre-specified fuel that does not necessarily match the stove design. The for example, combustion efficiency can vary widely with fuel moisture changes and the reporting of the system's thermal efficiency at low power is usually misrepresented if the pot of water is already boiling when the low power test is commenced.

Advanced testers using the WBT may find this comment useful and this comment has been made publically available to accompany the WBT. This issue may also be addressed with further discussion and study.

30.5. The emissions should be checked at 3 or 4 power levels. Testing at the SeTAR Centre shows dramatic variations in emissions and thermal performance as the cooking power is varied, something that passes unnoticed during a single power WBT. This variation is not unexpected - few stoves are developed with appropriate testing of thermal performance and emissions at multiple power levels.

Advanced testers using the WBT may find this comment useful and this comment has been made publically available to accompany the WBT. This issue may also be addressed with further discussion and study.

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***Benefits and limitations of the WBT***

…Ensure that manufactured stoves meet design specifications

30.6. The design specifications would normally include a range of pot sizes, depnding on the intended use (domestic, institutional etc). For wood fuel stoves, operation would be intended with a range of fuel moisture contents, not necessarily oven dryed.

The language in the WBT suggests options for pot and fuel selection based on the goals of the tester.

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… While lab-based tests allow stove developers to differentiate between well-designed and poorly-designed stoves, they give little indication of how the stoves are actually used.

30.7. It is a fact that stove WBT results are often published on the Internet and are (incorrectly) used by program managers to make technology selections. If the testing is published at all, it should include enough information to show how the stove performs during the expected range it will encounter in real life. For an analogy, it is helpful to consider the performance charts of a water pump. Published performance charts for a water pump include lines that show the expected output and pumping head for various operational speeds. It is pointless for pumps to be compared with each other by being tested at only one pumping head and one pipe size. The rating of their performance requires performance curves on a chart, not a single point. The WBT4 provides a single point in what should rightly be a 2-D matrix of points.

The Global Alliance for Clean Cookstoves will work with all countries and protocols to standardize reporting to provide program managers with education and streamlined data required to make their decisions. Advanced testers and program managers may be interested in evaluating more usage variables.

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To understand how stoves perform with local foods, cooking practices, and fuels, stove testers should use the Controlled Cooking Test (CCT) that has been developed in parallel with this test. The CCT is still a lab test. A Kitchen Performance Test (KPT)…

30.8. It is recommended that there be 4 tests used in common practise and a 5$^{th}$ test (the KPT) used where occasion warrants.

1. The Water Boiling Test (WBT) conducted at a minimum of three power levels, with two pot sizes representing the largest and smallest the stove is designed to accommodate, and possibly others as are deemed necessary.
2. The Field Water Boiling Test (FWBT) is the same as the WBT but conducted in the field.
3. The Controlled Cooking Test (CCT) which can be done in the lab or in the field whereby the cooking tasks are defined. Such tasks should cover the range of pots and power levels foreseen in the target community.
4. The Uncontrolled Cooking Test (UCT) which is conducted in the field during which the cooks choose any meal they want, operate the stove in any manner they feel is appropriate and using any pots they feel suited to the tasks. The stove performance is rated based on meal size and or meal composition.
5. The Kitchen Performance Test (KPT) is sometimes used but is so expensive that it is usually performed for rating the effectiveness of large scale implementations. It is subject to several errors that do not emerge from the other 4 tests including but not limited to: fuel harvested and sold may appear to have been ‘consumed’; cooking practices may vary because of the presence

of additional fuel (the result of a more efficient appliance); the use of additional fuel for space heating that was not used before.

An introduction to the Uncontrolled Cooking Test has been added to the Introduction and Background section.

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The field test also includes a procedure to compare fuel consumption in households using different types of stoves. This test is critical if project designers wish to justify claims about real impacts on fuel consumption resulting from the stoves that they are promoting.

30.9. The KPT is the measure of a community's behaviour, not the performance of a set of stoves. It requires considerable input from social scientists to evaluate the meaning of the collected data.

The description of the KPT has been modified to clarify this issue. In future discussions of the KPT, this suggestion will be very valuable.

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…Combining these with the thermal efficiency measurement, we can determine another useful parameter: emissions per task.

30.10. It is fundamentally incorrect to rate the performance of a stove in a lab setting on the basis of a task. Lab-based determinations of performance should be expressed in terms of the heat produced or the mass of fuel burned (normally the former). It is also useful to express the thermal efficiency separately from the combustion efficiency. This is particularly important in a laboratory setting where the design of a stove is being evaluated.

30.11. It is with good reason that engineers determine the performance of systems using emissions per MegaJoule. This is standard practise. It is not standard practise to evaluate a design using a single defined task as it provides nearly no performance information about the appliance.

Metrics for emissions per task, per energy delivered to pot, and per mass of fuel burned are provided.

30.12. Cooking tasks around the world are extremely diverse. Forcing all appliances to perform exactly the same task, as has also been the suggestion in previous versions of the WBT, nearly guarantees misrepresentative conclusions as it is rare that several stoves are designed to use the same fuels, the same pots, the same pot loads and to operate in at the same power levels.

These issues are discussed in Appendix 8 (Remaining Challenges).

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***Interpretation of Water Boiling Test measures***

30.13. The performance of a number of stove tests should be shown in graphical form with standard deviations and variance indicated. System efficiency is often an important consideration as are emissions at different power levels with different fuels. Research has shown that carbon monoxide production per MJ can vary by a factor of 50 during a comprehensive stove evaluation. Properly plotting the combustion

efficiency (completeness of the burning of the fuel) and emissions can assist the designer to improve performance.

Advanced testers using the WBT may find this comment useful and this comment has been made publically available to accompany the WBT. This issue may also be addressed with further discussion and study. The suggestion for plotting emissions has been added to Appendix 6.

30.14. This section (***Interpretation***) is written in a way that indicates the authors expect the WBT, ostensibly a lab test and design tool, to be used for selection of stoves for field trials. It must be made perfectly clear that a design tool must give an engineering evaluation across the range of variation expected in the field. It is not a technology selection tool. That is what the CCT and UCT are for. It is largely for this reason that conducting arbitrary cooking tasks in the laboratory are a poor predictor of cooking performance in the field. In particular, the use of the WBT 3.0 as a stove evaluation method has been somewhat of a disaster. There is simply no correlation between performance of a WBT3 test and cooking performance. The WBT3 approach (a defined cooking task with a defined pot and pot load) has proven to be nearly worthless as an evaluator of a design or in the tuning a stove because it does not provide the critical engineering information needed to do so, i.e. a differentiation of combustion and thermal efficiencies, and variations in performance across a range of pots and power.

This section has been updated to reflect this comment.

30.15. The WBT4 still calls for a single cooking task to be performed. It is still confused as to whether it is an engineering evaluation or a cooking test. It is advertised as the former while doings the latter and serving neither properly.

The suggestions related to performing an advanced engineering evaluation have been provided publically for advanced testers.

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Appendix 2 (Modifications to the Water Boiling Test) is needed only if common cooking practices include non-wood stoves or multi-pot stoves.

30.16. Modifications are required if:

- The pot sizes planned to be used in the target community do not match that indicated for the WBT4;
- The fuel moisture range that will be encountered is not catered for in the WBT4;
- The cooking tasks that will be encountered to not match the cooking task described in the WBT4;
- The operation of the stove is likely to be something other than a high power-low power sequence prescribed in the WBT4.

The description of Appendix 2 has been modified to be less exclusive.

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***Preparing the Laboratory***
Standard pots:

30.17. There is rarely such a thing as a standard pot and as the pot size (both volume and diameter:depth ratio) can have a significant effect on emissions and thermal performance, any stove assessment should include the range of pots that will be encountered. This often includes a large pot for preparation of a staple such as maize or rice, another for heating water and yet another for cooking meat or vegetable dishes. In many cases it includes a 20 or 25 litre metal container for heating bath and washing water.

The stoves must be evaluated using the pots for which they were designed and those which are likely to be encountered in the target community. All other things being equal, it has been found that some stoves may emit up to 100% more CO when one pot is substituted for another. The thermal efficiency can also vary considerably for obvious reasons.

These issues are addressed in the expanded description of fuel and pot selection.

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***Determine the local boiling point***

30.18. The local boiling point varies with atmospheric pressure (determined primarily by altitude above sea level and to a lesser extent local weather) and the tester should be prepared to adjust the evaluating mathematics for each test. Another method is to use the highest water temperature obtained during the test as the boiling point.

The spreadsheet will update the other calculations based on the local boiling point provided by the tester.

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***The cooking system includes a stove, a fuel, a pot, and an operator.***
All four affect the performance of the system. You should use the same fuel and pot for each test if you wish to compare design changes.

30.19. One should use the same set of pots and power levels in order to evaluate a stove, not a single pot and power level for all tests. A design change may have large consequences for emissions or performance at a point outside the WBT4 performance points.

Advanced testers using the WBT may find this comment useful and this comment has been made publically available to accompany the WBT. This issue may also be addressed with further discussion and study.

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***Testing a New Stove***

30.20. New stoves often have ceramic components which contain unknown amounts of moisture. The WBT4 does not count for moisture evaporated from the stove body during the test - apparently it is not expected that the test will be conducted on a scale. It is important that the loss of mass be determined be weighing the stove or its components before and immediately after each test. It is helpful to run the stove first to drive off any moisture before conducting any tests. This should be done with a small fire if the stove has large ceramic components because they can easily be damaged if fired quickly when new.

These suggestions have been incorporated into the section on new stoves.

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Determine the *type of pot* you will use, and record its size and shape. The 7-liter pot should be used unless the stove is designed for a much smaller pot and cannot boil 5 liters of water, *or* the stove is designed for a specific pot.

30.21. A single pot should not be specified. It should be the shape and size for which it is being designed, or for the range of pots that will be encountered in the target community.

These considerations are incorporated in the description of pot selection. Advanced testers conducting the WBT may find this comment useful and this comment has been made publically available to accompany the WBT.

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It will take 1½ - 2 hours to do the high and low power test for each stove.

30.22. A proper engineering evaluation of stove performance does not normally require lengthy tests. Once the system is stable and the performance continuous, a determination can be made of the power level, the emissions and the fuel burn rate. It is recommended that the scale upon which the test is conducted by accurate to 0.1 g so that the fuel burn rate can be determined to an accuracy of approximately 25 watts after 10 minutes of continuous operation (biomass stove at 2 kW).

30.23. It is common for stoves to take about 5 minutes to stabilise at a new power level, sometimes longer. This can usually be seen on the fuel burn rate chart and the emissions chart, presuming readings are taken at about 1 minute intervals. High mass stoves take longer to stabilise. Once the system reaches a stable state, a determination of the burn rate, the emissions and the system's thermal efficiency can be made. Such sections of a test can take 15 to 20 minutes each. It is advisable to do both 'wood mostly' and 'charcoal remaining' tests to determine the variations. If the power level is too low to maintain a boil, it is essential that the pot be replaced with one containing cold water. After any such change, a waiting period of 5 minutes is recommended to let the system stabilise.

Suggestions are welcome for references for advanced testers to help them test additional variables and conduct these types of engineering evaluations.

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For the ***cold-start high-power test***,

30.24. The operation of the stove at high power for twice as long as it takes to boil a large pot invests a great deal of heat into high mass stoves which is recovered during the simmering phase of the test. In some cases the simmering task can be accomplished without using any additional fuel at all, completely misrepresenting the true performance. As the simmering test is a task, not much useful information other than emissions at that power may be obtained. If the pot is replaced with one containing cold water, the system efficiency at low power may be calculated. Note that Simmering Power and Low Power are not the same thing.

30.25. It is often found that the maximum system efficiency (thermal) is when operating at a medium power level. As the WBT4 is a laboratory tool primarily for design evaluation, it is essential that the thermal performance be determined at various power levels. Trying to replicate a test at a predetermined power level is difficult for biomass burning stoves. Plotting the performance (emissions, efficiency, CO/CO2 ratio and so on) against the power level is very helpful in spotting trends and creating

performance curves. It must be kept in mind that the type of fuel and the relative quantity of wood vs char burning at the time be known. Long, task-based tests with varying fuel are inherently inaccurate thus shorter tests are to be preferred.

Advanced testers using the WBT may find this comment useful and this comment has been made publically available to accompany the WBT. This issue may also be addressed with further discussion and study.

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The ***simmer test*** provides the amount of fuel required to simmer a measured amount of water at just below boiling point for 45 minutes. This step simulates the long cooking of legumes or pulses common throughout much of the world.

30.26. Cooking food is not an effective way to determine the characteristic performance curves for a stove. It is merely a lab-based cooking test. A lab test should yield performance numbers for evaluating the effect of changes made to the appliance or its operation.. Once these are known, a cooking test, in fact many different cooking tests, can easily be simulated on a computer aggregating information from the fuel use and emissions profiles garnered from the performance charts. Task-based tests cannot be disaggregated into the component profiles. A boiling-simmering task does not give enough information about a stove's performance to make general statements about its performance.

Advanced testers using the WBT may find this comment useful and this comment has been made publically available to accompany the WBT. This issue may also be addressed with further discussion and study.

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The metrics provided by the WBT are:

For comments 30.27 – 30.35, these comments are reflected in the detailed descriptions of the metrics. For comments that specific WBT metrics do not indicate additional values, the descriptions of the metrics are worded carefully to indicate the bounds of what is being measured. The metrics and their definitions have been updated to address the concerns raised here. Some of these comments are addressed in other sections of the WBT, for example the box on improving repeatability. Advanced testers may be interested in evaluating additional variables in their stove testing.

⇒ time to boil;

30.27. It provides the time to boil on high power and does not indicate what the time to boil would be for other power levels, even if they are more fuel efficient.

⇒ burning rate;

30.28. It gives the fuel burn rate aggregated over the whole portion (boiling or simmering) of the test. It is not possible to determine the maximum power rating or the turn-down ratio of the stove from a WBT4.

⇒ specific fuel consumption;

30.29. The specific fuel consumption to boil uses the water mass remaining at the end of the section of the test in the denominator. It assumes that the water boiled away during the test was removed using 'free energy'. This is a fundamental error and should be corrected. There is no free energy.

The specific fuel consumption for simmering (a task) has been agreed as the average mass of water in the pot during the performance of the task. It does not matter much as simmering has a thermal efficiency of zero per cent so the mass is inconsequential.

⇒ firepower

30.30. As mentioned above, the determination of maximum firepower is not determined in a WTB4. The WBT4 gives the average firepower based on the erroneous assumption that the average fuel moisture content has not changed during that portion of the test, factored for remaining fuel that is obviously char. The accuracy of the results of this portion of the test vary with the stove type. Some stoves are batch loaded and the energy used during the boiling phase is often under-estimated as most of the fuel moisture will have been driven off during the boiling. As written it favours stoves which burn sticks at one end as the intrinsic error is reduced. The difference between these two stove types is aggravated if the fuel has more moisture.

⇒ turn-down ratio (ratio of the stove's high power output to its low power output);

30.31. The WBT4 does not determine the turn down ratio of the stove. It reports the ratio between the average high power rating (not the high power) and the power level needed to maintain a simmer (not the low power). The low power level of a stove can only be determined by running the stove at a low power, which may be far lower that that required to simmer a large pot of water. In addition, if the lid is removed from the pot, the calculated 'turn-down ratio' is reduced even more as the stove must operate at a higher power to maintain a simmering temperature.

⇒ thermal efficiency (for high power tests only)

30.32. There is no meaningful manner in which to conduct a 'high power test' for an open fire, thereby establishing a baseline for fuel savings and emission reductions. Tests should performed at various power levels and the results charted appropriately. The thermal efficiency at medium and low power can easily be determined by operating the stove at those power levels with a pot of cold water in place. The heat gained in the pot is an accurate indication of the system efficiency whatever the power level.

⇒ emissions per fuel burned

30.33. While the emissions per unit of fuel mass burned is indicative of performance, it is normal for engineering evaluations to report emissions per MJ of potential heat in the fuel consumed. For example CO should be reported as g of CO per MJ.

⇒ emissions per task (water boiled or heat generated)

30.34. Emissions should be reported in standard formats: mg of CO per MJ.

⇒ combustion efficiency (fraction of fuel burned completely)

30.35. The combustion efficiency is not the fraction of fuel burned completely. It is the heat actually yielded divided by the potential heat that could have been yielded. The burned fuel may or may not be completely burned. It is normally expressed as the ratio of CO to CO2 though there are reasons to fine tune this ratio.

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Footnote 2: While a lid helps to retain heat in the pot, and is often used for any actual cooking task, it does not affect the transfer of heat from the stove to the pot. Lids complicate the WBT by increasing the variability of the outcome and making it harder to compare results from different tests.

30.36. Lids do indeed help retain heat. The reference to lids 'increasing the variability of the outcome' is a red herring. It comes from the days when it was thought that the thermal efficiency during simmering could be determined and had meaning. The thermal efficiency of simmering is zero, by definition, as the enthalpy is the same throughout the simmer (no work is done). Water boiled off during simmering does not give a meaningful evaluation of the heat transfer efficiency nor the system efficiency because it is a small value compared with the untraced losses from the pot and radiated from the water surface.

What was being referred to is the measure of water boiled off during simmering or during low power. As that quantity can be varied by running the stove at a slightly higher power, early testers believed the simmering was 'more efficient'.

The heat transferred into a pot includes the untraced heat lost from the sides and top. The 'missing water' approach to determining the heat transfer efficiency to the pot is highly misleading. 'Back in the day' it was believed that the 'efficiency' number was the heat transfer efficiency, not the system efficiency, which is usually quite different and is what the WBT4 reports. There still seems to be some confusion about what that calculation determines. It is the system efficiency, but still fails to take into account the heat gained by the pot and lost through means other than heated or boiled water.

Test should normally be performed with the lids on, first because it allows the stove to be operated at a lower power and second because that is what people normally do in most countries. Leaving off the lid results in a lower reported 'turn down ratio' and gives a misleading specific fuel consumption number. In addition, many stoves are designed for pots with lids and will not bring an open pot to a full boil if it is off. In those cases where the pots will be used without lids, testing should reflect this so the designer is not misled.

This important issue has been added to Appendix 8 (Remaining Challenges).

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***Continuous:*** Weigh the unburned wood removed from the stove together with the remaining wood from the pre-weighed bundle.

30.37. This procedure assumes that the moisture content of the fuel removed is the same as the moisture in the original wood sample. For stoves that burn sticks on the end, the difference is relatively small. However, for batch loaded stoves there may be a large difference.

For a reasonably accurate determination of the energy offered to the pot during a stove test, the fuel should be dried to determine the moisture content of the remaining unburned fuel.

This suggestion to dry wood is included in the WBT.

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The tester must try to keep the simmering water as close as possible to 3 degrees C below the local boiling point.

30.38. Testers have reported that this task is very difficult to accomplish. Simmering is often defined by cooks as being a low boil – enough activity in the pot to stir the hot water. A cooking task should reflect this.

Suggestions have been added to help testers keep the temperature within the defined range. Other tests are suggested for reflecting local cooking practices.

30.39. For a lab performance test, simmering is a test of operation at low power. As the thermal efficiency cannot be determined at low power unless there is cold water in the pot, it is of limited value. The simmering task should be used in a CCT, not a lab test nor a Field Water Boiling Test.

This concern is addressed in the updated description of thermal efficiency.

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Footnote 3: The tester should not attempt to reduce power by splitting the wood into smaller pieces.

30.40. In some cases stoves are operated with split wood in order to allow for fine control over the power level. This instruction can only harm the rating of stoves that burn larger fuel. If the test is of a cook's ability to maintain a small fire (which is not a test of the stove at all) then it has to be fair for all stoves. It is a given that small pieces of wood (for example) will allow the operator to build a smaller fire. It shows that the usefulness of such a test is limited. It is not a test of the stove but of the operator.

This footnote has been removed from the WBT document.

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***It is the tester's responsibility to ensure that stove operation after these changes, or any other changes implemented to reduce variability, is just as representative of field conditions as the standard protocol.***

30.41. The standard protocol is not at all representative of field conditions, as expressly stated in the beginning and as has been shown countless times by comparisons between lab and field tests using the WBT3.

In particular, the test has historically been done with artificially dried fuel, with no lids on the pot, with simmering at an arbitrary temperature, with a single power level for boiling and another for simmering, a single pot with a single load (save in special circumstances).

Unless the tests are plotted in a heterogeneous manner showing performance vs power, little can be learned by performing WBT's. A test that can reproduce misleading or unrepresentative results has little value.

This comment has been removed from the WBT document. Results are reported separately for the different power levels. These comments have been made available for advanced testers to help them test additional variables in this heterogeneous manner.

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1. Fuel
*a. Type*: Wood with high heat content (between 20-21 MJ/kg), and without excessive pitch content, should be used for all tests. Choose one wood which is used widely in the region.

30.42. The fuel should be representative of fuels and moisture contents likely to be encountered in the target community. Emissions vary widely with moisture content.

*b. Dimensions*: Different sizes of solid fuels have different burning characteristics. Some laboratories have used wood with cross-sectional dimensions of 1.5 cm x 1.5 cm.

30.43. The size of fuel used should be representative of fuels likely to be encountered in the target community.

*c. Moisture content*: All testing should be carried out with wood of low moisture content (values used have been 6.5% or 10% on a wet basis). This reduces variability but may make combustion unlike field conditions.

30.44. The moisture content of fuel used should be representative of fuels likely to be encountered in the target community. Accounting for the moisture in the fuel should be an intrinsic part of an improved test protocol for stove performance.

Regarding comments 30.42-30.44: The suggestion for fuel is in the box devoted to improving repeatability of results. Other sections that describe fuel selection provide guidance on selecting fuel that takes into consideration what is used regionally. Instructions for measurement of fuel moisture is included in the WBT.

2. Initial Water Temperature: A fixed initial temperature can be chosen for the water rather than relying on ambient temperature (15 C has been used).4

30.45. The initial water temperature should where possible be such that an 80 degree rise to the boiling point is possible, as compensation made for this in the calculation.

The spreadsheet bases calculations based on initial water temperature.

3. Cooking Pot*:* The tests should be conducted with either a large standard pot (with a 7 liter capacity) or a small standard pot (with a 3.5 liter capacity), depending on the size of the stove.

30.46. The pots selected for testing should cover the range of shapes and sizes expected in the target community. This may include pots, frying pans, water drums, three-legged pots and kettles.

The guidance for pot selection includes the suggestion to use locally available pots. Advanced testers may be interested in evaluating additional variables in their stove testing.

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The temperature-corrected time to boil and specific consumption should still use a reference temperature of 25 C for comparability with other tests.

30.47. The standard temperatures of start to finish should be corrected to 20 C (Standard lab Temperature) and 100 C. This means the temperature rise is 80 C and the fuel consumption corrected to this value.

Same as comment 30.45.

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***Batch***: Weigh the stove loaded with fuel. Enter the weight of the fuel plus stove on the Test Entry Form in the space for "Weight of wood."

30.48. While slightly out of sequence, I did not find a correction for the charcoal produced partway through the test in a batch loaded stove anywhere in the WBT4.

It appears that the calculated energy offered to the pot in a batch loaded stove is going to be determined by the 'missing mass of fuel'. What is missing may be moisture from the entire mass of fuel, or wood gas but leaving the charcoal intact, or an even cross section of the biomass (for example) so this introduces a large potential error. As the test is only 50% accurate to begin with, the addition of an error this large for batch loaded stoves is untenable. It is recommended that the 'burn-out test' be used instead for any stove for which a reasonable determination of char production and moisture content cannot be made.

Updated instructions for measuring charcoal production in a batch loaded stove have been provided.

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Temp-corrected specific consumption (grams wood/grams water)

30.49. The formula in the draft is unreadable. It should correct to 80 degrees C delta T (from standard room temperature to standard boiling temperature)

Appendix 2 and 4 are currently being updated and will be released when finished.

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p.29 Temperature corrected specific fuel consumption:

30.50. It should be for 80 degrees C not 75 (80 = from standard room temperature to standard boiling temperature)

Same as comment 30.45.

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p.29 Note, by using in this calculation, we have accounted for both the remaining char and the wood moisture content.

30.51. It does not account for char in a batch loaded stove. As a result a batch loaded stove is reported to have used far more heat than it actually did, particularly if the load of fuel is partially burned.

Same as comment 30.48.

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The useful firepower is the average rate of energy released from fuel combustion that is transferred to the pot over the duration of the test. This value is useful for only high power testing.

30.52. This statement is misleading. The calculation actually gives the net heat retained in the pot. It is not a measure of heat transferred to the pot. The statement reflects a misunderstanding of the difference between the heat transfer efficiency and the net system efficiency. This value is useful at any firepower provided the water in the pot is cold.

It should be calculated for a variety of power levels and the results plotted on a chart to give a system efficiency performance curve.

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p.30 The assumption made in this test is based on the amount of char present when the water first boils.

30.53. This error is not one that was present in WBT3 and must be factored in with the other intrinsic errors.

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p.31 Δ*EH2O,simmer* Change in energy of the water (kJ)

30.54. There is no point in calculating the change in energy in the water during simmering as it is a dimensionless task and cannot be assigned an efficiency. The change in enthalpy, if any, will be negative and no meaningful number can be calculated from it.

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*TDR* Turn-down ratio

30.55. As mentioned above, this is not the turn down potential of the stove. As WBT4 has it, it is the ratio of high power to the power needed to simmer a large pot with the lid off. It is likely to grossly under-estimate the actual turn-down potential of the stove by 100% or more.

In the case of low power ethanol stoves it may be out by 300% or more.

Same as above.

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Whereas the specific consumption in the high power tests (SCc and SCh) indicated the mass of fuel required to produce one liter (or kilogram) of boiling water, the specific consumption in the simmer phase (SCs) indicates the mass of wood required…

30.56. The WTB4 is a task based test that tries to produce engineering values. The purpose of the boiling test is not to 'produce a litre of boiling water' it is to 'boil a litre of water'. The use of the final mass as the quantity of water boiled is conceptually incorrect. All the initial water was boiled and some remains at the time the test was completed. The energy used to boil away some of the water came from the fuel burned. It did not boil itself away. The specific fuel consumption is that quantity of fuel needed to bring a litre of water to a boil. It is not the quantity of fuel needed to bring a larger quantity of water to a boil leaving a litre remaining when the test finished.

The language has been updated based on these comments.

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p.32 It is also important to acknowledge that over-reliance on thermal efficiency can lead to misleading results, particularly in the simmer phase.

30.57. The misleading result is that it is possible to refer to the thermal efficiency when simmering. Without a means of determining the heat transfer efficiency between the hot gases and the pot, there is no point in reporting the 'system efficiency' for a task that generates no change in enthalpy.

This concern is addressed in the protocol document.

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Thus, producing excess steam, while it does reflect wood energy transferred to the cooking pot,

30.58. That is a continuation if a misunderstanding that goes all the way back to Baldwin (1987).
The language quoted is part of a section that describes the caveats for interpreting thermal efficiency.

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….the burning rate and specific consumption at high and low power, and the turn-down ratio, which indicates the degree to which power output from the stove can be controlled by the user.

30.59. It does not indicate the degree of control over power. As stated above, it is a measure of the power used to boil with the power needed to simmer a large open pot. It is not a meaningful metric. The ratio between high and low power is a meaningful metric but the WBT4 does not evaluate this ratio.

Same as above.

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**Appendix 5. Statistics Lessons for Performance Testing**

30.60. This section does not indicate the intrinsic error for its evaluations. According to Penn Taylor (2008 and 2009) it is about 50%. The statistical section looks for results with a confidence of 95% using a test that has an error of 50% built into its protocol.

The error for batch loaded stoves that are not getting their char separated will be much higher.

The instructions for char separation for batch fed stoves has been updated. The important issue of intrinsic error calculation has been added to Appendix 8 (Remaining Challenges) and can be combined with the statistical analyses described in Appendix 5.

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p.50 ***Pot insulation***
(Morgan DeFoort, Colorado State University)
The use of insulation above the water is another change proposed to reduce variability.

30.61. This is a continuation of the misunderstanding that the efficiency of simmering is always zero.

The insulation of the top of the water does not increase the accuracy of measurements. It changes the thermal performance of the system and should be avoided at all times. If one wants to determine the system efficiency at low power, put a pot of cold water on the stove and run it at low power. It will deliver the correct answer.

The Communities of Practice may be a good mechanism to continue discussing this issue.

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***Power to Boil***
(H. S. Mukunda, CGPL, Indian Institute of Science, Bangalore)
A stove might operate inefficiently if too much power is provided for the needed task. Test results are highly dependent on the power level chosen. Some guidance should be provided for acceptable ranges of firepower needed to boil the standard 2.5L and 5L of water. We should collect data on observed firepower from regional testing laboratories to provide a range for users.

30.62. This again speaks to the need to conduct tests without making reference to a 'standard pot'. There is no such thing a standard pot any more than there is a standard meal. Mukunda's point is that a test does not have to be conducted at high power. It is not a race. It is an evaluation of performance and there are many existing reporting formats for evaluating flame based appliances such as water boilers, furnaces and cooking stoves. The buyer and promoter want to know the thermal performance under a variety of conditions using a range of pots and a spectrum of fuels and moisture contents.

Thank you for this comment.

30.63. The WBT4 is very similar to the WBT 3 in most important respects. It is not accurate enough to be relied on for incrementally developing a stove and it is certainly not representative enough of real cooking to make a meaningful prediction of which stove may best suit a community.

The WBT has been updated to provide clearer guidance on what it measures and what is better suited for other tests.

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**31. Universidad Nacional Autónoma de México (UNAM)/GIRA, Submitted on 11/24/2009**

**First Name: Alejandro**
**Last Name: del Valle Reynoso**

Comments:
31.1. first of all, I'm very glad you are working on a better test and look forward to a little discussion on a few issues on the last WBT (which we made a little adjustments to in order to have a measurable and

standardizable feeding rate), not without taking a dive into the latest version which I got this morning from GIRA's Victor B. He and us at the UNAM's Eco-technology unit testing a new version of the Patsari and a catalytic device on a new combustion chamber in the same stove. I also have a lot of interest in how others have been doing emissions measuring, since we are also doing it but without previous experience. So I will go through the document and be in touch.
Kind regards to all.

Alejandro

Thank you for your comments and support.

**32. University of California, Irvine, Submitted on 12/19/2009***

***Additional documents were too large to include in this compiled document. They have been attached separately.

**First Name: Michael**
**Last Name: Johnson**

Comments:
Submitted on behalf of Dr. Michael Johnson and Dr. Rufus Edwards of the University of California, Irvine, and Dr. Omar Masera of the National Autonomous University of Mexico.

32.1. We agree with the protocol's statement "Laboratory test results might differ from results obtained when cooking real foods with local fuels, even if efficiency and emissions were measured in exactly the same way for both tests. In order to confirm that stove projects are having the desired impact (whether it is fuel conservation, smoke reduction, or both), the stoves must be measured under real conditions of use…. This (field) test is critical if project designers wish to justify claims about real impacts on fuel consumption resulting from the stoves that they are promoting. Such claims cannot be based on lab-based tests alone." However, given the discrepancies studies have shown between controlled tests and normal stove use in emission factors and fuel consumption (Bailis et al., 2007; Berrueta et al., 2008; Geller and Dutt, 1983; Gill, 1987; Johnson et al., 2008; Johnson et al., 2009b; Manibog, 1984; Roden et al., 2006; Roden et al., 2009; Smith, 1989), we suggest that the protocols explicitly state that WBTs should not be used in the determination of CO2-equivalent savings nor used to estimate contributions to GHG emissions or air pollution.

This suggestion has been incorporated into the Introduction.

32.2. Although not specifically applicable the revised water boiling test, we strongly suggest further development of laboratory tests which better approximate field conditions. As a starting point such testing may be aided by the following:

• We have many new economical sensors that report CO2, CO, PM and hydrocarbon concentrations in real time. We should be using these to derive minute by minute data on the combustion performance.

• We should be using a batch loading in the tests the time intervals for the batch loading can be calculated theoretically depending on the burn cycle you want to achieve by using Prasad's approach (Prasad et al., 1985).

• We should be replicating burn cycles that are representative of burn cycles in the field during daily cooking activities

• We should be monitoring using the CO/CO2 monitors so we can create similar emissions profiles on a minute by minute basis.

A new approach using these ideas is presented in (Johnson et al., 2009a), which has been uploaded.

Bailis, R., Berrueta, V., Chengappa, C., Dutta, K., Edwards, R., Masera, O., Still, D. and Smith, K.R.: 2007, 'Performance testing for monitoring improved biomass stove interventions: experiences of the Household Energy and Health project', Energy for Sustainable Development 11, 57-70.
Berrueta, V.M., Edwards, R.D. and Masera, O.R.: 2008, 'Energy performance of wood-burning cookstoves in Michoacan, Mexico', Renewable Energy 33, 859-870.
Geller, H. and Dutt, G.: 1983, 'Measuring Cooking Fuel Economy', Woof Fuel Surveys, Food and Agriculture Organization of the United Nations, Rome, pp. 148-178.
Gill, J.: 1987, 'Improved stoves in developing countries: A critique', Energ Policy 15, 135-144.
Johnson, M., Edwards, R., Alatorre Frenk, C. and Masera, O.: 2008, 'In-field greenhouse gas emissions from cookstoves in rural Mexican households', Atmos Environ 42, 1206-1222.
Johnson, M., Edwards, R., Berrueta, V. and Masera, O.: 2009a, 'New Approaches to Performance Testing of Improved Cookstoves', Environ Sci Technol.
Johnson, M., Edwards, R., Ghilardi, A., Berrueta, V., Gillen, D., Frenk, C.A. and Masera, O.: 2009b, 'Quantification of Carbon Savings from Improved Biomass Cookstove Projects', Environ Sci Technol 43, 2456-2462.
Manibog, F.R.: 1984, 'Improved Cooking Stoves in Developing Countries: Problems and Opportunities', Annu Rev Energy 9, 199-227.
Prasad, K.K., Sangen, E. and Visser, P.: 1985, 'Woodburning Cookstoves', in Hartnett, J.P. and Thomas F. Irvine, J. (eds.), Advances in Heat Transfer, Elsevier, pp. 159-317.
Roden, C.A., Bond, T.C., Conway, S., Benjamin, A. and Pinel, O.: 2006, 'Emission factors and real-time optical properties of particles emitted from traditional wood burning cookstoves', Environ Sci Technol 40, 6750-6757.
Roden, C.A., Bond, T.C., Conway, S., Osorto Pinel, A.B., MacCarty, N. and Still, D.: 2009, 'Laboratory and field investigations of particulate and carbon monoxide emissions from traditional and improved cookstoves', Atmos Environ 43, 1170-1181.
Smith, K.R.: 1989, 'Dialectics of Improved Stoves', Economic and Political Weekly 24, 517-522.

This continues to be an important goal.

Attach Comments:
**http://www.pciaonline.org/files/webform/wbt_comments/johnson%20et%20al%2...**