APPLIED R&D ON ***T-LUD TECHNOLOGY*** FOR CHARBRIQUETTE PRODUCTION IN CAMBODIA

PART 1-3

INTRODUCING T-LUD STOVES FOR USE IN CHARBRIQUETTE PRODUCTION PLANTS

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Acknowledgements

GERES Cambodia is grateful to Paul S. Anderson for sharing T-LUD stove technology, able to address and respond some of the energy needs in Southern countries. During his assignment in Cambodia in 2006, Mr. Anderson established the preconditions for all later achievements in the region.

Many thanks are extended to Iwan Baskoro, Senior technical advisor of GERES Cambodia, and to Jean François Rozis, Freelance consultant, who for over 12 years now have been working unfailingly for GERES Cambodia.

In a similar way, no achievement could have been made without the engagement and the expertise of Narith VONG, Technical coordinator at GERES Cambodia.

Teamwork has also been crucial to the success: I would like to thank all colleagues, interns and partners who took part in this great adventure!

GERES Cambodia is particularly grateful to the implementing and funding partners of the overall project:

Abstract

GERES has been working on alternative solid biomass fuels since 2005, starting from Cambodia.

In partnership with the French association “Pour un Sourire d’Enfant” (PSE), GERES launched a project (2007-2010) whose main objectives were: **(i)** to implement a production plant processing renewable biomass residues into charcoal briquettes; **(ii)** to create job opportunities for people subsisting on waste-picking in Phnom Penh dumpsite.

GERES not only coordinated the project but brought technical expertise to develop a carbonisation equipment and briquetting process that could be appropriate to the urban context.

The following technical report focuses on the development of innovative char-making equipment adapted from Paul S. Anderson’s “T-LUD” stove technology. The objective has been to produce good and regular quality charcoal with drastic emission reduction from carbonization.

The report summarizes the R&D work conducted in Phnom Penh during the project, work that has been constrained by the availability of limited means and resources and that was aimed, additionally, at exploring the possibility of replicating the equipment in other contexts.

Author

Aurélien HERAIL has worked as Project manager for biomass energy and alternative fuel production for GERES in Cambodia and Mali. For four years he has managed SGFE charbriquette project in Phnom Penh, dealing with a broad range of activities from fundraising to implementation/operation stage. He has led related R&D work, partially depicted in this report. His expertise includes biomass carbonization and combustion, alternative fuel production, stove efficiency, technical evaluation and project management.

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1. INTRODUCING THE *T-LUD*

1.1 STOVE TECHNOLOGY

"*T-LUD*" stands for "*Top-Lit Up-Draft*" and was initially a cookstove designed by Paul S. Anderson[1], expanding on the original independent works of Thomas Reed and Paal Wendelbo.

As its name suggests, it is a gasifier stove with an up-draft, fixed bed reactor.

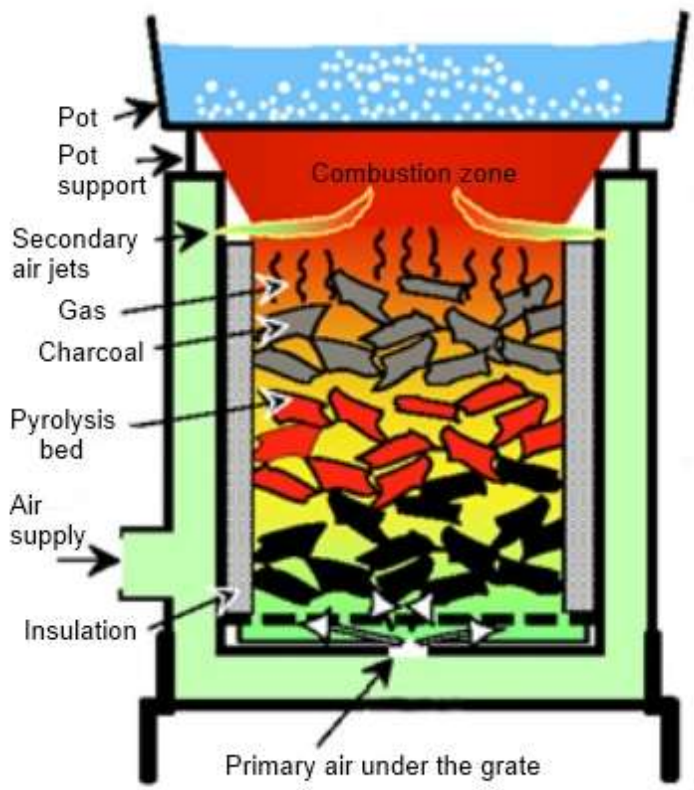
The biomass fuel is fed and lit at the top of the reactor and the fuel combustion moves downwards as a result of volume reduction induced by the biomass pyrolysis process.

The air intake is at the bottom, and the pyrolytic gases exits at the top of the reactor. The biomass (technically called the "pyrolysis bed") thus "moves" counter current to the gas flow.

The T-LUD stove breaks down volatile matter and tars from solid biomass as the pyrolysis bed moves downwards, leaving mostly solid char.

The heat needed respectively for drying and pyrolysis stages is mainly delivered by the upward-flowing pyrolytic gases and partly by radiation from the hearth zone.

Pyrolytic gases, which notably includes combustible gases such as carbon monoxide, methane and hydrogen, burns in the upper part of the stove when it meets with preheated secondary air under appropriate conditions. The quality of combustion can be quite high, approaching complete combustion; meanwhile, char can be collected if the combustion process is stopped just before oxygen oxidizes the char (the char-gasification stage).



Above: Drawing of T-LUD cookstove illustrating T-LUD technology. © P.S. Anderson

With the aim of producing char, and given the definition above, we understand here that a T-LUD can be considered a pyrolyzer ("char-making stove") more than a gasifier.

Two different T-LUD designs already exist worldwide:

- ***Natural draft***, with a sufficiently tall fuel canister, or additional chimney, creating the necessary draft which pulls the air through the reactor/stove.
- ***Forced draft***, with a fan, which creates pressure that pushes the air through the reactor/stove.

Left: T-LUD cookstove locally made by Paul S. Anderson in Cambodia in 2006

[1] See http://www.drtlud.com/ for further information about his work.

Primary and secondary air may come from the same fan/air inlet at the bottom, which blows air in between the fuel canister and the T-LUD container. This allows the secondary air to be pre-heated, thus improving combustion quality and reducing pollutants.

The environmental impact is significantly reduced compared to a traditional open fire; however, this technology cannot be considered state-of-the-art in terms of clean combustion stoves. This is mainly because a higher firing temperature and longer combustion time are necessary to achieve clean combustion of the pyrolytic gases.

1.2 QUICK FEEDBACK

As a large-scale appropriate cookstove dissemination specialist, GERES Cambodia identified the following constraints and barriers regarding the T-LUD cookstove:

1. T-LUD stoves necessarily require fuel of a standardized size, such as biomass chips or, preferably, pellets. Thus, any large-scale stove dissemination must be combined with an equally large fuel production supply (plant/site) within the targeted area.

   After field trials of a few weeks, the ability to supply standardized and affordable fuel was identified as a major constraint.

   Fuel nature and quality is a key condition to: (i) limit the risk of soot deposits on pots (a big issue for the cooks!); (ii) ensure high combustion quality; and, (iii) allow for the necessary cooking duration. Given the probable high price of the stove, the T-LUD would be clearly competing with LPG stoves, so only the cost, quality and availability of fuel will make the difference.
2. Turn down ratio (power adjustment) is very limited, contrary to LPG stoves. One solution involves a "plancha" design and/or the combination of two T-LUD stoves.
3. The use of metallic parts is a real constraint for some Southern countries[2], and raises the issues of quality and cost variability.
4. Given the materials, precision required in manufacturing, and necessity to keep a low stove price, mass production would require an industrial-scale production plant, which is difficult to adapt to Southern countries.

Some dissemination projects were carried out in India, where cost and availability of standardized biomass fuel and manufacturing materials/processes make it a relevant context for a pilot phase. Very few outcomes have been released from those pilots, but it is believed that T-LUD stove dissemination should be first validated in a country like India before being tested in other Southern countries.

1.3 A RELEVANT TECHNOLOGY FOR SOUTHERN COUNTRIES

Semi-continuous or continuous charring technologies and plants have been validated and are operating in industrialized countries. However those technologies seem quite complicated to introduce in Southern countries due to technical and economic barriers: high initial investment costs, maintenance constraints, specific technical skills,...

Therefore, T-LUD technology is particularly relevant and appropriate for Southern countries, as it:

- Is easy to operate, with a regular processing time, char ratio and quality;
- can achieve cleaner combustion, and lower environmental impact;
- can use a wide range of bulk biomass, which is roughly processed (chopped, dried);
- Has low manufacturing costs, can be made of local materials and maintained locally.

[2] Usually termed as "developing" and "less developed" countries. The term of "Southern countries" is preferred since it is based on objective geographic criteria instead of subjective capitalism-based criteria.

2. SCALING UP *T-LUD* TECHNOLOGY FOR CHARCOAL PRODUCTION

2.1 INTRODUCTION

Thanks to Paul S. Anderson, T-LUD technology is quite well known among international "stovers" (stove project developers), and is mostly used as a cookstove: the main objective is thus for users to cook on the vertical flame coming out from the burner. Once the pyrolysis phase has ended, the flame weakens and turns slightly blue; at this point, the stove must be stopped before the gasification of the remaining char occurs. In this case the char remaining is the by-product.

T-LUD technology is also of great interest because it can be scaled up for medium-scale char production, utilizing the heat produced for commercial drying or other purposes.

Besides developing a T-LUD-based pyrolyser, the innovative technical goal of the GERES-PSE project in Cambodia was to implement a "charring-drying" stove and charbriquette dryer based on T-LUD technology.

2.2 T-LUD PYROLYSER: DESIGNS AND TECHNICAL CHOICES

2.2.1 DEVICE & ENVIRONMENTAL REQUIREMENTS

Requirements	
FP 1	To achieve complete charring of the entire load of dry biomass with an average yield of 20% and homogenous fixed carbon content (range 65-85%, according to the nature of biomass)
FC 2	To burn most of the pyrolytic gases
FC 3	To unload glowing char and stop pyrolysis
FC 4	To minimize environmental impact
FC 5	To optimize life span
FC 6	To ensure worker safety and ease of operation

2.2.2 Initial design: *T-LUD pyrolyser v.00 - metal*

This initial design (v.00), based on the T-LUD cookstove, was built in order to validate whether up-scaling such technology was technically feasible, low cost, and would give good results in terms of power, temperature, quality and quantity of charcoal, etc.

After receiving encouraging results, it was decided to move forward with the development of such a device.

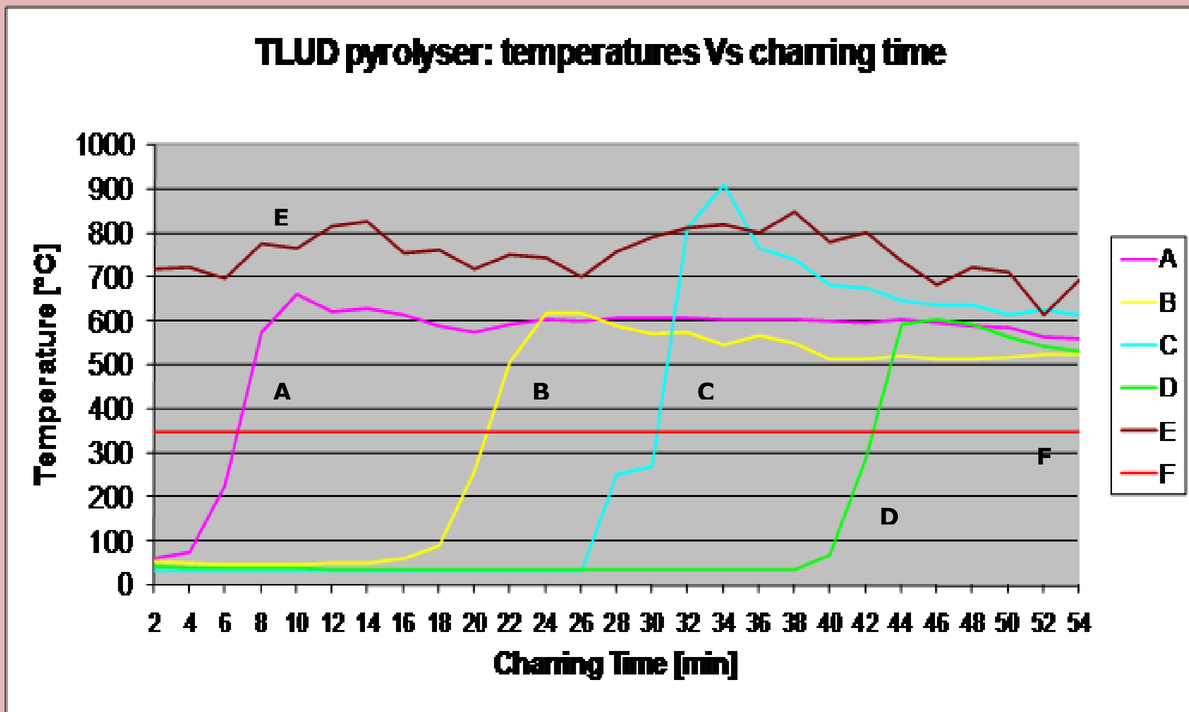
T-LUD pyrolyser v.00

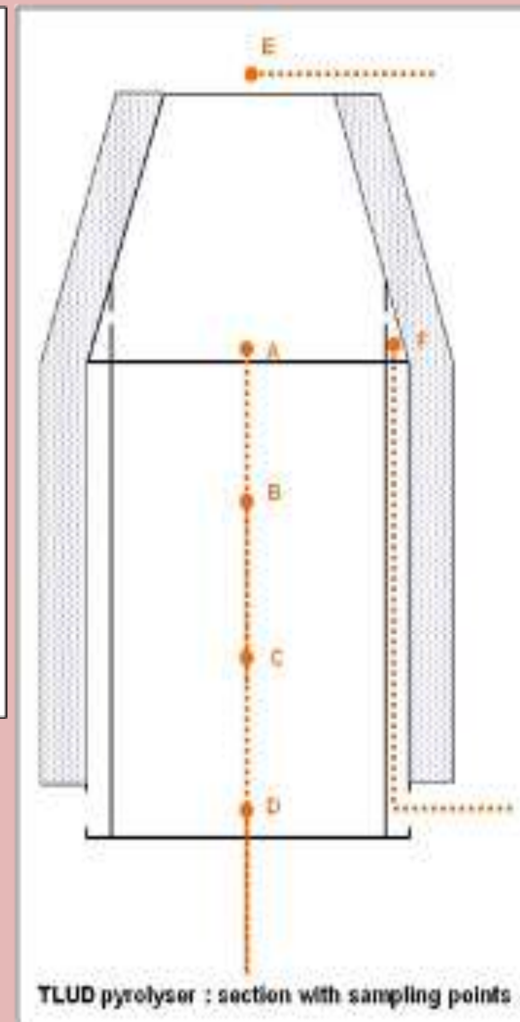
Above right: overview on first prototype (v.00) made of 200L metal drum, with external insulation, during initial tests.

Above top-left: view on the combustion zone during tests; secondary air jets are obvious!

Above bottom-left: view on the combustion zone after series of tests; metal is clearly not an appropriate material. Anyway objective here was only to validate initial data.

Temperatures from T-LUD pyrolyser (v.00 metal) charring coconut shell:





*A=40mm below Secondary Air / **B**=330mm below A*

***C**=310mm below B / **D**=30 mm above grate*

Carbonization temperature all along the fuel bed: 550-600°C
Temperature of combustion: around 750°C (without any additional combustion chamber).
NB: problem with channel F during recording.

2.2.3 UPGRADED DESIGN: *T-LUD PYROLYSER V.01 – BRICKS*

Technical specifications

Above: T-LUD pyrolyser v.01 made of hollow bricks. Since all bricks are aligned, the internal layer of holes conducts the secondary air to the combustion zone (burner), and the external layer improves insulation.
Warm secondary air enters the combustion zone and participates at the combustion.

Dimensions of fuel canister:	50cm (Diameter) * 120cm
Materials:	Concentrator: "hot" ceramic; Canister: bricks; Unloading chamber: bricks/metal door
Primary air:	Natural draft, inlet through the grate, airflow control at the door of the unloading chamber Primary air flow: n/a
Secondary air:	Natural draft, vertical inlet through the bricks (36 holes) Secondary air flow: n/a
Heat exchanger for secondary air:	Internal holes within the bricks (1st layer)
External insulation:	Internal holes within the bricks (2nd layer)
Grate:	Refractory grate on a metal frame, "guillotine" mechanism
Power:	Coconut husk: 32kW (Energy Content=12MJ/kg) Coconut shell: 50kW (EC=17MJ/kg)
Energy conversion efficiency*:	73%
Approximate cost:	250 USD (labor not included)
Char yield:	20% (by weight) on average (Husk: 16-20%, Shell: 20-24%)
Specific charcoal production rate:**	20.5 $kg/m^{-2}.h^{-1}$ (coconut shell, average) 21.4 $kg/m^{-2}.h^{-1}$ (coconut husk, average)
Charcoal production capacity*:**	Coconut shell: 10kg/batch, 1batch=120min Coconut husk: 3.5kg/batch, 1 batch=45min
Range of raw material:	Maximum size: 10cm*15cm*5cm Minimum size: 3cm*3cm*0.5cm
Maximum raw material moisture content:	25%

*Energy conversion efficiency defined as ("theoretical energy from the fuel" - "energy from the remaining char" – "thermal losses from canister and concentrator") / "theoretical energy from the fuel"
**Specific charcoal production rate = weight of charcoal produced/(reactor area*charring time)
*** Careful, figures may change according to raw material size and moisture content (power being fixed). Figures given here are indicative.

Grate

The grate is one of the most sensitive parts since it must be adapted to high temperatures, thermal shocks, frequent handling and mechanical constraints. After many tests, the optimal design of the grate integrated a metal frame with refractory tiles. This also had the advantage of a standardized tile size, enabling quick replacement at low cost.

Additional combustion chamber

Improving combustion has been a constant concern throughout the development of the T-LUD pyrolyser. Since combustion starts inside but always ends outside the burner, no significant improvement can be achieved without an additional combustion chamber.

Most of the volatile matter is combusted when appropriate conditions are met: high temperature, appropriate reaction time, and a turbulent air/gas mix. However the fact that no visible smoke can be seen at the outlet is not a sufficient indicator of combustion; proper gas sampling and analysis, especially CO and PM, have to be done. The real quality of combustion can only be checked by doing such analysis.

The additional combustion chamber developed had to address the following constraints:

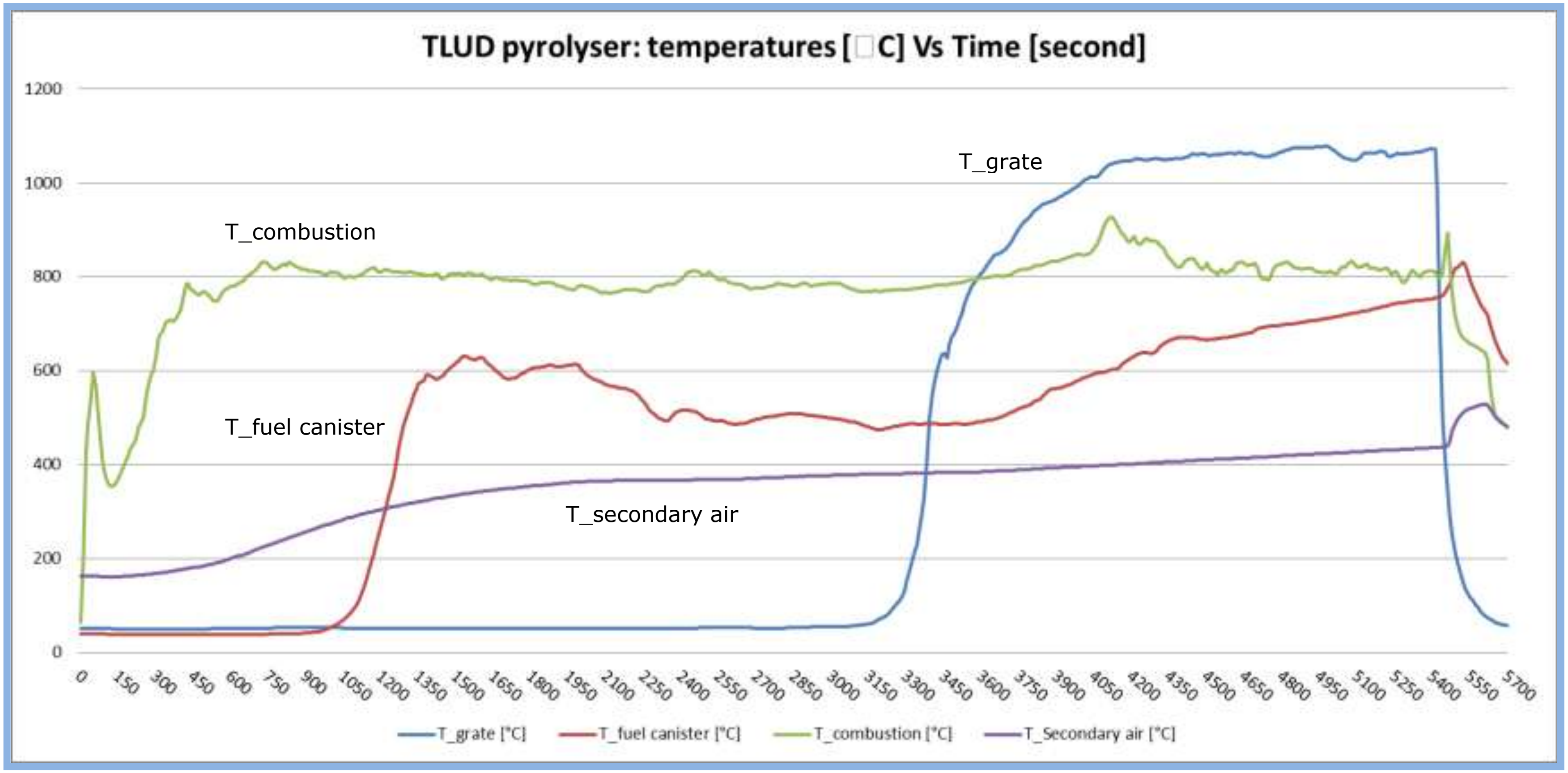
- Optimize combustion and maintain thermal efficiency;
- Be mobile, since the fuel is loaded from the top;
- Be easy and safe to handle by 1 operator, thus lightweight;
- Endure high temperatures (900-1100°C in the "heart" zone[3])

The design consists in a metal combustion pipe, with an insulated outer body. The pipe must be inserted inside the conical concentrator from the top. Thus, the lower part of the combustion pipe is inside the *T-LUD pyrolyser*'s concentrator, making a very hot "heart zone" for optimal combustion.

Dimensions and deflectors aimed at:	Insulation aimed at:
Increasing turbulence and mix between secondary air and pyrolytic gases	Keeping higher temperature inside the burner
Providing confined chamber for combustion	Insulating the outer part of the burner to limit thermal losses
Increasing oxidation reaction time	Insulating outer part of the burner, to keep a certain safety level for the operator

[3] « heart zone » refers to the highest temperature zone where most of the combustion occurs.

Temperatures record: T-LUD pyrolyser (v.01 bricks) with coconut shell (hot start)



- Standard charring time should be around 3500 seconds; the figure above shows the extreme temperature (1075°C) supported by the grate if appropriate charring time is passed! Besides potential damage to the kiln, the char yield will dramatically decrease from that point since the extreme heat is due to the carbon reacting with the oxygen (from primary air). This also shows the need for high-quality refractory stove materials.
- Temperature range of carbonization: 550-600°C
- Temperature of combustion: 800°C, but may change according to the fuel and the combustion chamber.

The velocity of secondary air was not as high as with the metal version. A test was done to check whether an axial fan on the secondary air inlet would provide better performance; it did not show significant difference. Besides, for reliability and operational reasons, it is preferred not to use additional fans.

Conclusion about T-LUD pyrolyser v.01

The global design validates a *natural draft T-LUD pyrolyser,* but an additional mobile combustion chamber is required to achieve optimized combustion (further development should be done with appropriate gas analysis).

None of the construction materials can be validated since they do not endure the high temperatures: more research is ongoing. It is believed that the availability of high alumina cement would solve this problem; unfortunately such material is not yet available in Cambodia.

The grate requires specific care and materials, due to high temperatures and regular operation.

Only the FC5 pyrolyser requirement could not be achieved.

It appeared that operators do not usually face problems with operating the T-LUD pyrolyser: an initial training followed by a few refresher sessions seems sufficient. However it is important to regularly follow-up and monitor operators, since operational details may affect the charcoal quality and equipment lifespan.

Proper maintenance follow-up is also required, especially regarding the inner refractory shield. If that shield is damaged, pieces may fall into the charcoal which may damage the machines involved further along the production process, and/or simply increase the ash content of the charbriquettes.

2.2.4 *T-LUD PYROLYSER V.02 - DUAL SKIN*

Requirements and improvements

The T-LUD pyrolyser v.02 was designed and implemented according to the previous outcome from v.01. This version was designed and built to be the heat source of a charbriquette dryer. Even though it was sized down since the power required was lower, it maintains the same constraints as the T-LUD v.01.

T-LUD areas of improvement:

1. Separate construction allows operators to dismantle and change parts at lower costs (separate platform, canister, combustion chamber)
2. Increased life span and reliability of main canister materials
3. Improved combustion and efficiency

Upgraded design is based on a combination of metal for the canister, and ceramic shield for the inner coating and the concentrator on top.

Left: design (3D drawing) of T-LUD v.02 before implementation.

Right: T-LUD v.02 after its construction at SGFE, here shown as the heat source of the charbriquette dryer.

Technical specifications of T-LUD pyrolyser v.02

Dimensions of fuel canister:	300mm (inner diameter) * 1000mm (height) "dual-skin" canister
Materials:	Concentrator and inner shield: "cold" ceramic
Primary air:	Natural draft, inlet throughout the grate, airflow control at the door of the unloading chamber Primary air flow: n/a
Secondary air:	Natural draft, 360° outlet Secondary air flow: n/a
Heat exchanger for secondary air:	Coaxial metal cylinders
External insulation:	None (surface temperature = 70-75°C)
Grate:	Refractory grate on a metal frame, "guillotine" mechanism
Power:	Coconut shell: 38kW (EC=17MJ/kg)
Energy conversion efficiency*:	79%
Approximate cost:	400 USD (labor not included)
Char yield:	12% (by weight) on average
Specific fuel consumption*:**	12,8 kg/h (coconut shell on average) Batch mode: 28kg coconut shell/load, 131min (coconut shell particle size 20mm*30*5)
Specific charcoal production** :**	1,5 kg/h Batch mode: 3,3 kg of char/load, 131min
Maximum raw material moisture content:	25%

*Energy conversion efficiency defined as=("theoretical energy from the fuel"-"energy from the remaining char"- thermal losses from canister and concentrator) / "theoretical energy from the fuel"
**Specific fuel consumption=weight of fuel/charring time
***Specific charcoal production rate=weight of charcoal produced/charring time
****Careful, figures may change according to raw material size and moisture content (power being fixed). Figures given here are indicative.

T-LUD v.02 has a char yield of 12%. Since the main objective is to dry charbriquettes, and not to produce char, the char yield has been voluntarily decreased. If the purpose is to produce char, the process should be stopped earlier than the natural extinguishment.

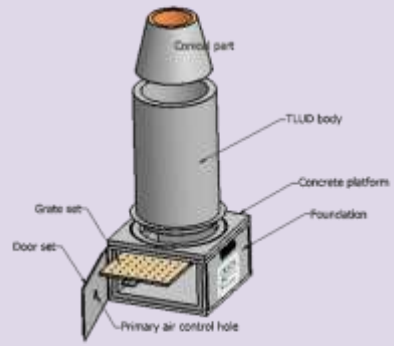
The char production rate remains about the same as the T-LUD v.01 because the lower yield is compensated by a higher energy density of the fuel: approx. 415kg/m3 with v.02 vs. 230kg/m3 with v.01.

Note: no additional combustion chamber was required with the v.02 to maximize combustion.

2.2.5 Latest version: *T-LUD pyrolyser v.03-40 - dual skin*

Main change between TLUD pyrolyser v.02 and v.03: concentrator, inner shield and grate are made of refractory cement in order to improve life spam. Charring yield was set back to 20%. Besides, TLUD v.03 was developed to match different needs for capacity and power:

- v.03-40 has a fuel capacity of 33kg and a power of 40kW
- v.03-90 has a fuel capacity of 200kg and a power of 90kW (see next paragraph)

	T-LUD pyrolyser v.03-40 - *dual skin*
Dimensions:	Fuel canister: inner diam300mm*1000mm height, unloading chamber: 700*700*350mm. "dual-skin" canister: inner refractory shield and external metal cylindrical body 
Materials:	Concentrator: ''cold'' ceramic made of refractory cement, canister: specific refractory bricks, unloading chamber: brick+ Portland mortar /metal door
Primary air:	Natural draft, inlet throughout the grate, airflow control at the door of the unloading chamber Primary air flow: n/a
Secondary air:	Natural draft, 360° outlet Secondary air flow: n/a
Heat exchanger for secondary air:	Coaxial metal cylinders: between external body and fuel canister
External insulation:	None (surface temperature=75°C)
Grate:	Refractory grate on a metal frame, ''guillotine'' mechanism
Power:	40kW (coco Shell, moisture content=21%, EC=17MJ/kg)
Energy conversion efficiency*:	85%
Approximate cost:	1000 USD (labor not included). Refractory cement was 40% of the cost since it had to be imported.
Charring yield:	22% on average
Specific fuel consumption :**	18,3 kg/h (on average) Batch mode: 33kg/load, 108min (coconut shell particle size 20mm*30*5)
Specific charcoal production* :**	4 kg/h (on average) Batch mode: 7kg/load, 108min
Maximum raw material moisture content:	25%

*Energy conversion efficiency defined as=("theoretical energy from the fuel"-"energy from the remaining char"- thermal losses from canister and concentrator) / "theoretical energy from the fuel"

**Specific fuel consumption=weight of fuel/charring time

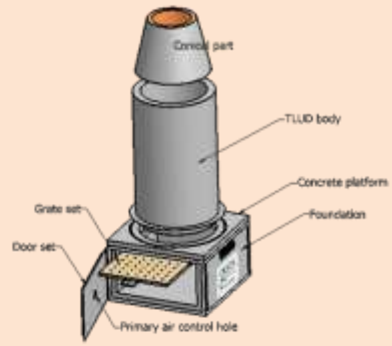
***Specific charcoal production rate=weight of charcoal produced/charring time

** Careful, figures may change according to raw material size and moisture content (power being fixed). Figures given here are indicative.

2.2.6 LARGER SCALE: *TLUD PYROLYSER V.03-90- DUAL SKIN*

Based on v.03-40, this version aims at increasing char production capacity.

TLUD pyrolyser v.03-90 - *Dual skin*



Dimensions:	**Fuel canister:** **inner diam700mm*1500mm height,** **"dual-skin" canister:** **inner refractory shield and external metal cylindrical body**
Materials:	Concentrator and inner shield: "cold" ceramic with refractory cement
Primary air:	Natural draft, inlet throughout the grate, airflow control at the door of the unloading chamber Primary air flow: n/a
Secondary air:	Natural draft, 360° outlet Secondary air flow: n/a
Heat exchanger for secondary air:	Coaxial metal cylinders: between external body and fuel canister
External insulation:	None (surface temperature=75°C)
Grate:	Refractory grate on a metal frame, ''guillotine'' mechanism
Power:	90kW (fuel: coconut shell, moisture content=21%, EC=17MJ/kg)
Energy conversion efficiency*:	79%
Approximate cost:	1300 USD (material only). Refractory cement was 40% the cost since it had to be imported.
Charring yield:	23% on average
Specific fuel consumption :**	37 kg/h (on average) batch mode: 200kg/load, 325min (coconut shell particle size 20mm*30*5)
Specific charcoal production rate* :**	8,5 kg/h (on average) batch mode: 46kg/load, 325min
Maximum raw material moisture content:	25%

*Energy conversion efficiency defined as=("theoretical energy from the fuel"-"energy from the remaining char"-thermal losses from canister and concentrator) / "theoretical energy from the fuel"

**Specific fuel consumption=weight of fuel/charring time

***Specific charcoal production rate=weight of charcoal produced/charring time

**** Careful, figures may change according to raw material size and moisture content (power being fixed). Figures given here are indicative.

3. Conclusion and perspectives

The project was an amazing opportunity to develop a new type of "charcoal kiln" able to process bulk biomass material into good quality charcoal with very limited environmental impact.

Version v.02 has shown encouraging results in terms of performances, reliability and costs. It has validated the technical design of the "dual skin" even though refractory shield was not yet made of appropriate refractory tiles/coating.

Metal component (i.e. canister) is "mobile" and interchangeable. Such canister allows a better heat exchange with the secondary air, increases air velocity while shifting it in a "swirl" move. Combined with a 360° secondary air inlet, combustion seems quite clean even without any additional combustion chamber. However it would require combustion analysis to get accurate figures. The canister also protects the top concrete platform. Besides TLUD assemblage is easier.

In order to address life span issue raised by v.02, an upgraded version was produced: v.03-40. Ceramic/refractory parts are now made of a material which stands high temperatures (1100°C). The 3 main components –grate, inner shield and concentrator- are made of tiles respectively interchangeable. This brings down costs, increases life span and ease the handling/assemblage.

Later in the project, a larger design was developed to focus on charcoal production: v.03-90. A remaining issue with TLUD pyrolyser has been its low production capacity and operational mode (batch mode) which make it inappropriate to industrial production. V.03-90 is the first step toward this objective but further development is needed.

Char samples should be regularly analyzed (fixed carbon, volatile matter and ash content) to ensure homogeneity and high quality throughout production.

Important progress has come with the work achieved here in term of "clean" carbonization, appropriate technology, reliable and affordable equipment for Southern countries. It shows a promising potential:

- ✓ Mobile and "clean" carbonization kilns able to produce regular and high quality charcoal from bulk biomass even in remote areas;
- ✓ Combustion of gas from pyrolysis provides energy for several additional uses: drying, food processing, cooking, etc.

Nevertheless, T-LUD development should not stop here, since several points have still to be addressed:

- ➲ Yet current size does not allow a realistic industrial production;
- ➲ The burner is vertical and requires the energy collection and use to be above the stove, which is more expensive and energy-consuming since in most cases drying of the biomass is at the ground level. Further research should be conducted to develop a horizontal burner.

4. LINKS

www.drtlud.com	The Dr TLUD website is a comprehensive online reference for TLUD technology which is frequently updated with additions of new and historical content.
http://stoves.bioenergylists.org	This site contains topics and information discussed on the Biomass Cooking Stoves email list to help develop better stoves for cooking with biomass fuels in developing regions. The purpose of this "stoves" list is to promote the development and introduction of improved biomass-burning stoves.
www.charcoalproject.org	The mission of The Charcoal Project is to promote, facilitate, and advocate for the widespread adoption of clean burning technologies, sustainable fuel alternatives, and policies that support energy-poverty alleviation for those who depend on biomass as their primary fuel around the world. The Charcoal Project is supported by a global network of volunteer specialists that include scientists, conservationists, marketing, web, social development, and business experts.
http://www.pciaonline.org/	Welcome to the legacy website of the Partnership for Clean Indoor Air (PCIA). Between 2002-2012, 590 Partner organizations joined together through the Partnership for Clean Indoor Air to contribute their resources and expertise to reduce smoke exposure from cooking and heating practices in households around the world.
http://www.hedon.info/	HEDON Household Energy Network is the leading knowledge sharing and networking NGO for household energy solutions in developing countries. HEDON informs and enables the work of its members through information sharing, learning, networking, and facilitation of partnerships.
http://www.arecop.org	THE ASIA REGIONAL COOKSTOVE PROGRAM (ARECOP) was initiated in 1991 as a network that facilitates the development of effective improved cookstove and biomass energy programs at the household and small industry levels. The Network serves as a bridge for exchanges of information, skills, expertise and resources among diverse sectors.
www.sgfe-cambodia.com	SGFE (Sustainable Green Fuel Enterprise) was created in 2008 with the aim of alleviating poverty and reducing deforestation in Cambodia, as well as improving waste management in urban areas, by developing a local economic activity: manufacturing charcoal briquettes using organic waste.

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