A call to stop using the Water Boiling Test

Dear Sir, dear Madam,

Local solid fuels play a major role in meeting the cooking and heating needs of about 3 billion people worldwide. For at least 40 years, stove designers have been innovating combustion devices to improve fuel efficiencies and reduce pollutant emission loads. Many improved stoves programmes have been funded and implemented over the years, all over Asia, Africa and Latin America, but they have not scaled rapidly. Many have failed and proven unsustainable.

A principal culprit is the testing approach to such stoves in laboratories.

The Water Boiling Test (WBT) protocol is the most widely used stove testing protocol, it has been used for years by the cooking stove community of implementers, manufacturers, and testers. The testing protocols are important tools: their role is to measure the performance of a stove in terms of fuel savings and reduction of noxious emissions. There has been different iterations of the WBT since its creation in 1982: the WBT, the WBT 2.0, 3.0, 4.1.2. and 4.2.3.

An increasing number of studies has been published over the years about serious issues with the WBT**.** And **there are now enough proofs showing that the WBT, including its latest version 4.2.3, is unable to assess the performance of an improved cookstove**, neither in the lab nor in the field.

Additionally to that, many stakeholders have complained about the huge variations in stove performance between what was reported in the lab, and in the field. It is now well established that the WBT should not be used to predict how a stove performs in a given context.

In February 2017, a study by Lombardi and al. summarized the issues:

« Some of WBT critical issues remain unsolved. In particular, the main weakness of the WBT concerns its real-life relevance. […] Criticism about WBT concerns also the repeatability of the protocol, with a number of researchers claiming that it would need to be reviewed in terms of accuracy. […] As a matter of fact, uncertainties related to temperature reading and vaporisation in the boiling region lead to high variability between test replicates.

A lot of debate has been made around formulation of metrics, primarily on thermal efficiency, which is often interpreted as the most immediate and distinctive stove performance parameter. Studies from Bailis et al. highlighted how relying on WBT thermal efficiency outputs, regardless of the relative importance of high and low power cooking tasks

among the target population, can lead to misleading interpretations. Furthermore, Zhang et al. and Jetter et al. questioned the scientific meaningfulness of thermal efficiency at simmering.

Finally, some unsolved issues concerning statistical significance of data are worth mentioning. WBT 4.2.3 includes “Statistic Lessons for Performance Testing”. The appendix specifies that the minimum number of test replicates for each model of stove should be three, […] Wang et al. investigated this topic using a simplified version of the WBT 3.0 and demonstrated that more than 5 replicates are likely to be required to avoid impractically large 95% confidence intervals and that even more replicates may be required to demonstrate a statistically significant difference in performance between two or more stoves. »

Despite the several updates of the WBT protocol over the years, none of the issues could ever be solved.

The recent conversations on the cooking stove discussion list of the Bioenergylist, specialized in state-of-the-art stove science, showed that there were no solutions to fix the WBT protocol.

Good science and reliable testing is at the core of every stove product development, and every stove project or programme.

It is difficult to measure the damages done by the use of a faulty testing protocol. How well do we really know about the lab or field performance of the stoves? How many test results are useless? How many stove projects or companies failed because of a test that was problematic in the first place? How many efforts, how much money was lost?

Before being able to do meaningful and impactful stove projects, we need to get the testing right.

Alternative testing methods to the WBT exist already. They allow accurate measurement of the stove performance, both in the laboratory and in the field, they allow for repeatability. They were reviewed, while the WBT never was. These alternative testing methods are listed below in this document and links are provided.

We are a group of concerned implementers and researchers. We have launched a call to stop using the Water Boiling Test 4.2.3. To stop using it to certify, select, as well as develop stoves.

Your organization is one of the stakeholders of the improved cookstove sector.

Today, **we need your help to make sure cookstoves are developed and selected according to reliable testing methods.**

We are asking your organization to support this effort and **stop using the WBT in its projects and programmes, as well as stop funding or supporting projects, programmes and companies who use the WBT.**

We are asking your organization to **support the use and development of scientifically valid alternative protocols.**

Your role is critical in promoting good science, good stoves and ultimately making a positive impact in the field.

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Studies on the WBT and its issues

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- Lombardi F., Riva F., Colombo E., Guidelines for reporting and analysing laboratory test results for biomass cooking stoves, 01/2017
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http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.461.783&rep=rep1&type=pdf

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- L'Orange C., DeFoort M., Willson B., Influence of testing parameters on biomass stove performance and development of an improved testing protocol, 2009
https://envirofit.org/wp-content/uploads/2016/06/2012-influence-of-testing-parameters.pdf

- Gorrity M., Trujillo G., Quality assurance for cookstoves testing centers: calculation of expanded uncertainty for WBT, 2013
http://www.newdawnengineering.com/website/library/Stove%20Testing/Testing%20Protocols/American%20WBT,%20CCT,%20KPT/2014%20March%20WBT%204.2.x%20Uncertainty,%20Gorrity,%20M.pdf

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http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.1000.3936&rep=rep1&type=pdf

- Zhang Y., Pemberton-Pigott C., Zhang Z., Ding H., Zhou Y., Dong R., Key differences of performance test protocols for household biomass cookstoves. Twenty-Second Domestic Use of Energy, IEEE 2014:1–11., 2014
  http://energyuse.org.za/document-archive/
  To access the file, select DUE [Domestic Use of energy COnference]. Select DUE 2014. Select PROCEEDINGS. Select paper by Zhang etal (PDFs arranged alphabetically).

- Wang Y., Sohn MD., How many replicate tests are needed to test cookstove performance and emissions? — Three is not always adequate., 2014
  http://gadgillab.berkeley.edu/wp-content/uploads/2014/03/D-13-00075-Wang-et-al._final.pdf

- Lloyd P., Annegarn H., Pemberton-Pigott C., Towards a standard for clean solid-fuelled cookstoves, 2015
  https://www.researchgate.net/publication/274706950_Towards_a_standard_for_clean_solid-fuelled_cookstoves

- Zhang Z., Zhang Y., Zhou Y., Riaz A., Pemberton-Pigott C., Annegarn H., Dong R., Systematic and conceptual errors in standards and protocols for thermal performance of biomass stoves, 2016
  https://www.researchgate.net/publication/309689616_Systematic_and_conceptual_errors_in_standards_and_protocols_for_thermal_performance_of_biomass_stoves

Notable alternative testing protocols:

- CSI method
- Heterogeneous Testing Protocol (HTP)
- SeTAR Energy Efficiency Test (current version is v1.57)

These protocols can be downloaded from the following Google Drive folder:
https://drive.google.com/drive/folders/0B5rmmRmIsdlnQlRQX3A1cXVOQ3M?usp=sharing

Reviews of the CSI and HTP testing protocols

The HTP was officially reviewed by an external expert group as required by the IWA 2012:11. The World Bank office in Beijing commissioned SGS Netherlands which provided a report after investigating the equipment, test protocol and calculations.

The Ulaanbaatar Clean Air Project test method for approving stove performance is the HTP before the CSI contextual portion was added, though the test conducted is in fact based on current observed practice. The Ulaanbaatar Clean Air Project test method has been reviewed and/or approved by:

- Mongolian University of Science and Technology, Prof Tseyen-Oidov and others
- Ulaanbaatar Clean Air Project, Operations Manager & Chief Engineer, Ms D Tsendsuren
- Dr B Odonkhishig and Dr Jargalsaikhan Buriad, head and Director, respectively, of the SEET Laboratory in Ulaanbaatar
- SGS Laboratories, Netherlands (who conduct most of the stove tests for EU certification), WB contract
- Team experts under Akeo Fukuyama, from the Environment Division of JICA contractor Suuri-Keikaku Co. Ltd.
- Millennium Challenge Account – Mongolia (MCA-Mongolia is the local branch of the Millennium Challenge Corporation, USA) which spend $20m on stove subsidies based on the results of the tests
- National University of Mongolia, Prof Lodoysamba, Innovation Manager, Department of Research (nuclear physicist and air quality expert)
- GTZ building energy efficiency programme in Ulaanbaatar, headed by Ruth Erlbeck (reviewed by her head technical man and a young German MSc physicist Mr Henning Schulte-Huxel who wrote a lot of the chemical balance calculation block on the FUELS tab)

The CSI Test Protocol which includes the contextual test method appended to the HTP test method and calculations has been reviewed by:

- World Bank technical review team for Indonesia (their infrastructure engineer and technical reviewer)
- College of Engineering, China Agricultural University (CAU), Prof Renjie Dong, head of the National Key Laboratory for Biogas, reviewed it at the request of the Senior Economist heading the CSI-Indonesia Pilot
- Yixiang Zhang, PhD candidate, College of engineering, CAU. He has published several reviews of certain aspects of the test method and its calculations.
- Degan Ostogic, Lead Energy specialist (engineer) in the WB Energy and Extractives supervising the CSI-Indonesia Stove Pilot, he also required a demonstration of the method in action.
- The head of stove testing at a Western nation's national regulatory body has reviewed the method for generating the Technical Test from a set of Cooking Tests. This provides the contextual element of the CSI Method.
- Prof Harold Annegarn, nuclear physicist, then at the Department of Geography Environmental Management and Energy Studies, University of Johannesburg
- Engineer David Beritault, formerly with GERES, for years the head of the Cambodian stove testing lab and now with CARITAS Switzerland, made a very

detailed review of the concepts and calculations underlying the method. He is a co-author of ISO TC-285 WG2, 19867 Part 2.

- James Robinson, BSc (Eng), MSc (Eng), MSc (aeronautics), former head of the SeTAR Centre, University of Johannesburg.
- Dr Tafadzwa Makonese, Head of the SeTAR Centre, Research Village, University of Johannesburg
- Indonesian BNI (National Standards Body technical committee) made a conceptual review with the intention of replacing their current Draft National Standard (which at present uses an early SeTAR Centre heat transfer efficiency test protocol, the forerunner of the HTP.