TLUD Stoves in 2011 -
Within a Classification of Stoves

(TLUD refers to “Top-Lit UpDraft” gasification)

A Presentation at 2011 ETHOS Conference
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Paul S. Anderson PhD

“Dr. TLUD” (Doc **Tee**-lud) **psanders@ilstu.edu**

Biomass Energy Foundation (BEF)

The Essence of Cookstoves

- **The hearth is the heart of the home.**
- **Cooking is an essential human activity.**
- **Affluent homes have numerous stove devices (cooking, toasting, tea-water, etc.)**
- **Impoverished homes boil, fry, roast, etc on 3-stone fires and simple stoves.**
- **No single stove can do all cooking well.**
- **There can be numerous “best practices.”**

Four Essential Components in Any Successful Stove Project

- **Fuels:** Stored and available energy.
- **Combustion Devices:** Release of the energy.
- **Applications:** Uses of the energy.
- **Human Factors:** Costs, availability, cooking preferences, sizes, social perceptions, marketing, etc.

Applications & Human Factors

- **Many many different stove structures and configurations for "cooking" tasks:**
  - **Large & small; high & low temperatures; slow & fast; chimney or not; pot-skillet-plancha-open-flame; shape of pot bottom; etc.**
- **Unlimited socio-cultural variations of human preferences for cooking:**
  - **Portable & stationary; high & low; color; family traditions; food preferences; marketing & distribution efforts; costs; perceptions; etc.**
- **These are important aspects, but are NOT the best criteria for classifying cook stoves.**

Major Classes of Fuels:

(In General) From Cleanest to Least Clean, From Most Expensive to Least Costly

- **Nuclear, solar, hydro-electric**
- **Gases and liquids from fossil fuels**
- **Gases from biomass**
- **Charcoal**
- **Solid biomass burning**
  - **Rocket stoves**
  - **Simple improved stoves**
  - **3-stone fires**

- ***Not based on combustion***
- ***Carbon positive & non-renewable***
- ***Biogas & Woodgas***
- ***Wasteful production***
- ***Traditional combustion with great variability.***
  - ***Includes wood, residues, and dung.***

Major Classes of Fuels:

- **Nuclear, solar, hydro-, electric** — *Not based on combustion*
- **Gases and liquids from fossil fuels** — *Carbon positive & non-renewable*

Those above can be too expensive and/or non-renewable.

- **Gases from biomass** — *Biogas & Woodgas*

Those below can have much higher emissions.

- **Charcoal** — *Wasteful production*
- **Solid biomass burning** — *Traditional combustion with great variability*
  - **Rocket stoves, simple ICS, and 3-stone fires**

Abundant Renewable Dry Biomass

(but people only use a highly selective small fraction for energy)

Wood **is the main biomass fuel. Collecting stick-wood can lead to deforestation. If wood is plentiful, wood chips are an excellent fuel for the gasifier stoves we will discuss.**

Tree-wastes **sawdust (pellets), trimmings, twigs, seedpods, leaves, coconut shells/husks/fronds, etc.,**

Agro-wastes **stems, hulls, husks, roots, cobs, by-products, dung, etc., some into biomass briquettes,**

Urban wastes **discarded combustibles including paper/cardboard, some D&C, and dried sewage,**

Environmental excesses **bamboo, dried aquatic invaders, reeds from wetlands, etc.**

Some Combustion Basics

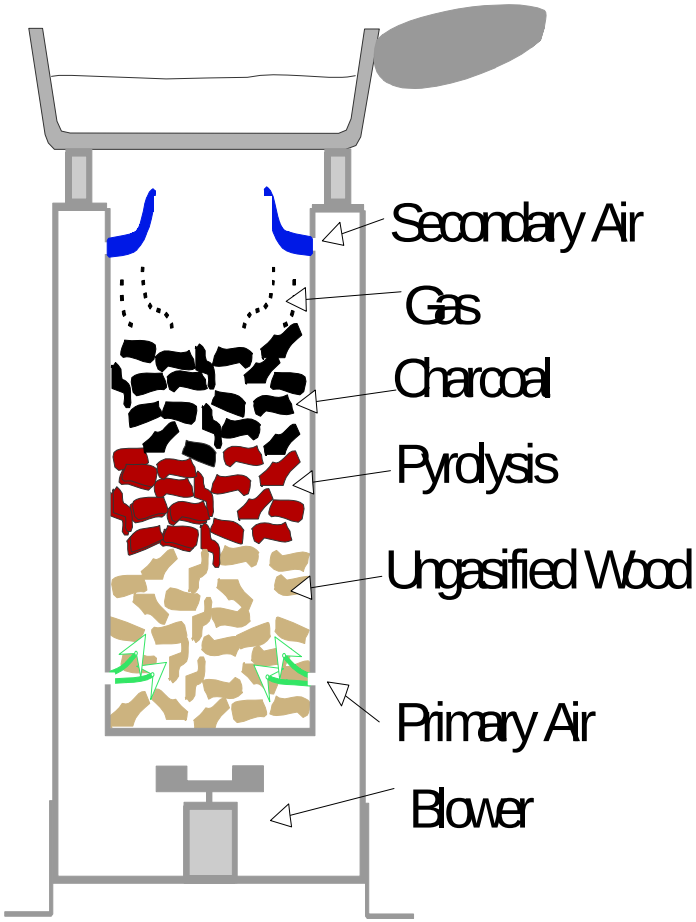
- **Gases can be combusted.**
- **Liquids must be vaporized or atomized.**
- **Solids must undergo "gasification" by pyrolysis and/or char-gasification.**
- **Many of the worst problems of cookstoves are caused by incomplete combustion of dry solid biomass.**
- **New methods of "micro-gasification" of dry biomass have become available since 1985 and are getting better.**

Gasifiers

- **Devices in which the dry biomass is transformed into combustible gases in processes *distinctly and controllably separate in time and location* from the eventual combustion of the gases.**
- **Many types, but only a few designs function with stove-sized fires and can be called "micro-gasifiers," including most of the TLUDs.**

TLUD is “Top-Lit UpDraft”

- **Ignition at the top** of a column of chunky dry biomass creates a down-ward **migrating pyrolytic zone** (or front) that is starved of oxygen, creating **charcoal** plus **pyrolytic gases (“smoke”)** that **move upward** to where fresh secondary air enters, resulting in **clean combustion of the gases** for heat for cooking.



Example with FA:
FA = Forced Air or Fan Assisted

Four World Problems

- **Poor health of families because of smoky kitchens using solid fuels like wood and coal.**
- **Deforestation because of fuel-wood collection.**
- **Increase in atmospheric CO_2 & soot, associated with Global Warming.**
- **Decline in soil fertility, especially in impoverished countries.**

Most Biomass Cookstoves

- **Emit smoke and carbon monoxide causing serious health problems in 400 million households.**
- **Consume stick-wood, causing deforestation.**
- **Emit particulate matter associated with Global Warming.**
- **Do NOT produce Biochar. At best they are carbon neutral.**

A simple TLUD cookstove design can accomplish FOUR purposes:

Improve family health

Preserve forests

Remove CO_2 from the air

Improve soils

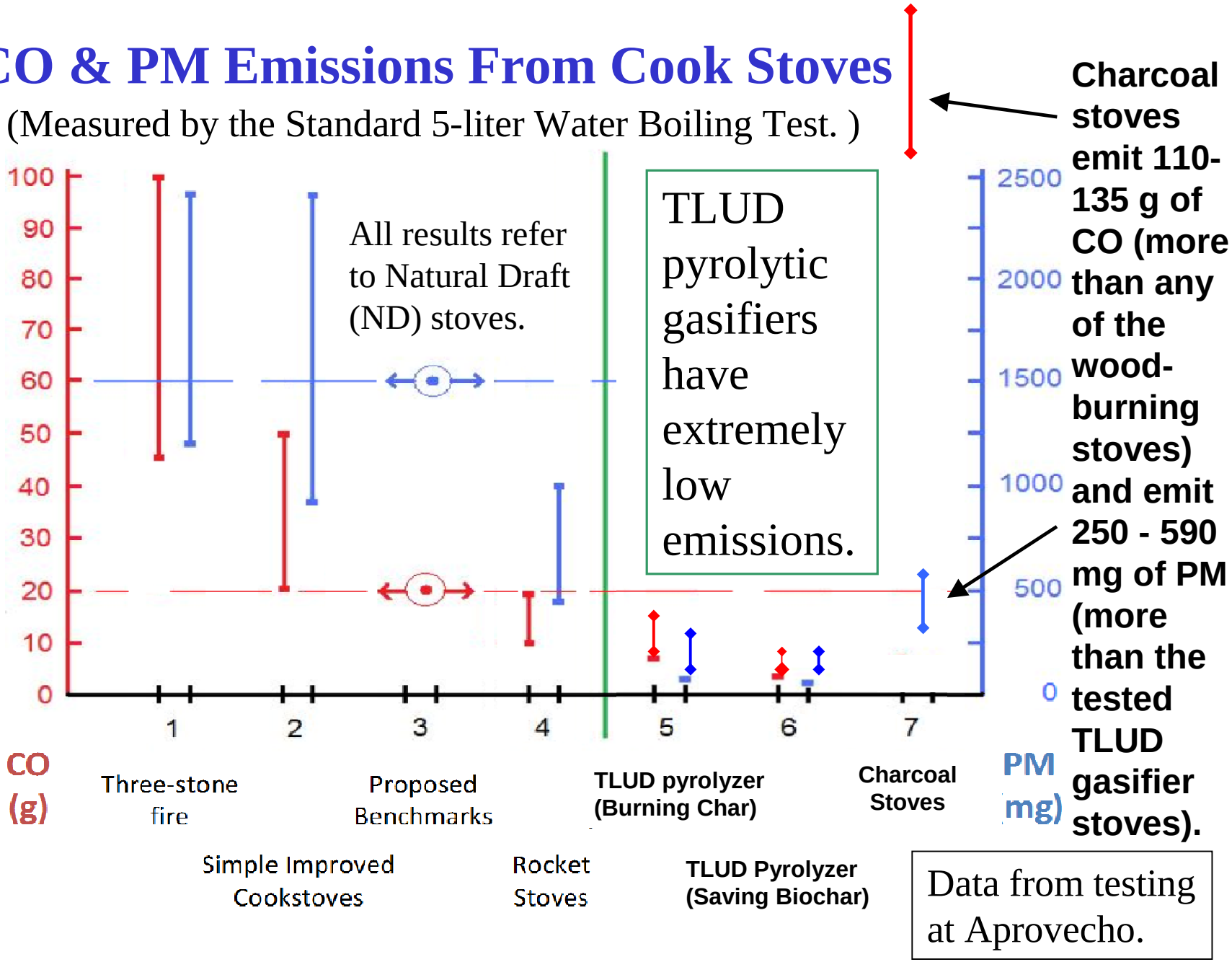
Four allies for one stove type.

Smoke in the Kitchen

- **In the least developed societies, indoor air pollution (IAP) is the fourth worst cause of poor health and avoidable deaths of women and small children.** **(WHO study, 2004)**
- **Carbon monoxide (CO) causes pre-mature and under-weight babies, plus general weakness in adults.**
- **Particulate matter ($PM_{2.5}$) causes Lower Respiratory Diseases that shorten lives, and contributes to climate change.**

CO & PM Emissions From Cook Stoves

(Measured by the Standard 5-liter Water Boiling Test.)



Charcoal stoves emit 110-135 g of CO (more than any of the wood-burning stoves) and emit 250 - 590 mg of PM (more than the tested TLUD gasifier stoves).

Data from testing at Aprovecho.

Conclusions from Emissions Data

- **No Natural Draft (ND) stick-wood stove has emissions as low as the TLUD-ND gasifier stoves. Do not promote second-best. Instead, help the best reach the most people.**
- **But if stick-wood must be used, then the Rocket Stove technology is probably the "best practice."**
- **TLUD pyrolytic gasifier stoves should be able to replace charcoal stoves in urban areas, with additional benefits of:**
  - **Reducing emissions from traditional charcoal making, and**
  - **Reducing the deforestation caused by charcoal making.**

New Manual
by Christa Roth for HERA-GIZ

Micro-gasification:

Cooking with gas from biomass

An introduction to the concept and the applications of wood-gas burning technologies for cooking

100 pages.

Soon (February 2011) to be available on

the Internet from GIZ - HERA

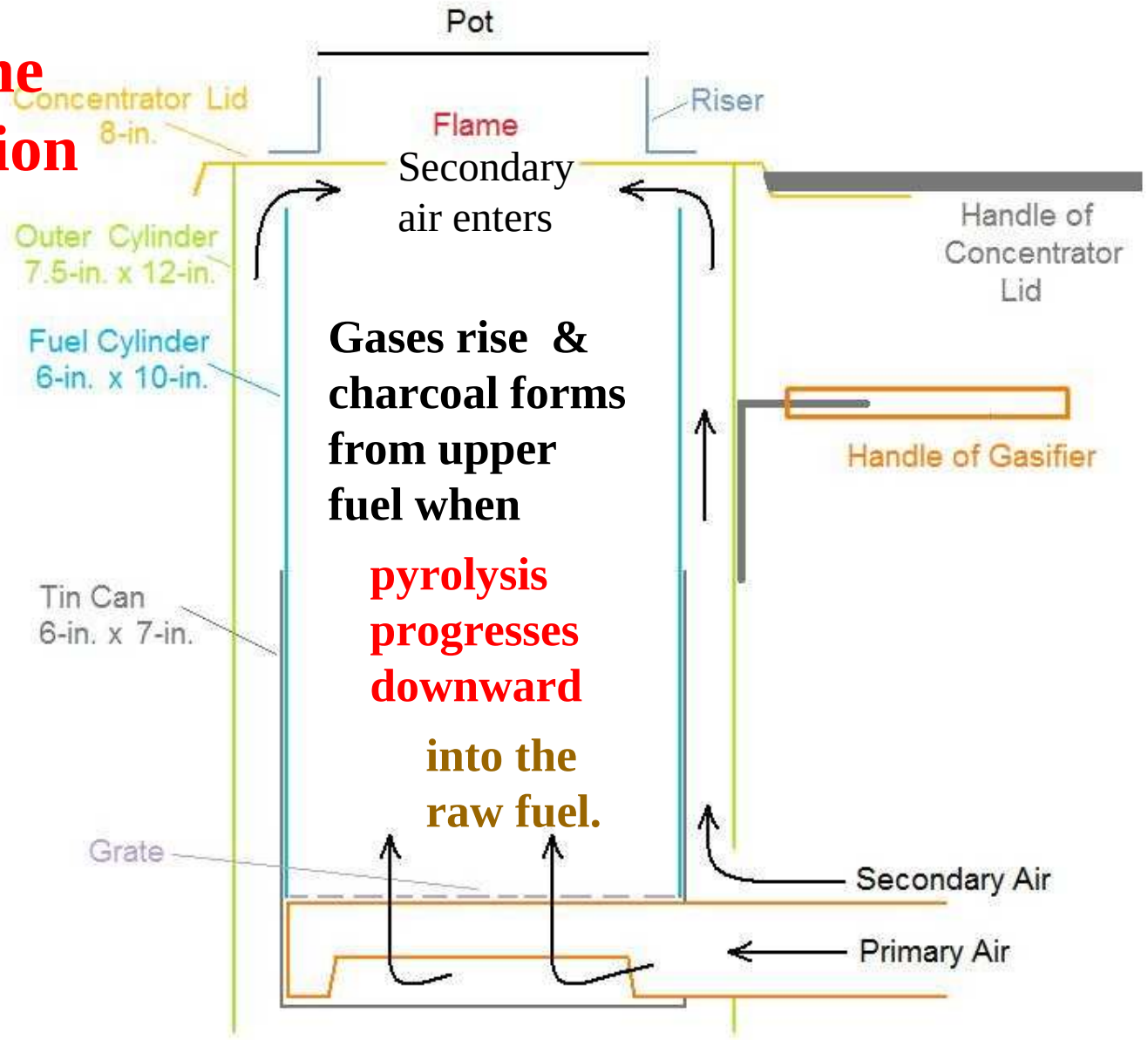
“Champion” TLUD-ND gasifier (2008)

Combustion zone & heat application

* * * * *

“Reactor” or gas generation device or pyrolysis unit, including fuel chamber inside.

ND = Natural Draft



Photos of Champion Gasifiers Made and Used in India - 2009

A humanitarian project near Chennai, India, sponsored by the Sunset Rotary Club of Bloomington-Normal (Illinois, USA).

Anderson's "Champion" TLUD made by Servals Automation

Prices depend on the stove configuration, including gasifier and stove structure for heat application.

Full set in stainless steel with 2 reactors costs US$37 in Chennai..

Finalized design and production started in Chennai in January 2009. Test sites are needed.

Tested in Nepal in 2009

[Results reported by STARIC for Champion TLUD gasifier.]

- **“The operation … is simple, easy to handle, operate and user friendly…”**
- **“The stove is quite good and its performance seems to be unbeatable by the local improved stoves.”**
- **“Compared to the traditional cook stove, it saves about 50-60% of the fuel wood.”**
- **This means combating deforestation. Other improved cookstoves do that also, but do not create biochar or use so many non-wood fuels.**











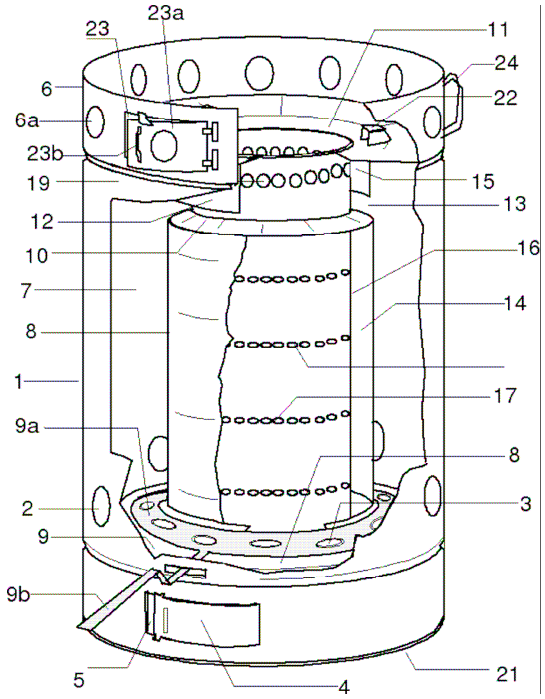


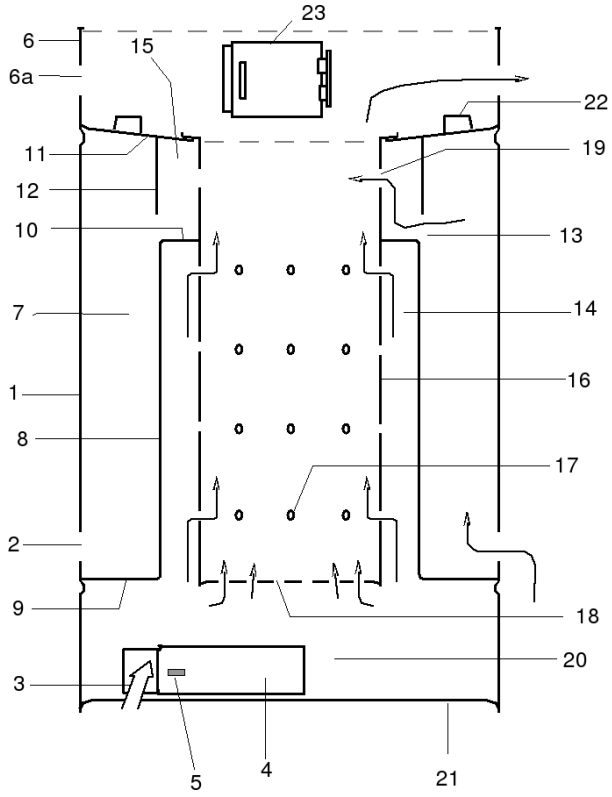

Variations of TLUD gasifier cookstoves.

[Top row is with fans.]

Nurhuda's TLUDs in Indonesia

Over 2500 units of model **UB-02** have been produced and sold at $10.





Nurhuda's TLUDs in Indonesia

The newest model, **UB-03-1**, sells for ~US$12.

Intentionally designed to appear similar to a kerosene (parafin) stove.

Nurhuda's Experience in Indonesia

- **General acceptance in locations where wood fuels are sparse.**
- **"People living …with possibility to get abundant firewood, usually…think that cooking with [this TLUD] stove will take longer time than traditional three-stone fires or simple stoves because they think that fire is not large enough."**
- **Response: TLUDs can be designed to give larger fires, while using much less wood with much less emissions & health problems. One example is the Finca Stove.**

Finca Stove in Costa Rica

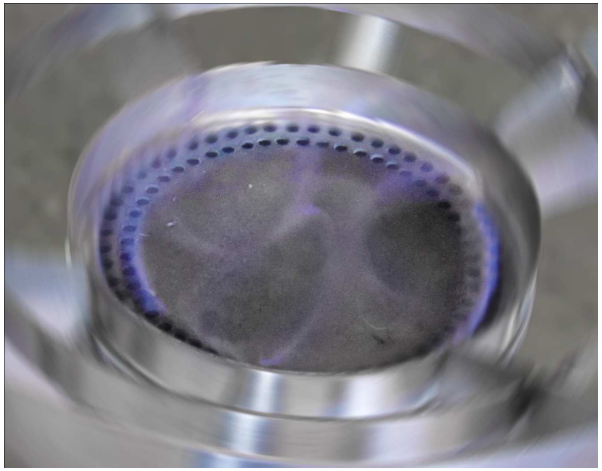
Art Donnelly and SeaChar

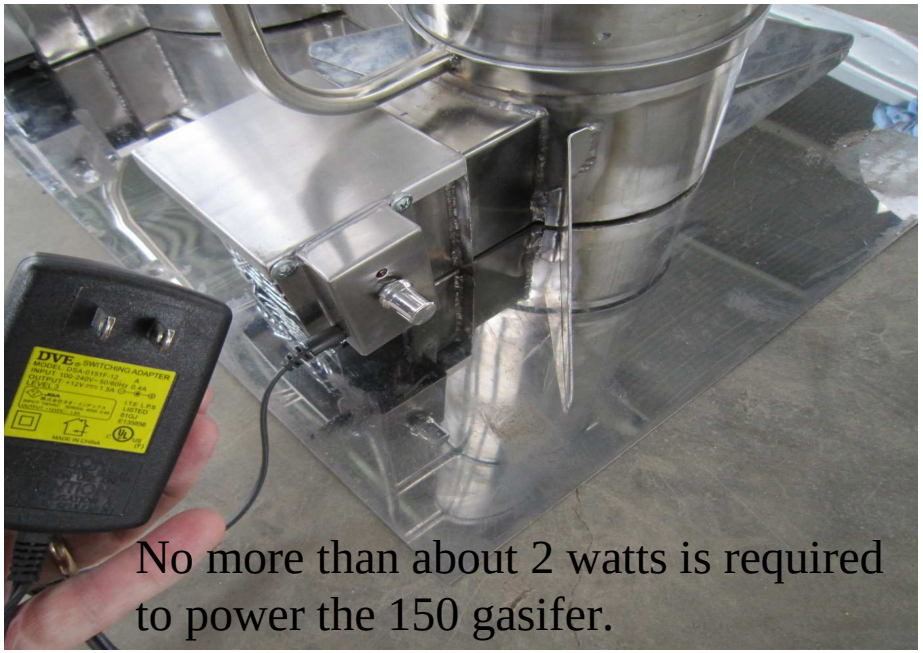
- A stove project for homes of migrant coffee-pickers.
- Stove production by a cooperative of women.
- Participation with university social researchers.
- Larger than most TLUDs; uses a 20-liter (5-gallon) bucket as its fuel chamber.

Uganda-Kenya TLUD with Ceramic Fuel Chamber

Rice Hull TLUD-FA

Development in Vietnam by Paul Olivier of concepts by Alexis Belonio





No more than about 2 watts is required to power the 150 gasifer.

Production in three sizes, all in stainless steel.

Jatropha Seed Stove

Pamoja and Jet City Stoveworks

- Very recent work; work in progress.
- See the separate presentation at this 2011 ETHOS Conference.
- High energy content in compact seed with appropriate size for use without alteration in TLUD cookstoves.
- The TLUD migrating pyrolysis zone vaporizes the Jatropha oil in a consistent way, making gases appropriate for the combustor.

Major Characteristics of TLUD Micro-gasifier Cookstoves

- **Fuel is usually chip size, for air passage.**
- **Fuel is stationary and used in batches.**
- **Primary and secondary air enter separately.**
- **Forced air (fans) can provide major benefits.**
- **Almost all pyrolysis occurs before char-gasification starts.**
- **Biochar is a natural by-product.**
- **Usually made of sheet metal, they have low mass for thermal collection.**

A Classification of Stoves

Paul S. Anderson, January 2011

- Based on fuels and combustion processes.
- Therefore NOT based on uses or cultures.
- NOT based on materials of construction, but materials strongly influence the combustion.
- Recognizing Forced Air (FA) (or Fan-Assisted) as an important sub-classification applicable to some stoves.
- Provisional and open for refinement.

Anderson's Classification of Cookstoves

(Draft January 2011)

1. Three-stove fire
2. Early "ICS" "Improved Cook Stoves" to 1990s (clay/ceramic/buckets)
3. Fuel-controlled stoves (mainly Rocket stoves)

   a. Simple (portable) b. Stationary (w/ chimney) c. Forced-air (FA)
4. Semi-gasifiers (mainly China and Vesto) w/ some air control
5. Gasifiers ("micro-" for cooking), some with FA (Fan Assistance)

   Top-lit updraft (known as TLUDs) w/ migrating pyrolytic zone (batch)

   Updrafts and downdrafts w/ stationary gasification zones (continuous)

   Other drafts, including cross and opposite/opposing drafts
6. "Fan-jet" with very strong air currents into the fuel (3 known examples):

   Philips-FA Lucia-FA Turbococina (Not Reed's Campstove)
7. Non-biomass. Stoves not using raw dry biomass fuels:

   Charcoal; alcohol; refined fossils; coal; biogas; electric; solar.

Multi-mode stoves can be used only one way at one time.

Why should you be involved?

- **TLUD pyrolytic gasifiers are clean burning!**
- **We are literally working at the frontiers of knowledge!!**
- **The results could make a difference:**
  - **Between sickness and health for some people.**
  - **For coping with the threats of climate change and soil depletion.**
- **Career, employment, income, personal benefits.**

Challenges *(and Next Steps)*

- The newness of the micro-gasification technology has deterred wider experimentation and dissemination.
- Except for a few corporate efforts, activities have been mainly by individuals with minimal funding.
- Those working on the technology are dispersed and too isolated to adequately interact with others, although the Internet is of great help.

(Challenges and) **Next Steps**

- Recently increased interest will bring the micro-gasifier stoves to greater visibility and more coverage at conferences.
- Additional funds would facilitate development and communications.
- More data sharing is needed.
- "Summit meetings" of main developers could highlight areas for further work.
- BEF Gasifier Stove Camps will be conducted around the world in 2011 by the Biomass Energy Foundation.

Thank you.

- **Contact information for :**

  Dr. Paul S. Anderson "Dr. TLUD"

  Email: psanders@ilstu.edu

  See: www.tridecca.com

- **I will assist in all countries, including**
  - **Uganda and Malawi in 2011**
  - **Peru in February 2011 for the PCIA Conf. (Partnership for Clean Indoor Air)**
  - **Worldwide via the BEF Gasifier Stove Camps**

(The next thirty slides are supplemental.)

TLUD Milestones and Examples

- The remaining 30+ slides are not officially part of the ETHOS 2011 presentation, but are provided here to facilitate their access to some readers.

TLUD Milestones (1985-2005)

- 1985 Dr. Tom Reed originates “inverted downdraft” gasification, later to be called “top-lit updraft” (TLUD) micro-gasification. In 2003 the Reed Woodgas Campstove (with forced air) is the first commercial TLUD-FA unit sold.
- 1990s Paal Wendelbo independently develops a natural draft TLUD stove in Uganda, producing 5000 units of the Peko Pe model.
- 2005 Dr. Paul Anderson’s natural draft TLUD wins the clean emissions contest at Stove Camp, earning its name “Champion.”.

Reed's Woodgas Campstove

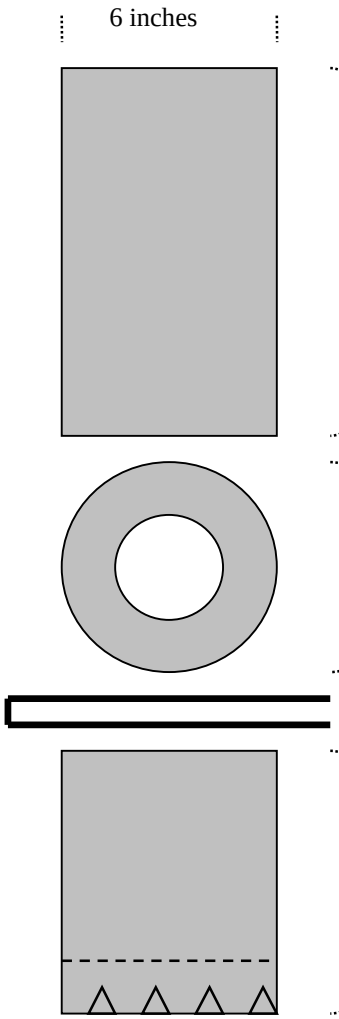
- Now produced in three sizes in India with 100% stainless steel construction.
- Price: US$55.
- Several thousand have been sold.

Wendelbo's Peko Pe Gasifier Stove

In northern Uganda - 1990s

Original “Champion” at Aprovecho Stove Camp 2005

Anderson's "Champion" TLUD gasifier [with natural draft air]

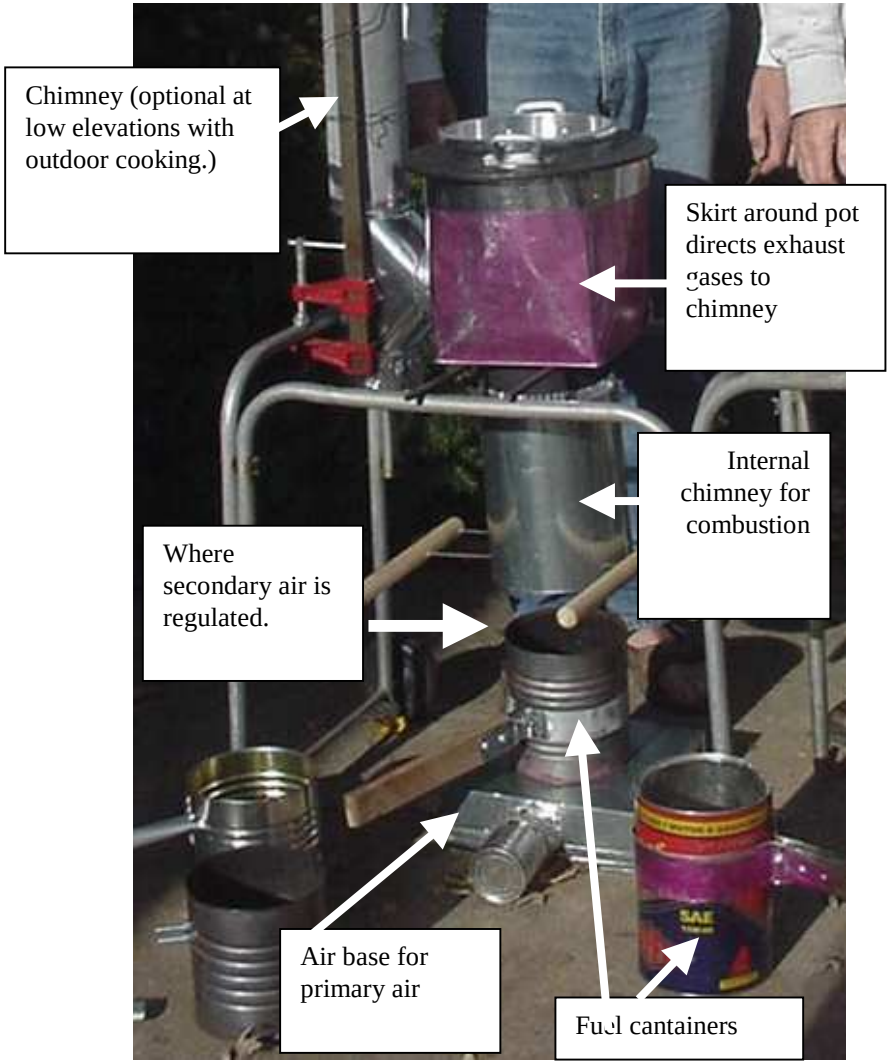


Internal chimney
for draft and combustion below the cooking pot.
(15 inches tall)
(38 cm.)

Concentrator disk
for gases
(with 3 inch hole)

Rod or wire
for spacing secondary air (1/8 inch)

Fuel container
(various sizes possible)
(options for grate or for holes in can bottom)



TLUD Milestones (2005-2010)

- Dr. Mukunda and team at the Indian Institute of Science in Bangalore use TLUD technology for the BP “Oorja” forced air stove (now First Energy). 400,000 units are distributed.
- Dr. Sai Baskar Reddy Nakka develops a variety of TLUDs in Hyderabad, India.

BP TLUD by IISc-Bangalore

- Mentioned at PCIA-III in Bangalore, but very little information is released.
- 400,000 units installed in India by 2008.
- Uses BP-made pellet fuel.
- Control of fan-forced air.
- Subsidized price of US$17.

Reddy's Magh-CM1 Cookstove

- One of several designs
- Ceramic base
- Made in India
- Information on Stoves REPP Website

TLUD Milestones (2005-2010)

- Prof. Alexis Belonio accomplishes the TLUD usage of rice hulls in the Philippines. His designs are in production in Indonesia and Vietnam.

Belonio's Rice Hull TLUD – 2008

Stainless steel; now being produced in Vietnam.

Models of Rice Husk Gas Stoves

With Drum-Type Burner

With Plate-Type Burner

With Open-Type Burner

The MJ Rice Husk Gas Stove

- The MJ Rice Husk Gas Stove is an improved version of the Rice Husk Gas Stove developed in the Philippines in 2005 by Belonio.
- Gaseous fuel with luminous ***bluish pink*** color flame is produced by burning rice husk with limited amount of air.
- A small computer fan supplies the air into the bed of burning rice husk.

TLUD Milestones (2005-2010)

- The Daxu TLUD stove in China wins a contest and begins production. Production numbers are not known for any projects in China.
- Muhammad Nurhuda in Indonesia uses a natural draft TLUD design from the Internet and launches a stove project now with 3300 units priced at approx. US$10 each.

Daxu TLUD Cookstove - China

-Winner of an Ashden Award for Enterprise in 2007.

-Winner of low emission among 8 Chinese cookstoves.

-Natural draft TLUD.

-Over 25,000 produced; possibly discontinued.

-Price US$140; many with subsidy sold for $6 to $26.

TLUD Milestones (2005-2010)

- Additional testing of emissions consistently shows the exceptionally clean combustion of TLUD designs.
- Also developing TLUDs are Robert Flanagan, Dr. Hugh McLaughlin, and others.
- Workshops, meetings, and camps about pyrolytic gasifiers are organized by the PCIA, ARECOP, and the Biomass Energy Foundation (BEF).

TLUD Milestones (2005-2010)

- The Center for Renewable Energy and Energy Conservation (CREEC) in Uganda has been awarded a US$150,000 grant by the World Bank BEIA Project to introduce TLUD cookstoves into 10,000 households in 2 years. This is the first and only 6-figure grant given for TLUD dissemination, but funds have not yet been released.
- Christa Roth has completed an extensive manual about Micro-gasification cookstoves, to be released by GIZ-HERA in early 2011.

More TLUD Gasifiers

Juntos-B Gasifier

with expanded steel mesh to support the pan

By Anderson 2004, w/ forced air

IISc-CGPL Lapsi Candy TLUD

- For Nepal, w/ ARECOP support
- Fuel capacity 6 kg dried lapsi seed in 1 batch for 2 hours to boil water from 85 kg of fruit pulp.
- 2 prototype units tested, 5 more on order in January 2008.
- Directional control of air
- No price info available.

Report is at: **http://www.arecop.org/regional/reg_detail.php?recordID=11**

Water Heaters with TLUD Gasifiers – India 2004

Stove Tops for Sunken Pots

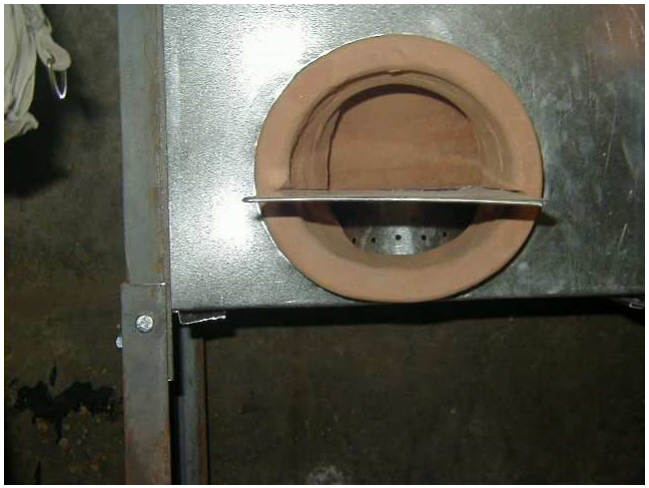
ARTI's Agni TLUD Cookstove

- Natural Draft TLUD.
- Based on the principles of Anderson's Champion Stove of 2005 before realizing that the riser should not be so tall.
- Produced in India.
- Approx. 30 units produced
- Price: Over US$ 50, by special order only.

Experimental “Combo-Stove”

First “Combo-Stove” was a Rocket-style Ecofogao with a TLUD-style gasifier fuel chamber underneath plus secondary air & fuel feeding via a lateral opening. (Brazil, Jan 2005)

Second “Combo-stove” was a new unit made with a “Rocket elbow”.

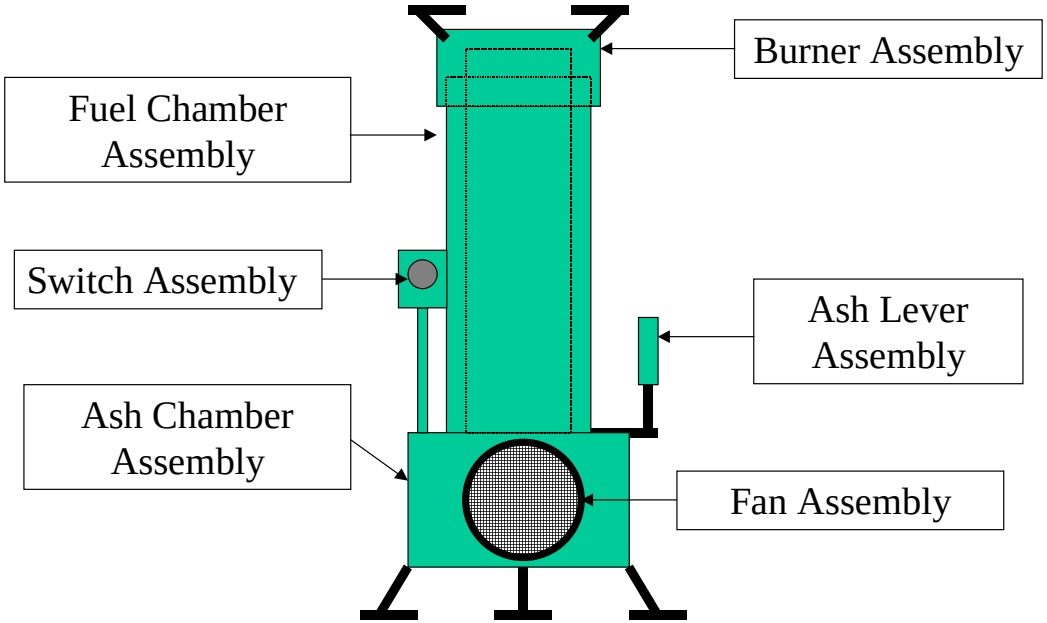


Continuation of second “Combo-stove” construction – Brazil 2005 project by Paul Anderson.

Belonio's Rice Husk TLUD gasifier [with forced air]

- Achieved the first consistently successful TLUD combustion of a fine-particle biomass waste, specifically rice husks.

Belonio's Rice Husk TLUD gasifier [with forced air]:



Schematic Drawing of Rice Husk Gas Stove

Belonio's Rice Husk TLUD Gasifier [with forced air]

- The first TLUD gasifier yielding a consistent light-blue flame and low emissions. Suspected to be because of the characteristics of rice husks.

Belonio's Rice Husk T-LUD Gasifier [with forced air]

- Successfully demonstrated remote (delayed) combustion of gases from a TLUD gasifier (all others use close-coupled combustion).



Belonio's Rice Husk T-LUD Gasifier [with forced air]:

- Began limited production in the Philippines, with modified designs now made in Vietnam.

Alexis Belonio and some of his stoves.

Nine clear “wins” and no evident “loses”

A. Families use low-value biomass and cut fewer trees, reducing deforestation. WIN

B. .Society observes less CO_2 entering the atmosphere (via charcoal co-product). WIN

C. .Kyoto/CDM “carbon credit” is generated by this charcoal and reforestation. WIN

D. .Impoverished families receive improved cookstoves to motivate A & B. WIN

E. .Reduced Indoor Air Pollution yields better health for biomass users. WIN

F. .Verifiable permanent sequestration of carbon via scattered burial. WIN

G. .Soil characteristics improve; crops are better (w/ improved food & health). WIN

H. .Appropriate sustainable technology creates employment & capacity building. WIN

I. .De-centralized implementation allows maximum localized adaptations. WIN

Technology for Combined Heat and Biochar from Small Installations

Three size ranges of micro-gasification:

- Top-Lit UpDraft **(TLUD)** pyrolyzers for cookstoves. **1 – 10 kW.** US$0 to $1000.
- Chip Energy's **AVUD** gasifiers for small size installations. **10 – 60 kW** $5000 to $25,000.
- Chip Energy's **multi-reactor AVUD** systems. **60 – 300 kW** $25,000 to $150,000.

(Thermal power: 300 kW = 1 million Btu/hr)