TChar Technology for Cookstoves:

Part A: Introduction

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Definition

TChar ™ (TEE-char) refers to combustion configurations that combine TLUD (TEE-lud) (Top-Lit UpDraft) pyrolytic gasifiers (which make charcoal) and charcoal stoves (which consume charcoal). A TChar stove starts with almost any type of dry biomass as fuel for gas-style cooking while making hot charcoal that is subsequently burned to continue the cooking on a charcoal stove that is the base of the TChar unit.

Advantages include:

1. Less forest degradation. (Reduces typical, inefficient charcoal production).
2. Fuels used are from abundant, less costly biomass closer to users, creating new jobs.
3. Lower fuel costs for each household; savings can pay for the stove in a few months.
4. Greater energy efficiency. (By using gases otherwise wasted in charcoal production).
5. Extremely clean combustion. (Could allow usage of biomass fuels in urban areas).
6. Where charcoal cooking is common, culturally traditional cooking is maintained.
7. Fast-starting high heat in the TLUD phase, followed by continued moderate and low heat with the charcoal cooking phase, which is the normal sequence for most cooking.
8. Very inexpensive stoves because of the simplicity of the TLUD top and the use of common charcoal stoves as the bottom, many of which are already in the households.

The TChar name and close spellings such as T-Char and tchar are reserved as trademarks in order to require users of the name to be consistent with its intended usage as expressed in this document and as determined by the Biomass Energy Foundation (BEF). The preferred spelling is with both the T and C capitalized. TChar is pronounced:

"TEE-char" in English (almost the same as "teacher"),

"TAY-char" in Spanish and Portuguese, or

"TAY-shar" in French (or "Tay-shar-bon" which is written as "TCharbon").

Note: Uses of the letter T (or T- or t or t-) at the start of a term or name concerning cookstoves and associated applications are reserved as trademarks of the Biomass Energy Foundation (BEF) for purposes of denoting the inclusion of TLUD (Top-Lit UpDraft) technology in the associated device, process, fuel or other item. For example, the usage of T-Rock (or TRocket, etc.) denotes TLUD functions incorporated with Rocket stoves.

The Top-Lit UpDraft (TLUD) technology utilizes a vertical container with dry biomass fuel ignited at the top, causing the twin processes of pyrolysis and carbonization (the making of gases and the making of charcoal) to progress steadily downward. The gases move upward and as they exit the stove they are combusted in a flame appropriate for cooking. In TLUD gasifiers, the fuel does not move (except by shrinkage when pyrolyzed). Instead, a "pyrolysis front" moves downward through the mass of fuel, converting the biomass to char. Unique among the gasifiers, TLUDs do virtually all of the biomass pyrolysis or wood-gasification before doing appreciable char-gasification. The transition between the two phases is quite distinct, changing from a characteristic yellow-orange flame (from burning tarry gases) to a smaller bluish flame that denotes the burning of carbon monoxide. The hot charcoal accumulates in the container until the batch has ended, when it should be transferred to a charcoal stove for continued cooking, or to a container where it is extinguished.

Readers who are not familiar with TLUD terminology (such as pyrolysis zone, concentrator disk, and primary air) and TLUD operations (such as top lighting and air control)) are referred to the reference materials. The GIZ-HERA manual "Micro-gasification: Cooking on gas from dry biomass" (http://www.gtz.de/de/dokumente/giz2011-en-micro-gasification.pdf) explains the differences of burning raw dry biomass and charcoal. Consult the authors or the websites www.bioenergylists.org and www.drtlud.com for abundant assistance on charcoal and TLUD stoves. YouTube videos recommended for visualization of TLUD operations are available at: www.youtube.com/user/drtlud

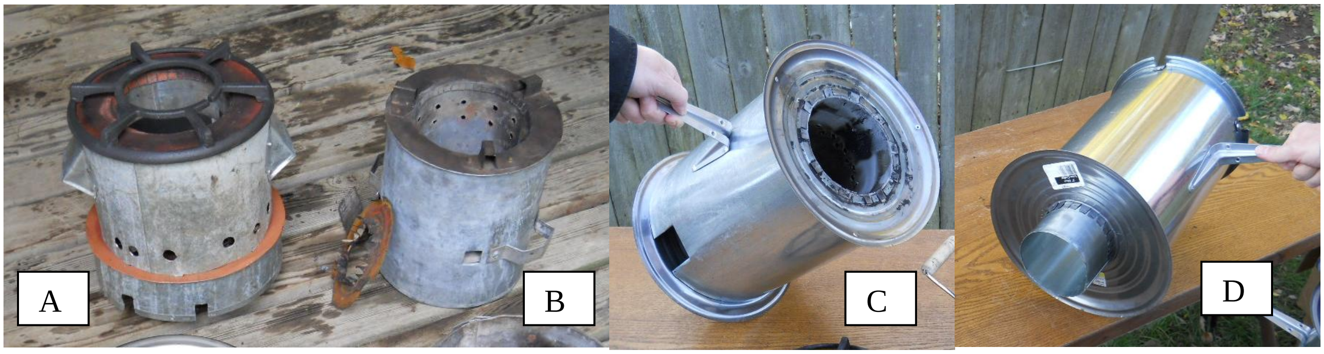
Basic Description of TChar Devices & Methods **(in cookstove terms)**

1. The lower part of a TChar stove is called a "T-Base." It is a charcoal burner that has sidewalls to contain charcoal over a grate which provides air inlets from underneath. It is complete with any pot-rests, handles, etc. necessary for it to be a functional, free-standing, charcoal-burning stove, as seen in Figure 1.

Figure 1: Examples of charcoal stoves that can serve as T-Base units of TChar stoves. A=Double-walled metal; B=Envirofit 2200; C=Single-walled metal; D=Ceramic w/metal clad.

2. The upper part of a TChar stove is a "T-Top" or "TTopper" that functions as a TLUD gasifier. The T-Top is normally a vertical cylinder to hold dry biomass fuel so that it can be ignited at the top in typical TLUD fashion. It is complete with any pot-rests or external pot supports, handles, concentrator ring, outer cylinders, etc. necessary for it to be a fully functional TLUD gasifier stove when placed onto an appropriate T-Base. See Figure 2.

Figure 2: Examples of T-Top sections of TChar stoves. *A= Prototype of Over-fit; B= Prototype of Inside fit; C & D= "Standard" model with On-top placement (shown are 5-9 inch diameters and 4-8 inch diameters of the two cylinders in C and D respectively.)*



When joined to form a complete TChar stove, matched combinations of T-Base and T-Top appear as shown in Figure 3. In this configuration, the charcoal burner serves essentially as an "air-base" (or "T-Base" or "T-Bottom") for entry of primary air into the bottom of the T-Top.

Figure 3: Ten assembled TChar stoves. *At left are two "Standard" T-Tops on a clad ceramic T-Base and an Envirofit 2200 T-Base. The other eight all include prototype components.*

3. Properly loaded and ignited at the top as in standard TLUD stove operations, the fuel is carbonized by a descending pyrolytic front, which is the most distinctive characteristic of TLUD technology. Being a batch operation with user-determined conditions including fuel type, fuel quantity, and air control, the simultaneous processes of pyrolysis and carbonization occur while there is an appropriate flame of combusting "woodgas" delivering heat to the cooking pot. When the woodgas flame ends, the upper part (the T-Top section) can be carefully lifted off and the created charcoal spreads within the T-Base unit that is then used as a charcoal stove to continue the cooking. Additional charcoal can be added as needed. See Figure 4.

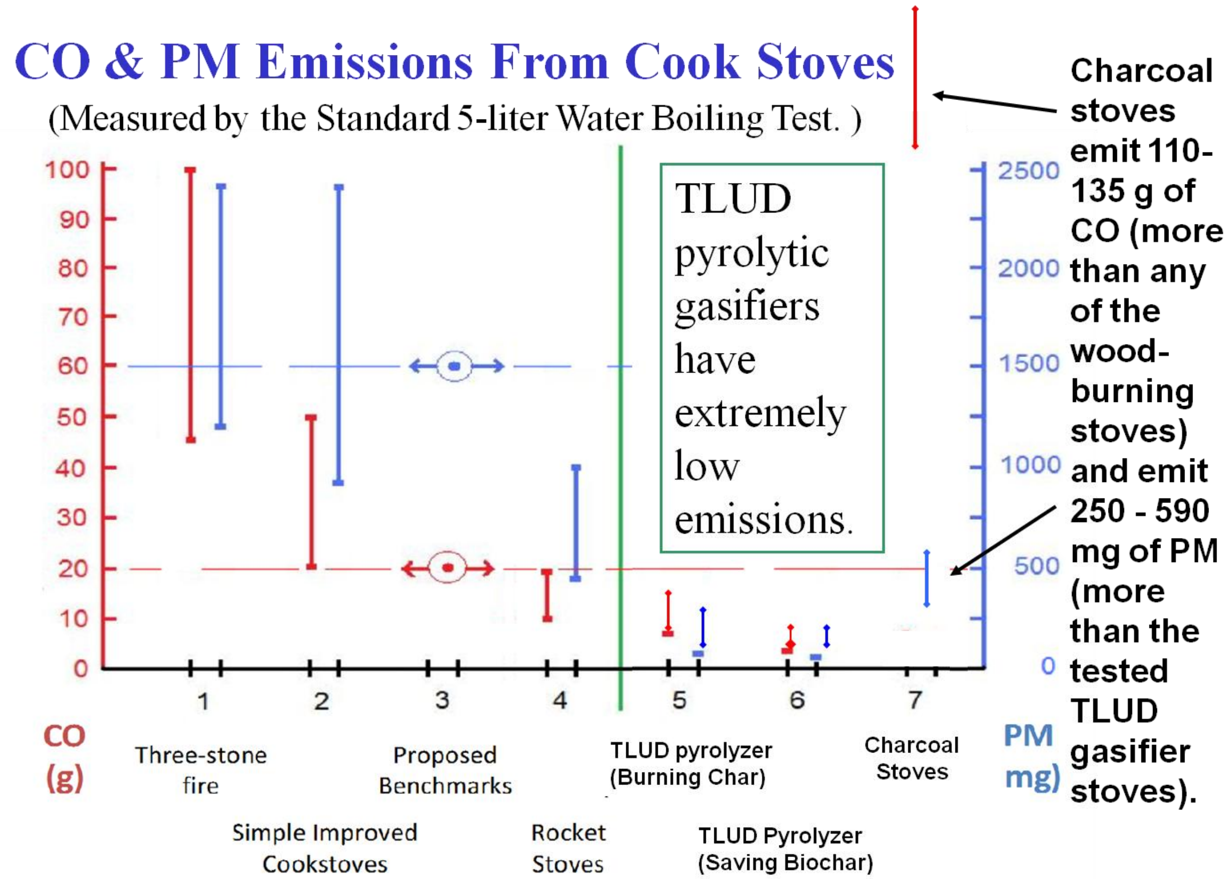
Figure 4. Photographic sequence of TChar operations (In Malawi July 2011). *Left to right: T-Top and T-Base assembled and loaded with bamboo splints; Cooking with TLUD gases; Removing the T-Top; Hot charcoal ready for placement of the pot; Charcoal ending.*

Emissions test results related to TChar Cook Stoves

In the few months since the TChar concept was initiated in June 2011, there have not been any complete tests of emissions and efficiencies with strict observance of methods and multiple repetitions to determine average values and standard deviations. However, simple testing already with the PEMS emissions equipment at both CREEC in Uganda and Zamorano University in Honduras gave preliminary results consistent with prior separate testing of TLUD stoves and charcoal stoves.

In 2005, the first comparative usage of the cookstove-emissions-testing equipment at Aprovecho Research Center (ARC) measured a TLUD stove to have carbon monoxide (CO) and particulate matter (PM) emissions significantly lower than other stoves at the 2005 Stove Camp. (That winning stove was subsequently named “Champion” and today is available with refinements from Servals in India.) Over the years and using the ARC’s PEMS equipment, hundreds of stove-test data-sets have been collected, including several of different models of TLUD stoves. One summary graph of pre-2010 data provided by ARC shows the major types of stoves and the consistency of measurements for each type. All known data from further testing of TLUD stoves is compatible with and serves as confirmation of the results shown in this graph in Figure 5. Please note: The developers of the TChar stoves do not have access to the emissions data files of the entities that conduct the testing.

Figure 5: CO and PM Emissions from Cook Stoves



Because TChar stoves operate in two distinct phases (a) as a TLUD device with pyrolysis while saving char and (b) as a charcoal stove that consumes char, the expected emissions results for TChar stoves during a standard Water Boiling Test (WBT) with five liters of water are the following:

a. The TLUD phase (that will release approximately 70% of the energy) is expected to have emissions of less than 8 grams of CO, and less than 200 mg of PM. These are conservative estimates based on data from *complete* WBT measurements.

b. The charcoal-stove phase is expected to have emissions of less than a third of what would be emitted by whatever specific charcoal stove is being used as the T-Base of the TChar stove. The reasons for these estimates are:

1) The charcoal is already hot and combusting when the charcoal phase starts.

2) The time period of charcoal burning is much shorter because it is only during the simmering part of the WBT.

Therefore, with a Ceramic Jiko as the T-Base (a charcoal stove) that is half of a TChar device, the CO should be less than 40 grams and the PM less than 400 mg. In contrast, an Envirofit Model 2200 as the T-Base is expected to produce less than 15 g of CO and less than 300 mg of PM.

Adding together the emissions from the two phases, the TChar stove is conservatively estimated to emit approximately 25 to 50 g of CO and less than 600 mg of PM, with the majority of the emissions coming from the charcoal-stove phase.

Observation: The TChar stoves have emissions significantly lower than existing charcoal stoves, making them (and other TLUD stoves) the only currently available, low-cost, solid-biomass-fuel stoves that could be acceptable for **urban usage** in developing societies, as well as usage in rural households.

Significance of TChar stoves **(in relation to charcoal stoves and other stoves)**

Charcoal stoves are ancient. They provide heat for cooking with minimal smoke, that is, minimal emissions of particulate matter (PM). As human populations (and their stoves) became more concentrated, urban areas became polluted with smoke from woodfires. (Invisible and oderless carbon monoxide (CO) emissions are largely ignored where charcoal cooking is in well ventilated places such as balconies or cooking shacks.) Whether voluntarily or pressured by neighbors or by govenmment mandates, people cleaned their urban air by shifting from wood to charcoal for cooking. Also, economic advantages of transportation of charcoal versus firewood grow stronger when wood supplies are further away as forests are depleted. In extreme cases as seen in Haiti and many African countries, production and markets for charcoal have severely damaged the environments of large areas and even whole nations.

In general, charcoal is the lowest and least desirable of the *processed fuels* that are now found throughout affluent societies. It is natural that wealthy people would advocate cooking with the better processed fuels of LPG, natural gas, and electricity, most of which is imported in many developing countries. However, this advocacy has three errors: 1) a disregard of the negative environmental impacts of those non-renewable (except hydro-electric) advanced fuels; 2) a lack of awareness of the destruction of existing cooking-fuel industries and employment based on renewable biomass in poor countries; and 3) the financial burden upon the poor, especially when subsidies are cut back.

Instead, what is needed is A) a clean-burning stove that uses locally produced renewable biomass, and is B) acceptable to large numbers of households, and is C) backed up with the development of an appropriate supply-chain of biomass fuels. The research since 2005 is now quite conclusive that Top-Lit UpDraft (TLUD) combustion accomplishes the requirement (A) for clean burning of dry biomass. Requirement (C) can be met with a simple economic response of supply to meet the demand; biomass is abundant for the TLUD-type fuels, and relatively small investments can initiate production that will grow as demand increases. (Certainly the environmental protection advocates should be delighted with this opportunity to stop the harmful practices of charcoal making.)

The challenge during recent years has been to demonstrate (B) the acceptance of TLUD stoves for household cooking, not everywhere and not for everyone, but in large numbers. Supportive data are starting to be presented. Meanwhile, TLUD developers have consistently pointed out the charcoal-creating aspect of those stoves, but with two drawbacks. First, the dumping out of the hot charcoal is somewhat inconvenient and creates safety concerns. Second, leaving the charcoal to burn in the TLUD structure is inefficient in terms of heat transfer (the pot is too far above the glowing charcoal), and the high heat of the charcoal seriously shortens the life of the metal in the lower parts of TLUD stoves. The TChar innovation resolves both of these drawbacks. The created charcoal stays in the base of the TChar stove that is specifically designed to withstand the higher heat and accomplish cooking with charcoal.

In essence, regular charcoal (that could perhaps be called "Reg-char") is usually made in distant places far from the end-user, and all the heat generated in the carbonizaion process is lost while spewing into the atmosphere considerable GreenHouse Gases (GHG). In contrast, a TLUD stove is operated locally by the end-user of the biomass fuel. The useful energy value in the pyrolytic gases emitted in the charcoal-making process is used for cooking in the TLUD phase, applying the low-emission principles of a "gas-burning stove" that makes its own gases from dry biomass fuels. Then the TLUD-made charcoal (that could be called TLUD-char) is burned in the T-Base of the TChar stove.

Note: There is a lack of clear terminology to distinguish between different charcoals by origins (such as by the temperature reached during pyrolysis) or by characteristics (such as content of volatile/mobile matter). Also, this is not "biochar" because the char is being burned, but it does have the generally desirable qualities of biochar that is destined to be placed into soils (as described in the "All biochars are not created equal..." paper.)

Differences and similarities of TChar stoves from charcoal stoves

A TChar stove has a quick and easy start, and a strong flame during many minutes in the TLUD phase. That is followed by operation as a charcoal burning stove that uses the hot charcoal created on location moments earlier. In terms of cooking, this is clean high heat first, followed by lower heat of charcoal, and is exactly what is needed for most cooking.

Other differences and similarities are:

- Simple, safe, and easy to operate, with an almost automatic transition from the pyrolytic phase to the char-burning phase (but the physical removal of the TLUD T-top is not automatic).
- Users can add more dry biomass during the pyrolytic phase.
- Users can add more charcoal during the charcoal phase in T-Base and charcoal stoves.
- Uses TLUD-created charcoal, NOT regular charcoal.
- The biomass fuel is not necessarily wood. TLUDs favor smaller pieces of fuel, utilizing many agricultural and environmental wastes and low value biomass. This reduces the unsustainable pressure on cutting large trees, the cause of forest degradation in many areas.
- Low emissions -- lower than a charcoal stove by itself because of the fast start with TLUD woodgas.
- The stability and safety of a charcoal stove (the T-Base) becomes a feature of TChar stoves that do not need to be moved during the cooking time.

Origin of TChar methods and stoves

Charcoal stoves are ancient, and TLUD combustion was identified in 1985 and has become known for stove usage in the past few years. But only in 2010 and 2011, during small TLUD stove projects in Africa (sponsored by Earth Capital Partners Foundation (UK)), did Christa Roth, Paul Anderson, and Carmel Lloyd have discussions that touched upon the topic of TLUD stoves to ***replace charcoal stoves***. Some TLUD-stove users in Malawi and Mozambique expressed their desire to continue using their charcoal stoves and to fuel them with the char from the TLUDs. In June 2011, Roth, Anderson and Lloyd were together for the Biomass Energy Foundation (BEF) Gasifier Stove Camp at CREEC in Uganda. Discussions led to Roth cutting the bottom out of a Peko Pe TLUD and placing it onto a charcoal stove as a base. Figure 6 shows the sequence of events.

Figure 6: The first TChar stove, in Kampala, Uganda in June 2011.

Assembled and operating.	*Concentrator lid has been removed. The fuel is maize/corn cobs.*	*T-Top (Peko Pe w/o grate) & T-Base (metal charcoal stove)*

In August and September, experimental TChar units were made in Uganda, Malawi, USA, Germany, Haiti, and Honduras by Roth, Anderson and associated stove enthusiasts.

In early October, Anderson spent 24 hours with Robert Fairchild in Kentucky seeking a TChar design appropriate for mass production, most specifically for Haiti. After 6 hours of frustration, the structure now referred to as the TChar "Standard" was conceptualized in the evening, and built and operated the next morning with hardware-store components for the two cylinders and two horizontal plates. They also laid out the proportions for the different sizes of TChar stoves (presented in Part B that continues this document). Fairchild built and took an additional unit to Haiti two weeks later, with several distinctive features. See Figure 7.

Figure 7: Fairchild's October 2011 prototype. *Note the hooks to hold together the T-Top and T-Base; also, there is a pipe in the center of the T-Base for secondary air in the charcoal phase.*

Less than five months after the initial identification of the TChar concepts and devices, presentations were made 1) to include the TChar stoves in the national stove programs being launched in Haiti and Timor Leste, 2) the release of YouTube videos showing TChar stoves in operation (see www.youtube.com/user/drtlud), plus 3) the launching of pilot projects in Malawi, Mozambique, Uganda, India, Haiti, and Central America. Persons interested in conducting pilot efforts about the TChar stoves are strongly encouraged to contact the authors for abundant support and up-to-date communications about TChar development around the world.

Conclusion to Part A

In summary, the TChar method cooks first with pyrolytic gases (created on the spot from dry biomass) and then cooks with charcoal that was created in the same stove. The authors believe that the TChar designs will take their place as significant variations of TLUD technology for cookstoves, along with Wendelbo's Peko Pe, Reed's Woodgas Campstove, Anderson's Champion, Belonio's Rice Husk designs, BP's Oorja, and some others that are taking shape in different TLUD projects around the world.

We expect major advances perhaps yearly involving control of air flows, fuel diversity, applications of the TLUD heat, and social/cultural adaptations. Probably only 20% of what can be learned about TLUD micro-gasification is currenly known. Everyone is welcome to work on the remaining 80%. Virtually all information about TLUD technology is open source and can be freely copied. Micro-gasification is not the re-invention of fire. But it is a re-definition and a new awakening about what can be accomplished with small fires.

There is also much more to the TChar story, and we are documenting it as fast as we can, while at times simultaneously doing research and development of additional features that become evident nearly every day. This document is currently planned to have five parts that can be updated and have annexes or subsections as needed:

A. Introduction	Defining TChar, basic info, importance, origin
B. Construction	Overview, guidelines, specifics, alternatives, production.
C. Operations	Fuels, fire duration, costs, human factors, planning projects.
D. Further Developments	Variations, enhancements, biochar, and visions.
E. Results and Reports	Documentation of projects and impacts around the world.

All interested parties are urged to contact the authors who will assist them to participate according to their goals and circumstances. Initiative is great, independence is fine, isolation is undesirable. Please communicate.

Anderson, Roth and Fairchild, 13 November 2011