Licence Professionnelle
Sciences et Technologies des Énergies Renouvelables
57, avenue d'Azereix - BP 1624 -65016 TARBES Cedex
France

Study about biomass waste in Cambodia and processing them as alternative fuels

Internship for bachelor degree, from 6th March to 30th June 2006
- Digital publication on July 2006 -

- Trainee : **Aurélien HERAIL,** aurelien.herail@laposte.net ; aurelien_herail@online.com.kh

- Supervisor : **Jean François ROZIS**

groupe energies renouvelables et environnement

CFSP

Acknowledgements

Firstly, I would like to thank the GERES for having allowed me to do this internship.

Secondly, a huge thanks to Jean François ROZIS, without whom this internship would not have been possible. His continuous availability and technical and methodological support were much appreciated.

I would particularly like to thank Iwan BASKORO, Minh Cuong LE QUAN and all the CFSP team in Cambodia for their warm welcome, their trust and for having allowed me to work in the best possible conditions.

Finally, I would equally like to acknowledge Polin NOP's precious help in interpreting, which allowed me to carrying out all my research effectively and in a culturally enriching way.

Internship summary

Objective :

The first objective of this internship at GERES-CFSP was to study waste/residue availability in Cambodia, mostly biomass, and the different ways to process them as alternative fuels.
The aim of this prefaisability study was to present to the GERES different technically and economically profitable projects which could be put in place over the next few years.
The work was part of the main GERES Cambodian project which aims to stop deforestation in this country by working on an alternative and sustainable energy policy.

Main steps of the work :

- ✓ State of the art of biomass fuel consumptions in both rural and urban places.
- ✓ State of the art of waste/residues, as fuels, available in both rural and urban places.
- ✓ Summarize the way to process these waste/residues as alternative fuels according consumers requirements.

Work strategy :

At first, the work was to collect data in organizations and by interviewing people, mostly through field investigations.
All the data collected related to energy consumptions in small scale industries, industries and domestic use in rural and urban places. This work has also been done for waste/residues availabilities.
Second, the work was to analyse these data in order to make a projects proposal based on Cambodian context.

Conclusion :

Regarding social, economical and technical context in Cambodia, three way of valorization are interesting to consider :
Gasification for thermal and electrical applications, carbonization for char briquetting activity and densification for biomass briquetting activity.
In total, four projects are economically interesting for the nearly next years while two others will be later.
Actually in Cambodia artisanal/small scale activities are preferable to industrials.

TABLE OF CONTENTS

REMARK

This translated version is shorter than the original (French version), for further information and details please contact GERES Cambodia, www.cfsp.org.kh, or Aurélien HERAIL, aurelien.herail@laposte.net ; aurelien_herail@online.com.kh .

List of figures

Abbreviations and acronyms

A
ASDD : Association Supporting Disability for Development

C
CFSP : Cambodia Fuelwood Saving Project
CEDAC : Centre d’Etudes et de Développement Agricole Cambodgien

D
DATe : Development & Appropriate Technology

E
EdC : Electricité du Cambodge

G
GERES : Groupe Energies Renouvelables, Environnement et Solidarité

M
MIME : Ministry of Industry Mines and Energy

N
NIS : National Institute of Statistics
NLS : New Lao Stove

O
NGO : Non Gouvernemental Organization
UN : United Nations

P
UNDP: United Nations Development Programme
PP : Phnom Penh
P_u: Used power (considering there is P_a: Absorbed power)

S
SME : Small and Medium Enterprises

T
TLS : Traditional Lao Stove

W
WENetCam : Wood Energy Network of Cambodia

Comment

In general, the use of the term « waste » is not entirely appropriate to Cambodia because most used products -considered as waste because they are of no further use – are recycled into another form or reused as they are.

Biomass waste is included in this category and is, according to the type, more or less reused: for fuel (heat or electrical) or agricultural purposes (fertilizer, compost, animal food, so in a profitable way).

Like this, not all of the population use waste ; it is possible to find in a locality waste that is reused by some and not by others. Here, the implementations can also vary.
The qualification of « waste » therefore becomes difficult to attribute. However, when it is regularly observed that a used product is regrouped to be gathered by the collect service, the use of term « waste » seems altogether appropriate
On the other hand, certain biomass waste is frequently, and in large quantities, reused to be valorised in a profitable way. The use of the term « residue » thus seems more appropriate than that of « waste ».

Moreover, as this report frequently refers to charcoal, it is important to define the two existing types:
The first is renewable charcoal in so far as for each tree cut down to fabricate it, a new one is planted. Hence the CO_2 emissions of this renewable charcoal are absorbed by the new trees planted; the final charcoal outcome thus is worthless.

The second type is non-renewable charcoal as there is no biomass management; trees are not replanted to replace those which have been cut down. In this case the CO_2 emissions can't be reabsorbed by the new trees, the cycle is broken and the balance becomes positive. Its in this situation that the charcoal market established financial compensation to re-establish a null CO_2 outcome.

It's considered that the combustion of 1kg of this charcoal=2,74kg of CO_2*

(source: Smith KR, Rasmussen RA, Manegdeg F, and Apte M. 1992 Greenhouse Gases from Small-Scale Combustion in Developing Countries: A Pilot Study in Manila Research Triangle Park, NC: U.S. Environmental Protection Agency [EPA/600/R-92-005 (NTIS PB92-139369)])

NB: This study refers to different costs,
These are the rates taken into account in June 2006:
1US$ = 4000 Riels
1US$ = 1,2 €

1- State of situation in Cambodia

1.1- Socio energy observations

Apart from biomass resources which are a veritable wealth in Cambodia, this country has few « conventional » energy sources available. However, there are some interesting potential renewable energy resources such as hydraulics, though still not fully exploited. Thus all fossil energy used, in particular gas and petrol for producing electricity and transport, is imported.

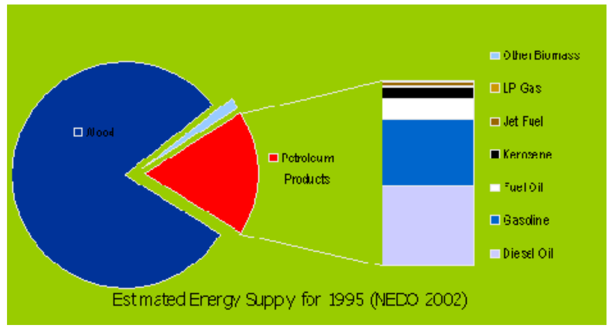
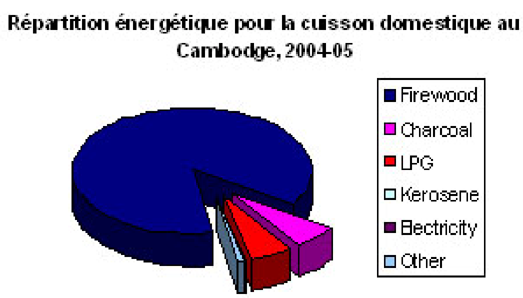


Fig.1.1 : global energy consumption

Wood represents more than 80% of all the energy used.

Fig.1.2



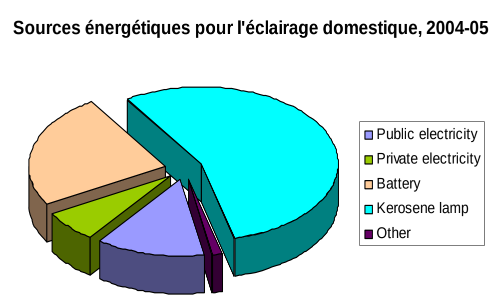
Source : NIS, CSE 2004-05

In Cambodia, wood and charcoal are the principal energy sources for the majority of households and small industries. 93,1% of this energy is used for domestic cooking*(NIS, CSE 2004-05)*.

The deforestation rate in Cambodia is still at -1,6%/year *(Independant forest sector, 2003).*
For small companies, wood and biomass energy are the only affordable traditional resources available.

Currently, less than 15% of households have access to electricity via diesel and batteries (53,6% in the city versus 8,6% in the countryside). In the countryside the number of people using batteries for lighting is around three times higher than in the city, Phnom Penh included.

Fig.1.3



Source : NIS, CSE 2004-05

1.2- Different types of energy consumers

The activity categories have been established according to the following criteria:

- **Household use** : stove with P_u<10kW
- **Small production activity** : kiln with 10kW<P_u<100kW
- **Industrial activity** : kiln P_u>100kW

It is important to specify that the aim of the investigation was not to establish a precise characterisation of the various consumers, but rather have some examples. The aim being to identify energy requirements and to probe eventual interest for using alternative combustible energy.

1.2.1- Household use

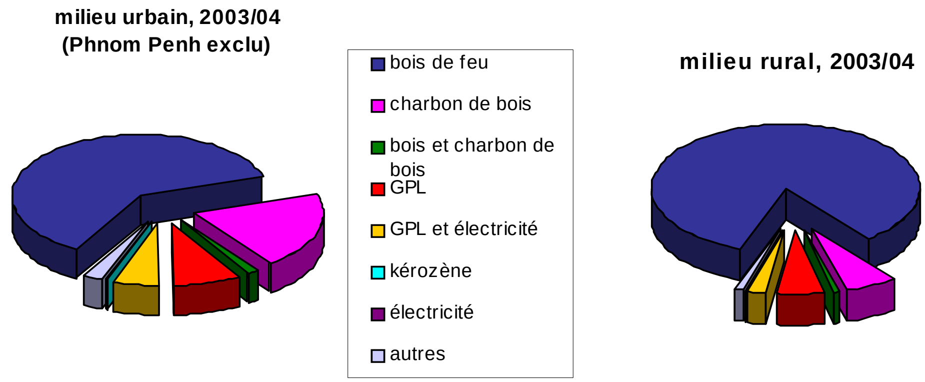


Fig.1.4: Distribution of energy sources used for domestic cooking

The need for charcoal and wood for domestic use in Phnom Penh was evaluated in 2003/4: 26 000 tons/year and 100000 tons/year for wood.
If the current evolution continues, then in 2009 charcoal consumption will be 21000 tons per year and wood consumption virtually non existent.
It seems that in the next few years charcoal and wood consumption in Phnom Penh will decrease. On the other hand, it appears that it increase in other cities and rural areas. *(source: « Woodenergy Baseline Study for Clean Development Mechanism », GERES-CFSP 2006).*

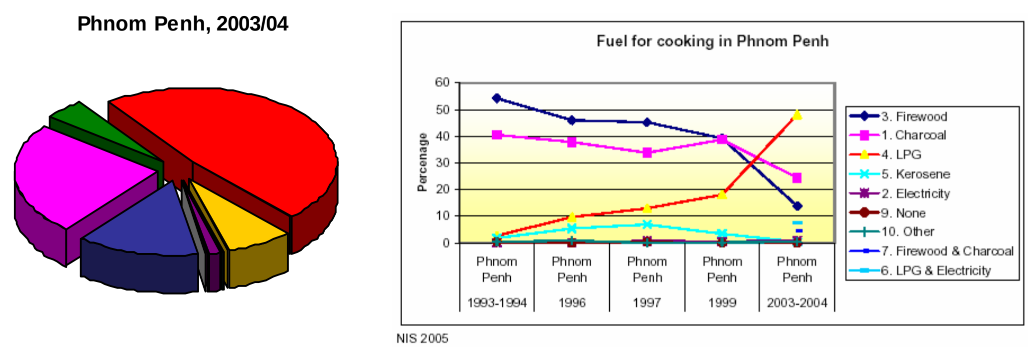


Fig.1.5: Distribution and evolution of energy used for domestic cooking in Phnom Penh

Following a study carried out in 1998 and a survey of 50 families (5,9 members/family), the charcoal consumption observed was 2,1kg/day for a TLS « Traditional Lao Stove » household and 1,2kg/day for a NLS « New Lao Stove » household..
Wood consumption is 4,9kg/day/TLS *(source : « Woodenergy Baseline Study for Clean Development Mechanism », GERES-CFSP 2006).*

Left: TLS stove, « Traditional Lao Stove »

Right: Improved stove, NLS « New Lao Stove » with a yield of 37% allowing a charcoal saving of 20% (GERES-CFSP project).

1.2.2- Small production activities

These concern mainly families and are widespread regardless of their environment (urban or rural). The production is relatively modest.

Numerous families having difficulties getting wood supplies, buying it or wanting to increase their earnings already use biomass waste/residue in their kilns. So, in certain cases, it seems more appropriate to increase the kiln output while, on the other hand, in others, a substitute combustible could be a solution.

- **Noodle production**

Two of these manufacturers were visited, one at Phnom Penh[1] and the other on the outskirts of Kampong Chhnang[2]. Each only had one stove.

[1] : n°32 st.432 ; [2] : Mr.Taing Keav. Chamkar Tamao village, Sre Thmey commune, Rolea Pha Bar district, Kampong Chhnang province

Right: photo of a stove for noodle production.

The daily noodle productions were identical (300kg/day) but the first producer uses on average 70kg of sawdust: day and the second uses 100kg of rice husk/day. The price of the sawdust is roughly 0,15US$/kg, rice husk was free in this particular case.

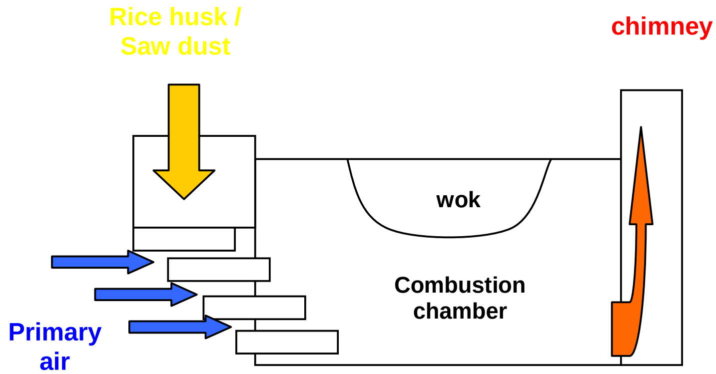


Fig.1.6 : principle of the « stairs feeding » stove used in many small scale productions, mostly for noodle, rice wine and palm sugar.

Top: detail of a rice husk burner. Here vertical bars replacing "stairs", primary air inlet is between each bar.

Bottom: focus on a « stairs » burner used with sawdust.

- **Palm sugar production**

This production is very widespread in Kampong Chhnang, Kandal and Kampong Speu. In total, nearly 20000 rural familles live there. This activity is seasonal, from January to May /June.

In *Tropaing Sbov village, Sre Thmei commune* 80% of families run such an activity using wood.
The family visited was producing 22kg of sugar/day, that is to say two cooking sessions, using around 0,5 stere of wood/day. This wood was collected 30/40 km from their house.
The logs were 2 metres long, brought back with an ox cart for 1,25US$/ox cart every 3 days. This would be the equivalent of 0,85US$/stere of wood.

In *Trea village, Prey Pouch commune, Angsour district* in Kandal province, numerous families were visited :
5 to 7 families produce sugar in this village and 24 in *O Kambot* village. Currently, all of them use wood as opposed to sawdust and rice husks used a few years ago. Moreover they now use garment waste from companies in Phnom Penh.
Garment waste consumption has been evaluated at around 50 kg for a production of 10kg of sugar per 3 hour cycle. That is to say 18 tons/season/producer, given a 20 kg production of sugar/day on average.
The average cost of garment waste is 0,02US$/kg.

- **Rice wine production**

A producer in *Khlaing Prak village, Pha'ei commune, Kampong Chhnang district* uses all sorts of biomass waste/residues. Thus he uses bagasse, plant leaves, dried pig excrement, sawdust , but mainly rice husk which is the only one he has to pay for: 0,25US$/bag of 130kg and 0,25US$ more per bag for transportation.
The daily production is 2*30 litres/day with a fuel consumption of 2 bags of rice husk/day, or only one bag if blended with bagasse. This producer uses 2 stoves for this production.

Left: Photo focusing on the biomass feeding inlet of the stove.

In Kandal province, *O Kambot village*, a family visited also produces rice wine with garment waste as a fuel. They produce 30 litres/day with one stove which consumes around 30/35 kg of garment/day. The stove is always the same type, one with a « stairs feeding » burner.

Right: Photo of the stove (on the right) and of the alembic (on the left).

- **Bread production**

There are around 50 bakeries in Phnom Penh.
For a production using 700 kg of flour, the wood consumption is 5 steres with a price of 8,75US$/stere of wood. Interestingly, 2 years ago the price of wood was 3,75US$/stère, which means an inflation of 133% in only 2 years.



Left: cooking chambers with a water pulverization system (3 pots) to give a good colour to the bread during the cooking.
Middle: log feeding gate which is also the primary air inlet.
Right: 50 cm logs.
** n°1900 st.60, Psa Touch village, Toul Sanke commune in Phnom Penh*

- **Restaurants**

In the towns, there are many restaurants, especially in Phnom Penh. A Khmer cantine, serving 100 meals/day on average, using 4 TLS and 1 NLS needs 40 kg of charcoal/day. TLS works between 4 and 5 hours/day and NLS between 8 and 9 hours/day. NLS uses ¼ of the daily charcoal quantity.

Photo de TLS d'une cantine Khmer de rue

In this cantine they also use LPG stoves which consume around 2*10kg of gas every 3 weeks, considering a daily utilization between 2 to 3 hours. Every 10kg bottle of gas is 12,5US$.

Remark : It is interesting to notice that a TLS lifetime is around 3 or 4 months for a selling price of 1US$ while the NLS's is between 1 and 2 years for a price of 3,75US$.

1.2.3- Industrial activity

Actually, the most important industrial activities using wood are brick factories.

Up: photo of the wood stock in a bricks factory.
Down: photo of a worker during a combustion cycle.

There are two kinds of factories: those that use wood and those which use rice husk.
Brick Kilns run on wood; between 150 and 170 steres, 1,1m long on average, per kiln and per combustion cycle. Their dimensions are on average 5m width, 40m long and 3m high. A « cooking » cycle of 100000 bricks is around 7 days/kiln.
The factory visited has 3 kilns and can produce 2,5 cycles/month in total, that means a monthly production of nearly 250000 bricks. The absorbed power is around 2MW while the effective power has been evaluated at only 600kW. The largest factories are able to run 7/8 cycles/month and have up to 8 kilns.
The wood supply is delivered by trucks of 45 steres/each every 3 days; the price of the wood is 8US$/stere.
Because of the global rarefaction of wood, prices doubled in a year (from 4US$ in 2005 to 8 US$ in 2006).

There are around 54 brick factories (between 2 and 8 cycles/month) which use wood along the RN6, up to 20km out of Phnom Penh. We can estimate an average global consumption of 800 steres/month/factory, that is to say 43200 steres/year for the north-east periphery of Phnom Penh.

There are 2 kinds of brick kilns which use rice husk for fuel, one is rectangular and the other is dome-shaped:

The rectangular one needs 12-13 trucks of 10t/truck and 250 bags/truck, so around 120-130t/cooking cycle/kiln for 70000 bricks/cycle. A cycle takes around 8-9 days of cooking/kiln during the dry season.

The dome kiln, approxi5m of diameter and 6m height, can cook 60000 bricks/cycle, which is 10-15 days of cooking.
Its fuel consumption is 90 tons of rice husk/cycle.

1.3- The challenge of alternative fuel

The main stake is to find an alternative fuel to wood and mainly charcoal, for household cooking.
Indeed, nearly 85000 tons of charcoal/year is burnt in Phnom Penh for cooking. *(Source: « Woodenergy Baseline Study for Clean Development Mechanism », GERES-CFSP 2006. However an extra woodflow of 5000 tons has been detected from Phnom Penh to Vietnam. This amount deducted of the 89632t written in this report gives 85000t).*

There are nearly 36000 families who use NLS stoves (CFSP project) which allow a saving of 6379 tons of charcoal/year, that is to say 9% of the total quantity.
Another CFSP project is about producing « renewable » charcoal which will allow, in the best case, a saving of 10% of « non renewable » charcoal by the end of 2012.
Finding an alternative fuel which allows the continual saving of non renewable charcoal would be another step in the global wood saving project run in Cambodia by CFSP-GERES.

1.4- Combustible waste / residue assessment

Observation: The following quantities and prices are from short field surveys and investigations so they must not be considered as a generality in urban and rural areas.

1.4.1- Sources in rural environment, Battambang and Kampong Chhnang provinces.

Peanuts shells (agronomic waste)

Source assessed throught producers between **Battambang and Pailin.**

Left: Peanut shells used for levelling some producer's garden

*Right: Peanut shells sample, on a square pattern (5mm*5mm)*

- **Quantity** : peanut "produced" in 2005:

Between 200 and 300 bags/producer, 20 to 30 kg/bag.
Minimum quantity: **4 tons/year/producer**.
There are around 100 producers in Battambang district, quantity per farming: **400tons/year in Battambang district.**

- **Availability :**

In that region, peanut is croped 3 times:
- From end February to early March, in slightly low quantity
- From June to August, around 100 tons
- From November to january, between 20 and 30 tons

- **Price :**

A 20 kg shell bag costs between US$0,03 and US$0,05.
It means an approximate price of **US$2 /ton**.
Seeds cost around US$/1,8 kg.

- **Current use :**

That waste is mainly employed as combustible for local palm sugar manufacture. It can also be employed as fertilizer for rice paddy, orange grove and nursery.

- **Advantages :**
  - Densification and gasification would turn this waste valuable.
  - This waste is very cheap and abundant in that region.
- **Disadvantage :**
  - Density is low, we must processed big volumes.

Carbonized peanut shell (process waste)

Source assessed from an electrical power station near **Battambang** *(Phnom Sampov Koet village, Phnom Sam Pov commune, Banon district)***,** drived with a 75kW dual fuel gas generator feed with peanut shell

Left: carbonized peanut shells taken from gasification process (2nd layout)

*Right: Carbonized peanut shells sample, on a square pattern (5mm*5mm)*

- **Quantity :**

A global production estimation of that waste is very difficult. However, we can consider a gasification ratio between 70% and 80%, we can estimate a daily production of **275 kg/day** (dry) for a gas generation station (dual fuel: 70%gas / 30%diesel) working at 60kW during 11 hours.

- **Availability :**

Peanut shell is a raw material for gasification process. The availability totally depends on gasification power plant in Battambang which uses it alternatively with corn core and *Leuceana* (fast growth wood).

- **Price :**
  Around **1 US$/ton** (mainly for transportation).

- **Current use**: that waste is not yet employed.

- **Advantages :**
  - Centralised production
  - Possible to process this waste as char briquette
  - Cheap waste

- **Disadvantage :**
  - Very localized production
  - Some shells are not properly burnt. It implies that the combustion of char briquettes made of these unburnt shells emits a lot of smoke.
  - High ash content: 39%; Carbon content: 47% *(source : CIRAD, France, 2006)*

Corn core (agronomic residu)

That waste is very abundant in the **Battambang** and most especially in the **Sampov and Banan district**.

Left: stock in a producer's garden

*Right: corn core sample, on a square pattern (5mm*5mm)*

- **Quantity :**

Around **200 tons/producer** from December to March. Many farmers grow the corn in Battambang province. It is difficult to know how many they are.

- **Availability :**

Very important source, **mainly from January to March**.
There are three main origins: Pailin, Samlot et Redik.

- **Price :**

The core is sold in 25Kg bag; 0,25US$/bag. It costs **10US$/ton,** but it can sometimes be free in the country sides, for example in Banan district, close to Battambang.

- **Current use :**

This waste is employed as combustible in stoves, agricultural dryers in Pailin or as raw material for gasification process. It can also be thrown and spread in the fields by farmers.

- **Advantages :**
  - Can make a very good quality of char briquette, with a good combustion.
  - Already dry during the dry season

- **Disadvantage :**
  - Not available all year long.

Carbonized corn core (waste from the gasification process)

The previous mentioned electric power plant near **Battambang** *(Phnom Sampov Koet village, Phnom Sam Pov commune, Banon district)* works with corn core.
Another power plant (lower power) also makes some carbonized corn core. It is very interesting because the corn compound is dry (compared to the other gasifier design which provides it wet) due to a different ash removing.

Left: carbonized corn core from gasification process (1st layout)

*Right: carbonized corn core sample, on a square pattern (5mm*5mm)*

- **Quantity :**

We can estimate as we previously did for the peanut shell. We can take an estimated average quantity of 160kg/day for a gazification power plant (dual fuel, 70%gas / 30%diesel) running 60kW during 11hours. That quantity added to another small power plant of 7kW capacity, running 13h/day (100%gas) and producing around 35 kg/day, makes a total quantity of **200kg/day** in the whole Battambang area.

- **Availability** :

The corn core is the raw material of the gasification process; the availability is directly linked by the power plant production which uses it alternatively with peanut shell and *Leuceana*.

- **Price** :
  Around **US$1/ton** (mainly for transportation).

- **Current use**: that waste is not yet employed.

- **Advantages :**
  - Very centralised production.
  - That process waste is a directly “pre-conditioned” raw material for char briquetting activity.
  - That waste is cheap and it is made without any carbonisation kiln.
  - Ash content is low: 5,7%%; important carbon content: 88% *(source : CIRAD, France, 2006).*

- **Disadvantage :**
  - Very localized production.
  - Coal waste often blended with peanut shell.

Rice husk (agronomic residu)

This a waste from the rice production, very abundant in Cambodia, especially in **Battambang and Kompong Chhnang provinces.**

Left: rice hush stock (1st layout: stored in bags for sales; 2nd layout: raw material)

*Right: rice hush sample, on a square pattern (5mm*5mm)*

- **Quantity :**

It is difficult to give an accurate weight production, but we can estimate it trough the rice production: 20% of the paddy rice is rice husk.
One of the biggest rice mills from Kampong Chhnang produces around 2.2 tons/day of rice husk.

- **Availability :**

Rice husk is available **regularly during all year**, whatever the season. Farmers and rice mills keep paddy rice and sell it during dry season when there is not any crop.

- **Price :**

In the country side of Battambang province rice husk is free. However, in the bricks factories, near traffic roads, people buy it **0,25US$/ton**, delivered to the factory.
In Kampong Chhnang province, 1 truck of 2 tons of rice husk is around **2,5US$/ton**.

- **Current use :**

This residue is used in huge quantities as fuel in kilns of bricks factories. It is also used as fuel in stoves of household and small scale industries, or used as fertilizer in fields.

- **Advantages :**
  - Abundant all year
  - Cheap and sometimes free in the country side
  - Low and regular particule size
  - Already dry in dry season

- **disadvantages :**
  - Low bulk density (100kg/m^3)
  - High ash content (around 20%)
  - Siliceous material

1.4.2- Sources in urban environment, Phnom Penh

Coconut husk/fiber

Left: waste from a coconut wholesaler.

Right: coconut husk, waste from coconut consumption (mostly for the juice), in a street of PP waiting for CINTRI collection.

- **Quantity:**

That is a big source of waste, evaluated at around **30 tons/day*** in Phnom Penh. There are many places all around in the city where we can find it (in big and small amount), that is not centralised.
*(data from interview, not yet verified)

- **Availability :**

Mainly, coconut comes from *Kompot* province. Coconut is available all year long but the consumption is much more important in dry season than in rainy's, so is the waste.

- **Price:**

The price is not directly linked with the amount of coconut husk but it consists in a garbage tax per month (10US$/month for wholesalers and 5US$/month for sellers).
A wholesaler (90/100 dozens of coconut per day) produces, on average, 10 bags of 10/15kg per day, which means around 100/150kg per day or 3800 kg/month. So the price of coconut husk/fiber was evaluated at **2US$/ton**.

- **Current use :**

Actually a Chinese company buys dry fibre, directly from wholesalers. They use it to make car sit and cushion.

- **Advantages :**
  - Two sources were localized in PP, producing a big amount of waste
  - Sellers and wholesalers are ready to collaborate by regrouping their coconut waste.

- **Disadvantages :**
  - The moisture content is around 85% when collected recently.

Bagasse (waste from sugar cane consumption)

Left: bagasse mixed with other waste, waiting for garbage collection to the dump site.

Right: bagasse from a sugar cane juice seller.

- **Quantity :**

That is also a big source of waste in Phnom Penh: around **20 t/day during dry season and around 46 t/day during rainy season** *(source: study on the quantity of sugarcane residues in PP, CEDAC 2001)*. Considering volumes, the total amount is around 38700m^3/year, that is to say 6,6% of global amount of waste. We can estimate at 10/20 kg of bagasse per day and per seller, regrouped in baskets.

- **Availability :**

In 2000, there was an estimation of 1820 sellers situated in 33 different places: in markets, schools, hospitals, pagodas and resorts.
The amount of sugarcane waste in dry season is two times higher than that in rainy season. This waste is available in every cities and many villages in Cambodia, same places but different quantities.

- **Price :**

All the producers have to bring this waste in a collection place, mostly containers. The financial mechanism is the same as coconut husk. However, if we can collect it directly in the sellers shop, and in that way helping sellers to rid of the volume of their waste, bagasse is mainly free.

- **Current use :**

Globally, this waste is not used and is blended with others before being collected. Even so a part seems to be used in paper production (not confirmed).

- **Advantages :**
  - Abundant and available all year long.
  - Sellers would be OK to sort out this waste from others.
  - Moisture content can decrease at 9% in few days only, during dry season with natural air drying.

- **Disadvantages :**
  - Moisture content is around 50% when collected recently.
  - Production is localized but not centralised, that is a difficulty for the collection.

2- Proposal of different ways to process combustible waste as alternative fuels

The fact that there are several sources of combustible waste/residues -mostly biomass- permits people to make all sorts of benefits by processing them as alternative fuels. That is also a sustainable response, economically interesting, for the waste management.
However an alternative fuel, especially for household cooking, must not only answer to energetic requirements but also to the social context.
In the case of an industrial use, costs of the kiln/stove adaptation and the certitude of non-destruction of the kiln are the main criteria.

2.1- Projects of gasification valorization

Pyrolysis-gasification is a process of energetic valorization of the biomass.
The aim is to produce combustible gas from the combustion of biomass before using it in a generator to produce electricity or in a burner to produce heat.

This physico-chimic conversion takes place in a gasifier (or reactor) which is designed according to the desired power.

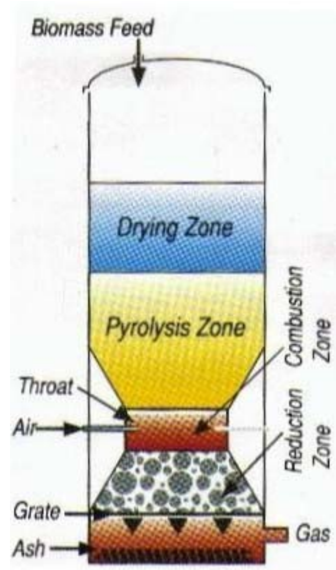


Fig.2.1: descriptive of the gasification process and principle of a down-draught gasifier.

One of the objectives of this report is to study the viability of three projects about gasification:

- Rural electrification and/or battery charging service.
- Dissemination of gasifier-stoves for household cooking in urban and/or rural places.
- Dissemination of gasifier-burners to implement industrial kilns in bricks factories around Phnom Penh.

2.1.1- Rural electrification and battery charging service

Global context

Electricity costs in Cambodia range from US$0.09/kWh to US$0.53/kWh for government services (EdC), and can be much higher for small private services or battery charging services. Cambodia has the highest electricity costs of any ASEAN country.

Thus an estimated 600 Rural Electricity Enterprises (REE) operate small diesel-powered mini-grids to sell power. The range of tariff charged by REEs is from US$0.3 to US$0.91*(EdC, 2001)*, the average tariff has been estimated at US$0.53/kWh.

Moreover, an estimated 8,000 battery charging businesses provide services to households and businesses, and the effective tariff is often over US$1.00. *(sustainable energy in cambodia : status and assesment of the potential for clean development mechanism projects, 2004)*.

Localization

Battambang province has been evaluated for project piloting because there are sources of agricultural residues available and a gasification unit has been detected there.

The 7kW power plant project run by SME (Small and Medium Enterprises) will be considered as example is this report. This “community based renewable energy pilot-project” is a Village Energy Cooperative Model close to Battambang.

Energy access and rural development are advantages of this “social” model:

It allowed the creation of jobs for making a cheap electricity (US$0.37 vs US$.70 for the private 75kW gasifier power plant also visited in Battambang (cf. part 1.4.1).

Two types of business are interesting to consider and will be simulated:

- The association of an electricity supply through local micro-grid to a battery charging service
- Battery charging service associated to LED-lamp dissemination (low consumption lamps with a good enlightenment).

Technico-économical caractérization

The choice of the gasification unit should be based on both availability and daily amount of raw material and on the required power; a compromise should be found to have a well proportioned unit.

Indeed, the proportion of the power plant should take into account that the need of electricity will increase in the next few years and that the best yield of the engine is for a load of 60%, at least, of the nominal power.

- **Raw material**

3 agricultural résidues are available in Battambang province :

- ✓ Rice husk
- ✓ Peanut shells
- ✓ Corn core

The particule size and the moisture content are both main parameters of the raw material.

- **Technical characteristics**

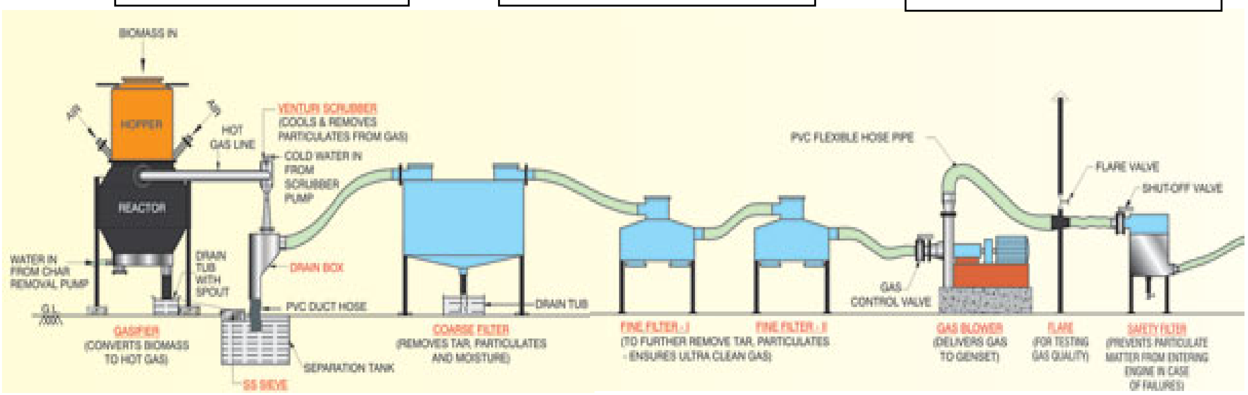
Low power units (up to 10 kW gas engine) are more pertinent at a village scale because they allow a reduction of the investment, the running cost and the scale of the grid.
The final objective is to propose the cheapest price per kWh by avoiding the customers to support a high global investment.

Fig.2.2 : Scheme of a small scale gasification plant

1st step: gas production in the gasifier or reactor.

2nd step: gas cooling system and gas filtration.

3rd step (out of this figure) : gas admission (cool and clean) in the engine.



And its real application:

Left: photo of a 7kW power plant (SME project in Battambang).
We can notice the red gasifier, the filter on its right and the engine in green, top right.

Right: Stock of raw material composed of Leucaena (before being cut) and corn core (ready to use).

A business of battery renting (by using low maintenance batteries, dry batteries for instance) is also interesting to consider.
The activity consist of charging batteries during the journey (morning+beginning of the afternoon) and then, renting them to the customers according to their requirements.

2 mains advantages :

- ✓ The cost of the electric system for battery charging is much less important than a micro-grid's.
- ✓ The production of electricity is stable and well controlled.

In that way the price of kWh is cheap and customers will only pay for their own consumptions.

- **Economical characteristics and simulation :**

Small scale gasifier unit (Ankur GAS-9, SME project) grid + battery charging	
EXPENDITURE	**US$**
Investment costs	
gasifier+filtering system+engine+generateur	15000
1km low voltage grid	10000
battery charging system (transformer, wire,..)	350
TOTAL INVESTMENT	25350
Annual running costs	
semester maintenance	140
transportation	60
communication	60
office automation	36
dues	8
all system depreciation	1692
salary of 3 techniciens	1200
Annual costs of raw material	
leucaena (20US$/ton, 2,5tons/month)	540
it is important to say that this evaluated cost is based on 9 month running with Leucaena and 3 month with corn core (considering used during its season without any storage)	
TOTAL annual	**3736**
INCOME	**US$**
Selling price and dissemination	
grid (0,375 US$/kWh)	2700
battery charging (0,24 US$/kWh or 0,19 US$/battery 50Ah)	1728
TOTAL annual	**4428**
Annual final result [US$]	692

Small scale gasifier unit (Ankur GAS-9, evaluation) Battery renting	
EXPENDITURE	**US$**
Investment costs	
gasifier+filtering system+engine+generateur 7kWeff	15000
140 batteries 50Ah	2800
battery charging system (transformer, wire,..)	450
TOTAL INVESTMENT	18250
Annual running costs	
semester maintenance	140
transport	60
communication	60
office automation	36
batteries depreciation (lifetime=5years)	560
all gasification system depreciation (lifetime =15years)	1120
salary of 3 techniciens	1200
Annual costs of raw material	
leucaena (20US$/tonne, 2,5tonnes/mois)	540
it is important to say that this evaluated cost is based on 9 month running with Leucaena and 3 month with corn core which has been evaluated at 10US$/ton. hypotesis: the power plant runs **8h/day and 5days/week, full load**	
TOTAL annuel	**3716**
INCOME	**US$**
Selling price and dissemination	
battery charging (0,3 US$/kWh or 0,24 US$/battery 50Ah)	4032
TOTAL annual	**4032**
Annual final result [US$]	316

Fig.2.3 : Economical comparative of rural electrification / battery renting

COMMENT:
Characteristics on the left are real while the one on the right are simulated.
That is important to say that the aim of such a unit is not to make big profits. It must be lead as a village energy cooperative where the little profits serve only to perpetuate this business.

Socio environmental impact

Rural electrification made with small scale gasifier is a sustainable solution to improve the access to energy and, at the same time, to guarantee a cheap kWh; that is a **local and dynamic economical activity**.

Moreover, a gasification power plant (like 7kW SMEs) requires biomass as agricultural residues and allows a fuel saving of 1 litre of diesel per 4kg of wood/corn core, or per 5kg of rice husk *(SME, dec.2005)*. That is to say a saving of 3 litres/running hour, which is equivalent to **8kg of CO_2 / running hour** (California Energy Commission, *Inventory of California Greenhouse Gas Emissions and Sinks: 1990-1999*, December 2001)

Considering the utilization of the char-residue, 8hours operation can produce around 40kg of char briquettes (dry). In that way it is possible to save more CO_2 emissions: **13,7kg of CO_2/running hour** if these renewable char briquettes are used in the same quantity as non renewable charcoal (1kg of charcoal = 1kg of char briquettes)

*Bases of calculation: 1kg of charcoal = 2,74 kg of CO_2 emissions

2.1.2- Dissemination project of gasifier stove for household cooking.

Localization

Small gasification stoves can be disseminated in both, urban and rural environments. The predisposed areas are the ones where rice husk, peanut shells, wood shaving and others biomass, with a small particule size, is available.

Technico-économical characterization

- **Raw material**

The technology of a gasification stove is based on a combustible with small particles size, 0,5*1*2cm (+/- 50%) is the maximum size.

- **Technical characteristics**

  - Example of ***Rice Husk Gas Stove*** **(designer: A.T.Belonio)**

This stove is composed of a gasifier reactor, where rice husk is placed and burnt with limited amount of air (primary air), a burner which converts (with secondary air) the gas coming out from the reactor to a bluish flame, and a char chamber with a fan, component of the stove that provides the air needed by the fuel during gasification.

The ratio between primary and secondary air is precise and definite by secondary air holes.

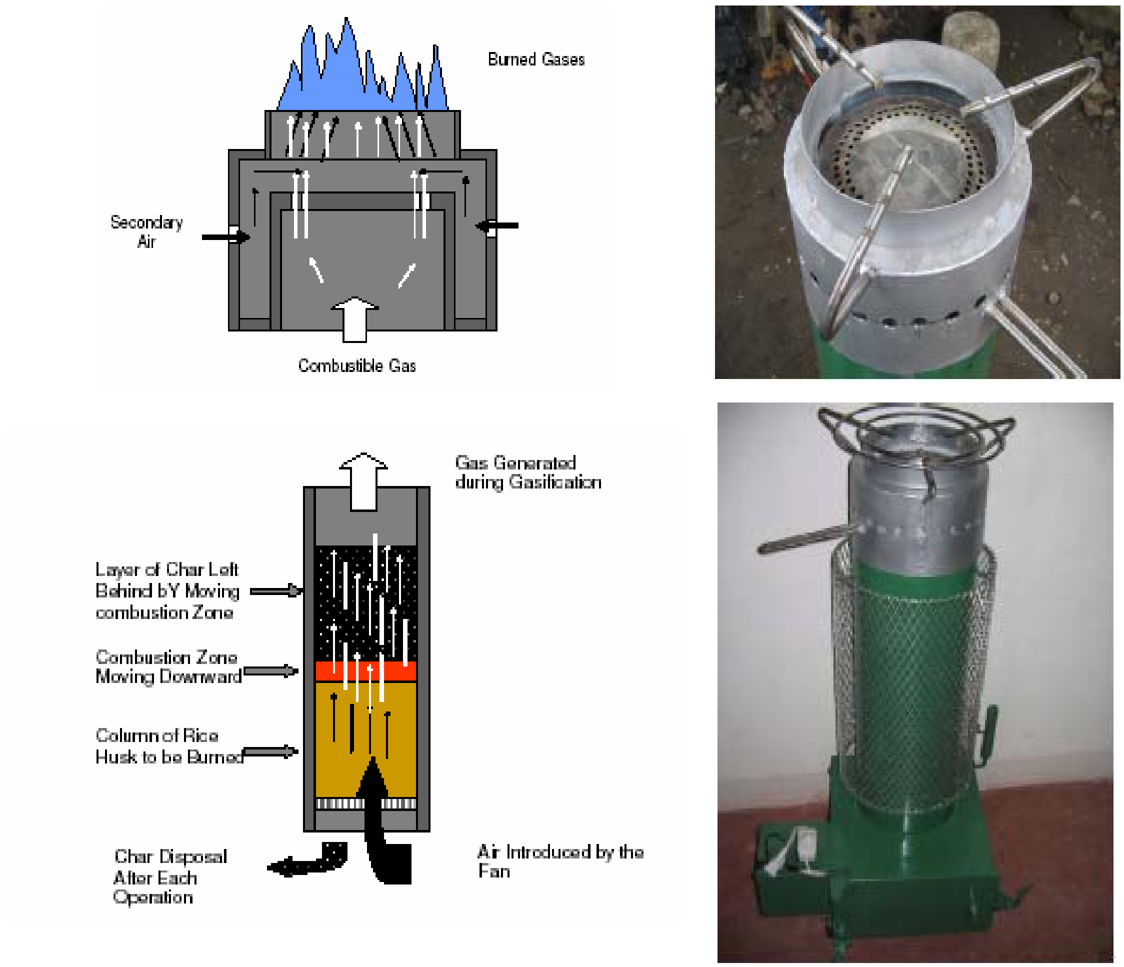


Fig.2.4: Principle scheme of Rice husk gas stove (A.T.Belonio), gasifier stove for household cooking.
Down: photo of the Rice husk gas stove, we can notice the fan next to the char chamber which blows the primary air.
Up: focus on the burner, we can see the holes on its periphery for secondary air inlet.

Fig.2.5 : Results of laboratory experiments for *Rice Husk Gas Stove* performances*:*

Loading Capacity	Weight of Fuel (kg)	Fuel Start-Up Time (min)	Gas Ignition Time (sec)	Total Operating Time (min)
Full Load				
Trial 1	1.300	1.75	40	48.95
2	1.300	1.82	32	46.10
3	1.300	1.35	57	51.40
Average	1.300	1.64	43	48.82
¾ Load				
Trial 1	0.975	0.97	33	29.70
2	0.975	0.77	26	28.63
3	0.975	0.63	16	29.38
Average	0.975	0.79	25	29.23
½ load				
Trial 1	0.650	0.58	10	19.63
2	0.650	0.47	8	19.48
3	0.650	0.42	11	22.30
Average	0.650	0.49	9.66	20.47

Loading Capacity	Fuel Consumption Rate (kg/hr)	Char Produced (%)	Combustion Zone Velocity (cm/min)	Specific Gasification Rate ($kg/hr\text{-}m^2$)	Electric Consumption (W-hr)
Full Load	1.59	35.0	1.23	56.81	13.01
¾ Load	2.00	33.6	1.53	113.63	7.79
½ Load	1.90	16.9	1.46	107.95	5.45

*Average of 3 runs

The type of the fan can be a 220V16W but a 12V3W seems more appropriated because it works on battery supply. However the need of electricity makes this stove unautonomous.
A thermo electrical probe, « Seebeck effect » type, can solve this problem. This probe is able to produce enough electricity to supply the fan when submitted to a source of heat.

➢ Example of ***Juntos Gasifier Stove*** **(designer: P.S.Anderson)**

The design of this stove is based on the same technology as the *Rice Husk Gas Stove's* and the only difference between both is in the construction, the *Juntos* is much more fairly easy to make with local materials.

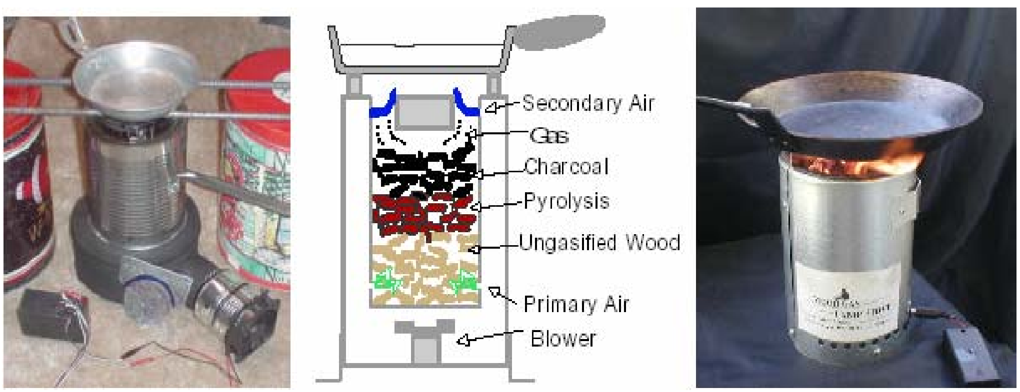


Fig.2.6: Operation scheme of gasifier stove and photos of Juntos B gasifier (on the left) and of WoodGas CampStove, designer T.Reed, (on the right).

- **Economical characterisation :**

This is an evaluation based on data from the Rice husk gas stove's designer *(Alexis T.Belonio, Central Philippine University)* and consists also in an evaluation of the production of such a stove.
The following costs are indicative and have to be adapted to Cambodia.

Rice Husk Gas Stove		LPG stove		New Lao stove	
					
EXPENDITURE	**US$**	**EXPENDITURE**	**US$**	**EXPENDITURE**	**US$**
Investment costs		**Investment costs**		**Investment costs**	
Simulation of production					
buiding materials for 6 stoves	255	current minimum price of one stove	8	price of one stove	2,5
production cost for 6 stoves (labour, consumable, energy)	110	refill bottle price	1		
production overcost (20%)	73				
gross margin (15%)	65				
tax (10%)	47				
selling price (6 stoves)	550				
TOTAL INVESTMENT per stove	91	TOTAL INVESTMENT	9	TOTAL INVESTMENT	2,5
Annual running cost		**Annual running cost**		**Annual running cost**	
depreciation (lifetime =3years)	30	depreciation (lifetime =2/3years)	3,5	depreciation (lifetime =2years)	1,25
maintenance	9	maintenance	0	maintenance	0
electricity (if connected to a grid), based on a consumption of 13Wh and a price of 0,14US$/kWh	2	electricity	0	electricity	0
Raw material cost		**Raw material cost**		**Raw material cost**	
Evaluation of raw material annual cost (whatever the biomass fuel)	4,35	Evaluation of the annual energy cost (butane)	115	Evaluation of raw material annual cost (whatever the biomass fuel)	82
It is difficult to determine a precise cost because it mainly depends on the locality. the previous cost is based on the maximum cost noticed, which is 2,5US$/ton of rice husk. Fuel consumption pondered is 1,59kg/hour during 3 hours.		1 bottle of 220g of butane=1US$, refill (250g)=0,175US$. Fuel consumption =150g/hour. Calculation based on 3hours running /day. It is suposed that only one bottle was bought and then refilled every time.		Pondered cost is based on a daily fuel consumption of 1,8 kg of charcoal/day (CFSP,2005) with a current price of 0,125US$/kg of charcoal.	
TOTAL annual	**45,35**	**TOTAL annual**	**118,5**	**TOTAL annual**	**83,25**

Fig.2.7 : Economical comparative of stove for household cooking

This calculation shows that the annual cost of a small gasifier stove would be lower than two others usual stoves in Cambodia. The main problem to make this gasifier stove attractive remains in the lack of such calculation and in the inability of users to invest.
However, if there is any possibility to produce the *Juntos Gasifier Stove* at a selling price of US$20, including a thermo electrical probe to supply the fan, this technology stands a big chance to be adopt by users.
Moreover, there is a possibility to sell it at a higher price considering an accrued lifetime.

Socio environmental impact

The production and dissemination of such a gasifier stove is another opportunity (like NLS project) to **create jobs**.
This stove does not use any charcoal and permits a saving of 660 kg of charcoal/year/stove *(CFSP,2005)*, that is to say **1808 kg of CO_2/year/stove***, **comparing to NLS,** or 835kg of charcoal/year/stove *(CFSP,2005)*, that is to say 2288 kg of CO_2/year/stove*, comparing to TLS.
*Bases of calculation: 1kg of charcoal = 2,74 kg of CO_2

2.1.3- Dissemination project of gasifier burner

Global context

That is also important to think about a solution to improve actual kilns in industrial activities, and in that way to reduce fuel consumption.
A gasifier burner permits to increase the combustion yield and reduces consumptions; but it is also important to adapt it on a kiln/stove already efficient.
A fairly new kiln, with a dome shape, has come in bricks factories few years ago and seems to have a better design than traditional rectangular's.
However the following proposal is based on a study done in Philippines which is difficult to transpose (especially modification cost and burner adaptation) to Cambodia because the technology does not yet exists in the country.

Localization

These dome kilns are designed to work with rice husk as fuel. That insinuates there are mostly along the road between Pursat and Battambang.
Small scale productions using rice husk are also in **Kampong Chnnang and Battambang provinces**.

Technico-économical caractérization

Using combustible gas from gasification directly in a burner, and not in an engine, has a big technical advantage: no need to cool and filter gas before burning them.
This technology is the same than the previous gasifier stove, only the scale is different; the principle is the same.
The model on that photo (25cmx1m) has been developed to work on two ovens in a bakery in Philippines and is representative of the one which should be adapted on dome kilns in Cambodia.
The only difference with the previous gasifier stove is that the burner is in the oven/kiln and not at the top of the reactor. Pipes bring gas from the reactor to the burner. This unit is a two fuel reactors unit which allows the user to cook permanently by burning alternately the reactors every 30 to 40 minutes.

A switch permits to adjust the fan velocity for primary air inlet which determines the size of the flame.
The investment cost for this gasifier burner is around US$600 and its running cost around 0,5US$/hour.

Socio environmental impact

Regarding the efficiency of this burner, it is possible to **reduce rice husk consumptions**, cooking times, so in the same time to **increase the production** of products.
Moreover, an **economical activity must be run** to produce gasifier burners.

2.2- Char briquetting project

The aim of this project is to propose a char briquette which can substitute to charcoal for household cooking. The real challenge will be to propose this alternative charcoal at a lower selling price than the traditional one.

2.2.1- Technico economical caracterization of a production unit:

Global context

Household cooking has a huge impact on deforestation; CFSP has already been working on this problem, especially through two anterior projects:

- Firstly by NLS (improved stove) dissemination project, which allows a saving of 20% of charcoal/NLS.
- Secondly, through the renewable charcoal production project which will allow a saving of 10% of non renewable charcoal consumption until 2012.

The interest of the char briquetting project is to keep on this way of saving by proposing an alternative char briquette.

Localization

Such a project must takes place close to sources of biomass waste and places where charcoal consumption is high; so a priori, nearby cities and villages all around the periphery.

A comparative calculation will be established, based on the char briquetting unit run by the ASDD association in Battambang province.

- **Raw material**

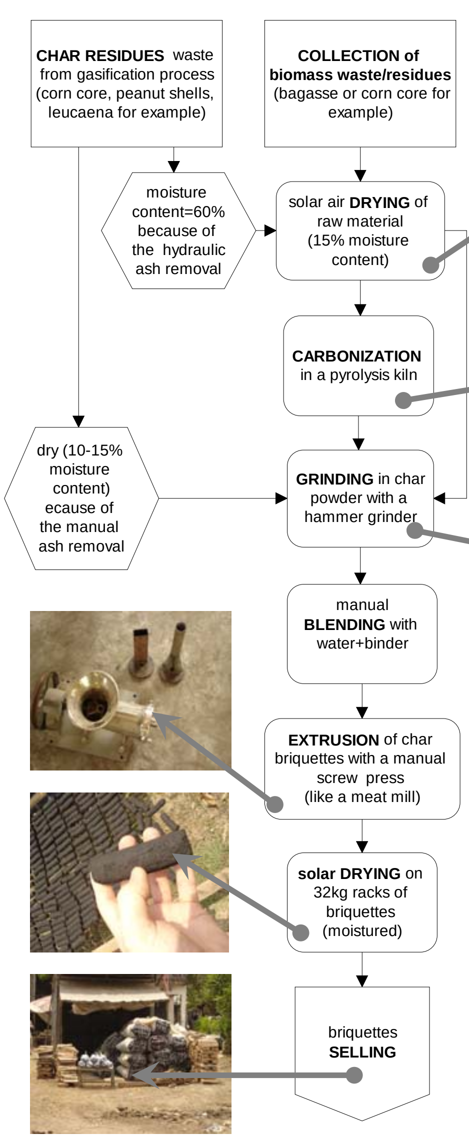
Carbonization in a kiln takes a long time and the carbonization yield are low (15% for bagasse, 20% for coconut husk and 50% for corn core). Moreover this activity needs several kilns and lots of workers to have a reasonable daily production.

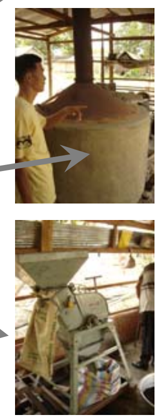
People from ASDD association use moist residues (moisture content=60%) from the 75kW gasification power plant (dual fuel) which produces around 340kg of char residues/day (corn core or peanut shells or *Leucaena*). These char residues are sold 1US$ /ton.

The 7kW gasification power plant *(SME project)* produces very good quality of dry char residues (moisture content=6%, carbon content=89,6% -*source : CIRAD, France, 2006*-), free, which is able to produce around 4kg of briquettes (dry)/running hour. So it seems possible to produce 32kg of briquettes/day (8 hours operation) only by using residues from such a 7kW power plant. This amount is not very high so it can be interesting to combine it with a production from a carbonization kiln.

- **Technical characterization**

Fig.2.8: Scheme of a char briquettes production with two kind of raw material: Already carbonized or not



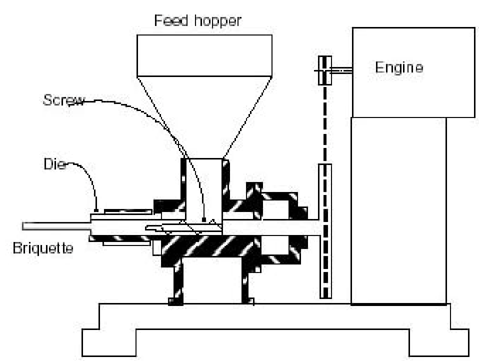


Actual production is between 500 and 700 kg/week according to the meteo, by using only char residues.

Problems of this unit to increase the production:

- Transportation takes a long time and a lot of money when supply sources are not centralised. A truck is necessary.
- Manual blending of casava powder + water + char powder takes too much time (40min for 15/20kg of mix).
- Briquettes air drying takes too much time (at least, 2 times more during rainy season than dry season, what takes 2 days).

In order to increase the production to its theorical maximum (2500 kg/week), the screw press must be changed for a bigger model, with mechanical or electrical driving, and a dryer must be built.
Thus it is interesting to make this dryer working with a gasification burner, and then put the char residues in the production process.



Principal scheme of a mechanical driving screw press

- **Economical characterization**

Char briquettes production (ASDD), 700kg/week	
EXPENDITURE	**US$**
Investment costs	
Engine 17kW+hammer mill+screw press	700
pyrolysis kiln	300
TOTAL INVESTMENT	1000
Annual running costs	
monthly maintenance	240
salaries of 4 workers (80US$/month/worker)	3840
consumable per month: petrol (5l), diesel (20l), binding agent (cassava and résin)	420
truck rental (10US$/day, 1 time/week)	520
building rental	1080
system depreciation (2 years)	500
Raw material annual cost	
char residues (1US$/ton, 4tons/month)	48
TOTAL annual	**6648**

INCOME	**US$**
Selling price and dissemination	
Corn core and bagasse char briquettes sold 0,075US$/kg	3120
TOTAL annual	**3120**

Annual final result [US$]	-3528
If char briquette and charcoal were sold at the same price (0,125US$/kg), That would generate an annual final result of 5200US$	

Economical simulation for an increased production: 2500kg/week	
EXPENDITURE	**US$**
Investment costs	
Engine 17kW+hammer mill+screw press	750
truck	3500
dryer (buiding)	1000
gasification burner 4kW	1500
pyrolysis kiln	300
TOTAL INVESTMENT	7050
Annual running costs	
monthly maintenance	3000
salaries of 6 workers (80US$/month/worker)	5760
consumable per month: diesel, binding agent (cassava and résin), corn core(_)	1500
building rental	1080
truck depreciation (3 years)	1200
system depreciation (2 years)	1525
Raw material annual cost	
char residues (1US$/ton, 15tons/month)	180
raw material for gasifier (corn core) 4kg/h, 8h/day	83
TOTAL annual	**14328**

ICOME	**US$**
Selling price and dissemination	
Corn core and bagasse char briquettes sold 0,125US$/kg production = 500kg/day, 260 days/year	16250
TOTAL annual	**16250**

Annual final result [US$]	1922

Fig.2.9: Economical analysis for artisanal manufacture of char briquettes

It is important to say that ASDD association received an UNDP fund of 35000US$ to start this project. Char briquettes production recently begun and people are actually in development and problems solvation phases. That explains why the production is still going on while the final result is negative.
Moreover here is a commercial strategy: make a good customers network first, and then increase selling prices gradually until getting profitability.

Socio environmental impact

A good char briquette quality has many advantages comparing to charcoal:
It is not dirty, the energy content can be identical, it burns for a longer time, it does not sparkle, it does not smoke a lot, the selling price is nearly the same and the briquette has a good quality aspect.
Nevertheless, its biggest environmental advantage is that such a briquette is made with waste/residues unvalorized.
A benefit of briquettes production is a **local jobs creation**. Supposing a flow of 2500kg/week, it permits to hire 6 persons (full time job) and also a charcoal saving of 130 tons/year, that is to say **356 tons of CO_2/year**.
It is a good way to reduce waste furthermore it takes part in local economy.

COMMENT:
The process for a small or a big unit is globally the same.
The main difference between these units comes from the raw material supply and the size of the different machines/buildings entering in the process.

- **Others technologies for briquettes production**

Two others process are interesting to consider:

- ***Roll press***

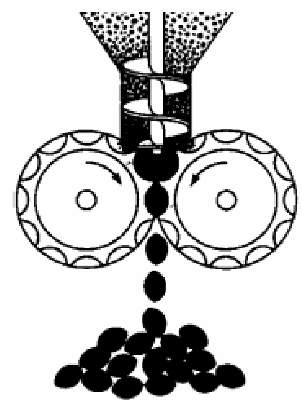


Fig.2.10: principle scheme of roll press with a force feeder (screw).

Advantages :

- The process is continuous and allows, with multiple units, high production capacities.
- The compaction costs are low. The energy consumption is limited.
- Normally, no drying step is necessary.

Disadvantages:

- Powder leakage can be important. It is usually necessary to recycle the uncompacted powder.
- Aspect and dimension of compacts made by briquetting are less regular than those produced by die pressing.

For a 900kg/h berlingots production (35mm size), such a roll press, imported from Thailand, would costs 7200 US$ per unit with 700 US$ more for transportation. Its electrical power is 5,5kW.

➢ *Agglomérating system*

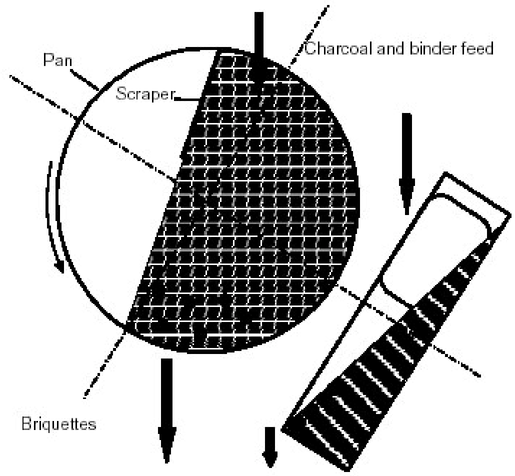


Fig.2.11 : principle of a drum agglomerator

Agglomeration is a method of size enlargement by glueing powder particles together. The equipment basically consists of a rotating volume wich is filled with balls of varying size and fed with powder and, often, with a binder. The rotation of the agglomerator results in centrifugal, gravitational and frictional forces, wich cause a smooth rolling of the balls. The same forces, together with inertial forces, press the balls strongly against the powder wich, due to this pressure, sticks to them. In this way the balls grow layer-wise in diametre.
The smallest curently technically feasible production scale is 50kg(dry)/hour.

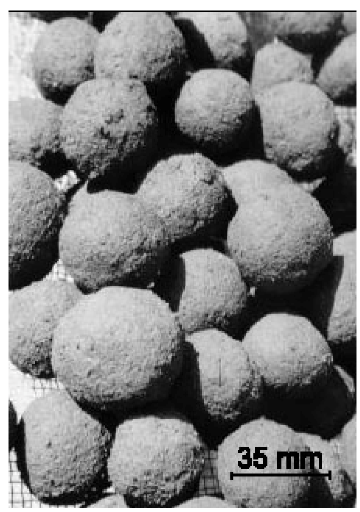


Photo of agglomerated char balls.

Advantages :
- Investment costs are moderated
- Production costs are limited
- Larger production capacities can be obtained only by conbining more agglomerators in one plant

Disadvantages :
- It is difficult to maintain a constant ball size distribution and hence stable operation.
- Balls have to be dried after the process

Fig.2.12: Economical simulation of a char briquetting plant, minimum flow: 500kg/day

EXPENDITURE	US$	EXPENDITURE	US$
Investment costs			
buildings		Equipment and machines	
"Raw material preparation" buiding (storage, drying, baskets feeding areas)	15900	handling and security gasification burner (estimation) fan	10000
"char production" building (cooking and grinding areas, kilns included)	63735	palettes, baskets handling and security containers Electric grinder 1kW	12820
"briquette production " buiding (mixing, extruding and drying areas)	21200	gas stoves pots, spatula Electric mixer 2kW Electric screw press 12kW conveyor brûleur gaz (non inclus) handling and security racks generator 40 kVA+installation	35370
"packaging and storing" buiding	18550	bookcases, office software	1885
Administrative building	5800	desk, chairs	340
TOTAL buildings	125185	TOTAL equipment	60415
TOTAL INVESTMENT	**185600**		

First year running costs	
Grid electricity:900kWh/month, résin:510kg/month (0,3US$/kg), casava:1020 kg/month (0,2US$/kg), clay:510kg/month (0,125US$/kg)	5050
salaries of 24 workers	29040
packaging, advertising, product development	16406
equipment amortization on 5 years	12083
Annual raw material cost	
3,75 tons of bagasse/day, collected by CINTRI : 6,9US$/ton	6728
TOTAL annual	**69307**

INCOME	US$
Selling price and distribution	
Char bagasse briquettes sold 0,125US$/kg (production=260days/year)	16250
TOTAL annual	**16250**

Annual final result [US$]	-53057
RK: a 3 tons/day production would generate 97500 US$/year.	

An economical simulation for an industrial char briquetting unit (500kg/day minimum) highlights several problems:

- Financial investment to build the plant is very high.
- Even if the annual cost for energy is low, financial investment for technical equipment is high. Moreover using biogas from dump site needs special equipment which can be more expensive (than the evaluation in the simulation) and a special study must be done.
- The main economical problem is from the imbalance between the sales and the material amortization; moreover the sales are not fairly enough to cover the salaries.
- If we want the balance null (building investment excluded), the briquette must be sold at 0,53US$, what is **4 times more than the charcoal price.**

Even if the production was to its maximum 3 tons/day), the investment for material and buildings would be proportional, that means the production unit would ever be unprofitable.

Socio environmental impact

An industrial production of char briquettes requires a lot of labour and is a **local economic activity**.

There are two mains benefits of using a big quantity of biomass waste from Phnom Penh: a reduction of the global amount of waste and a cost reduction in the waste management.

Moreover, such a briquette permits a charcoal saving of 130 tons/year. That is to say a saving of **356 tons of CO_2/year** for a 500kg/day production.

Considering a 3tons/day production, that is a saving of 2137 tons of CO_2/year.

2.3- Densified briquetting project

2.3.1- Technico-economical characterization of an industrial briquetting plant:

Global context

Globally it is becoming harder to find wood and very expensive to use it as fuel. This observation is a real problem for the future of certain users who do not have alternative solutions, especially for small scale industries in/around Phnom Penh.

Their stoves are generally adapted to fuelwood, with log shape.

So, a combustible like densified briquette which is energetically interesting can be an alternative to that problem and does not need any main modifications of stove/kiln design. This is important because lots of users are scared of proceeding any modifications on their stove without any visibility/guarantee.

Technico-economical characterization

Densification without binder is well parameterised industrial process, well dominated and economically viable in developed countries.

This is possible because raw material supply is well managed, modern technologies are available, big investments are possible and selling prices allows the producers to rich the profitability.

Thenceforth adapting this know how to Cambodian context, which is totally different, is a real challenge.

Whatever the type of production, industrial or artisanal, steps of the process remains identical. Only equipments, meaning briquettes flow and final quality change.

The high flow technologies (several tons/day) cost hundreds of millions dollars, investment which is, actually, impossible in Cambodia. Nevertheless it can be interesting to study on the possibility of implanting a small scale unit with moderated costs.

- **Raw material**

Even if big amounts of bagasse and coconut husk were detected in Phnom Penh, raw material problems still remain (without considering collection):

- Moisture content is high (between 65% for fresh bagasse and 85% for fresh coconut husk).
- The particule size is variable, especially for coconut husk (between 200mm x200 x30 and 100mm x20 x3).
- These materials are very fibrous, so difficult to grind.

- **Press technologies**

- **Hydraulic press with piston**
  - Flow: 50 à 350 kg/hour

Advantages:
- Low investment
- Easy to install
- Ability to work with bigger particules size
- Ability to work with a moiture content up to 18%

Disadvantages:
- Quality of the product often aleatory
- Problems of reliability
- High running costs

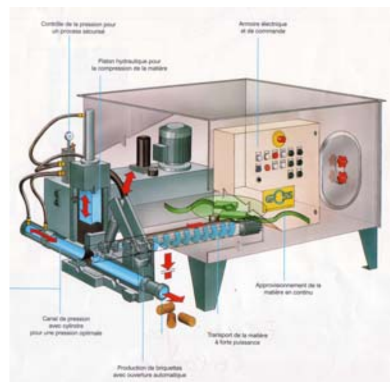


Fig.2.13: Technical scheme of a hydraulic press with piston

- ***Inertial press with piston***
  - Flow: 350 kg to 2 tons/hour

Advantages:
- Regular good quality of the product
- Reliable technology

Disadvantages:
- Only for big industrial quantities
- High investment
- Encumbrance

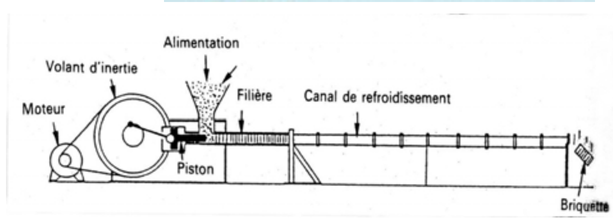


Fig.2.14: principal scheme of an inertial press with piston

Top: photo of an inertial press with piston.
Cooling canal (between 5 and 10m) prevents of briquette explosion which can happen because of the high internal vapor pressure due to the compacting.

- ***Screw press***
  - Flow: up to 100kg/hour

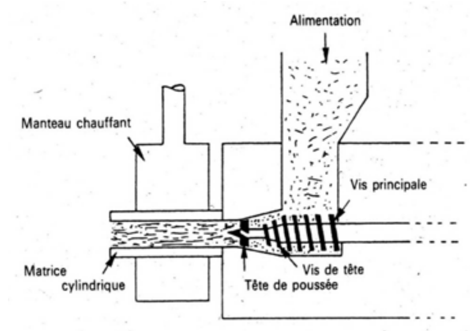


Fig.2.15: principle scheme of a screw press

Up: photo and principle scheme of a screw press with die-heater. This die-heater serves to get the necessary counter-pressure to make a densified briquette.

Advantages:

- Moderated costs
- Technology adapted to developing countries (already exists)

Disadvantages:

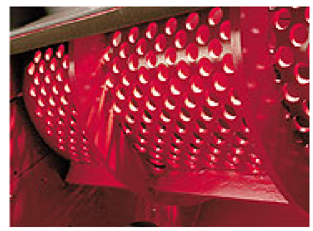
- Work only with small particules size (rice husk)
  Remark : siliceous material (rice husk for instance) engender reliability problems of the screw press, mainly of the screw.
- Reliability problem (screw)
- Moisture content <14%

Collection of bagasse or coconut husk

Drying is the first step to make the grinding easier, also because the material is fibrous. The dryer can be the same as char briquette's. Here, no need to carbonize the material so global amount is less important.

DRYING
moisture content <18%

The **grinder** must be sturdy, with a good reliability, easy to use and to maintain, with low running cost and able to work with lots of raw materials. Moreover the flow capacity must be high enough
An electric grinder, single rotor with pushrod, is a basic model which must be imported.



Right: focus on the sift, particules are « selected » through the holes diameter.
The flow depends on the material and on the sift size (from 10mm to 50mm).
Bagasse seems to be more appropriated.

GRINDING/ SIFTING
particule size<20x20x4 mm

A hydraulic piston press (flow: 50 kg/h), has a pressure of compaction of 120 bars and produces cylindrical briquettes (50mm* 50mm long). It is able to work with a maximum moisture content (of raw material) of 18%.

DENSIFICATION
piston press

DENSIFIED BRIQUETTE
50mm*50mm

Final product:
Briquette of densified bagasse,
1234 kg/m3 ; PCI= 17,6 MJ/kg
Moisture content=14%
(Wood log = 14,5MJ/kg)
Mineral content=4,9%

Fig.2.16: scheme of an industrial densification briquetting plant

Fig.4.7: Economical simulation for densified briquetting plant, flow: 400kg/day

EXPENDITURE	US$	EXPENDITURE	US$
Investment costs			
Buildings		Machines and equipments	
"Raw material preparation" building	15900	handling and security gasification burner (estimation) fan	10000
"briquette production " building	21200	monorotor grinder with pushrod 11kV	18500
		hydraulic press 7kW, flow 50kg/hour	17800
		générator 40 kVA+installation	15000
"packaging and storing" building	18550	bookcases, office software	1885
Administrative building	5800	desk, chairs	340
TOTAL buildings	61450	TOTAL équipment	63525
TOTAL INVESTMENT	**124975**		

First year running costs	
grid electricity:3600kWh/month	8640
salaries of 13 workers	26880
packaging, advertising, product development	16406
Equipment amortizing on 5 years	8747
Annual raw material cost	
500 kg of bagasse/day, collected by CINTRI : 6,9US$/ton	897
TOTAL annual	**61570**

INCOME	US$
Selling price and distribution	
Densified briquette sold 0,125US$/kg (production=260days/year)	13000
TOTAL annual	**13000**

Annual final result [US$]	-48570
Even sold at the charcoal price (0,125US$/kg), which is higher than woods, densified briquette is not yet profitable.	

Globally, the same problems as char briquetting activity appear through this simulation:

- Financial investment for buildings is very high.
- The global cost of electricity is very high.
- The main economical problem is still the same: the imbalance between the sales and the material amortization; moreover the sales are not fairly enough to cover the salaries.

In order to have a final result null (buildings investment excluded), the briquette should be sold 0,60US$ per unit; this is **4,8 times more than the charcoal and 8 times more than wood**.

The energy content of such a briquette is higher (between 15 and 20% more) than wood. Considering that, actually, wood price increases so much, certain users would be ready to pay more for briquettes. However this alternative combustible is not yet economically profitable.

Socio environmental impact

An industrial briquetting plant gives to small scale industries in Phnom Penh an alternative to wood rarefaction. This activity permits them to continue their production and permits also to run a new one around the dump site of PP.
Moreover such an activity permits a saving of **126 tons of wood/year** (regarding the energy content), that is to say a saving of **72 tonsCO2/year*** (for a production of 400kg/day).
(*methodology of calculation, SSC IIG of CDM : 0,57kgCO2/kg bois non renouvelable)
However this industrial briquetting plant is not yet profitable but it, probably, will be in few years.
An artisanal briquetting plant seems more appropriated to the actual context and would be a good way to introduce this alternative fuel.

2.3.2- Technico-economical characterization of an artisanal briquetting plant:

Global context

Densified briquette has already made the proof of its interest and its feasibility in certain developing countries.
Actually, a Nepalese NGO called « FoST » (Foundation for Sustainable Technologies) works on an artisanal briquetting plant in order to run a new economical activity. They already have a prototype of a manual press and it seems that they agree, for a mutual benefit, to work with GERES Cambodia to develop a mechanical press to improve the production.

Localization

A pilot project requires an important source of biomass, but can be run in both rural and urban places.
Moreover a similar project can also be developed in partnership with/in a school in order to sensitize students to biomass waste valorization.

Technico economical characteristics

- **Raw material**

Densified briquettes can be made of all sorts of dry biomass, bagasse for instance. The advantage of this material is that it dries quickly and it is very popular and disseminated, in the countrie side and in urban places; there are huge sources in cities.
Its physical characteristics are similar to wood. Nevertheless, dry bagasse grinding has to be experimented.

An artisanal briquette often needs a binding agent because of the big particles size (after grinding) and low pressures of the press. This binder can be, for example, a natural resin, fish waste, molasses, wood ash, manure, corn starch, wheat starch…

Another agglomeration process uses rice husk mixed with clay and water to make ball-shape briquettes.

- **Densification with a press**

Technically, there are many solutions to design and make a manual press. A press to make clay bricks is an example, sold with different cheap moulds it costs around 120US$/press.
But the main inconvenient with manual press is always the low flow capacity and the important need of labour.
However this previous aspect can be an advantage in Cambodian economical context because it can create lots of jobs.

Left: photo of a manual press (appropriated technology-ECHO, 2001). The lever arm allows to rich high pressure of compaction, it well illustrates the principle.
Right : example of densified briquette without any binding agent and made of several biomass waste and plastics. It's a aspect is typically of manual densified briquette.

- **Densification by agglomeration**

It is interesting to consider the agglomeration process, which is another way of densification, through a pilot project in Senegal led by Gembloux researchers.
In this African country, wood rarefaction is a similar problem as Cambodia's.
The aim of this project is to produce agglomerated rice balls.

This is a three phases process:

- Grinding of rice husk before being mixed with water and clay (which is the binding agent)
- Granulation in an agglomerator
- Drying of these rice (husk) balls

The ball size is determined by the agglomerator, and must be defined according to the final use.

Right: photo of an agglomerator prototype
Left: photo rice (husk) balls called « Bioterre® ».

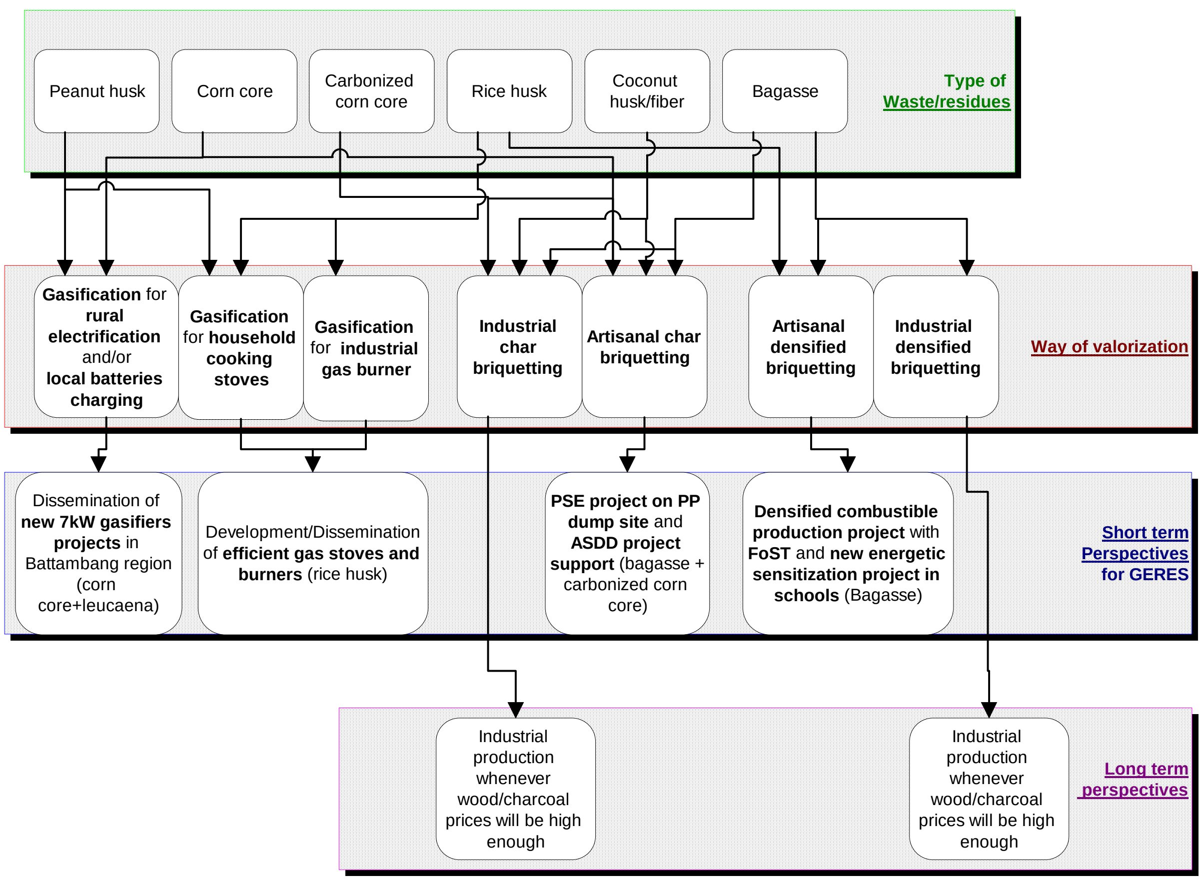
Such an agglomeration plant has already came into service in Senegal and the selling price of rice balls is 0,12US$/kg (60FCFA/kg). Regarding the usual charcoal price in Cambodia (0,125US$/kg), these combustible balls seem profitable.
According to a survey done nearby thirty housewives in Senegal, 90% of them agree to use these densified balls (called « Bioterre® ») insted of traditional charcoal. Nevertheless, it seems that households have to buy, at first, adapted stoves which cost 13,2US$/each (7000 FCFA).

The agglomeration process, through densified balls, should be experienced to validate the process. Then, the objective is to produce this combustible at the lowest cost as possible for a large dissemination.

Socio environmental impact
Actually, artisanal densification is more appropriated to the local context because it requires low investments and lots of labourers. Thus this activity is positive on the local economy. Moreover, this activity can also prepare the consumers to use this type of alternative fuel before producing it in large quantities with an industrial plant.
It would **save wood and valorize waste** at the same time.
Managers of the « *Bioterre®* » project claim that in Senegal 1000 tons rice husk can save up to 400 ha of forest.

2.4- global outcome and perspectives

- **Fig.2.18 : Recapitulating chart**



Main current difficulties to develop an industrial activity:

- Need of a big investment at the beginning
- Prices of « rival » fuels are still lower
- Management of raw material in big quantities still has to be confirmed.

Actually it is preferable to develop artisanal production plant and non-lucrative services than industrial productions.

- **Fig.2.19 : Outcome chart**

	EVALUATION CRITERIA					
WAY OF VALORIZATION	**Cost of combustible or service**	**Initial investment**	**Social impact**	**Environmental impact**	**Economical impact**	**CO2 savings**
Rural electrification and batteries charging	Network : 0,375US$/kWh Battery : 0,24US$/kWh	25350 US$	- job creation - creation of a village energy cooperative (kind of public service)	- residues valorization - creation of a residue which is charcoal substitute (after process) - Diesel fuel savings	- Creation of an activity of wood (fast growth wood) supply, that is to say new incomes	**8 kg/running hour+ 13,7 kg/h** if char residues are used in char briquetting activity
Batterie renting	0,3US$/kWh	18250 US$				
Efficient gasification stove for household cooking	4,35US$/year (running 3h/day)	*Rice Husk Gas Stove* : 90US$ *Juntos Gasifier Stove*: 20US$	- job creation for stoves production - cooking with flame and smoke reduction inside habitat	- Savings of traditional charcoal, that is to say reduction of the deforestation - reduction of fossils energies (100% imported) consumption	- annual cost 2 time less important comparing to NLSs and 3 time less comparing to LPG stove	**1808 kg/year/stove** comparing to NLS andt **2288 kg/year/stove** comparing to TLS
Industrial gasification burner	–	600 US$/burner Estimated output between 50 and 100kW	- job creation for the production	- consumptions reduction	- diminution des coûts d'approvisionnement - éventuellement, diminution du temps de cuisson, augmentation de la production	–
Industrial char briquetting Mini = 500kg/day	Current minimum price : 0,53US$/kg (actual charcoal price=0,125US$/kg)	185600 US$ (buidings included)	- job creation (23 workers) around PP dump site - creation of an urban collect	- Savings of traditional charcoal, that is to say reduction of the deforestation - waste and biogas valorization from PP dump site, so reduction of CH4 emissions.	- Final objective : make profits	**365 tons/year**
Artisanal char briquetting maxi= 500kg/day	0,125US$/kg	7050 US$	- job creation - creation of a supplying network - support for gasification process	- Savings of traditional charcoal, that is to say reduction of the deforestation - valorisation de déchets	- profits, 1922US$/year with a possibility to increase prices, depending on the good quallity of briquette (ex: corn core briquette)	**365 tons/year**
Artisanal densified briquetting Maxi=100kg/d	Maxi at the beginning : 0,125US$/kg Than increase if good dissemination	Evaluation : <1000US$ (2 press, grinder, dryer)	- job creation	- Savings of wood and traditional charcoal, that is to say reduction of the deforestation - valorisation de déchets	- profits	
Industrial densified briquetting Prod=400kg/d	Current minimum price : 0,60US$/kg	124975 US$	- job creation	- Saving of 126 tons of wood/year, that is to say reduction of the deforestation	- Final objective : make profits - Energetic solution for small scale industries in PP	72 tons/year (260 days of production /year)

3- Pilot project implementation: Incineration of hazardous waste from hospitals

3.1- Context

Current waste management in hospitals, and especially waste elimination –mostly incineration- , is a serious health problem which affects many people in developing countries.
A pilot project, possibly run in the next few years by NGOs « Planète Bois » and « GERES », to improve hazardous waste incineration is under discussion. The aim of this possible project is to work on an appropriated technology of post combustion incinerator. This technology would be very efficient and the most environmentally friendly as possible; that means, notably, an incinerator made of local materials and using local energy.
Thus, an alternative fuel like biomass briquette made of waste/residues can be a solution environmentally and energetically interesting in such a project.
Cambodia seems to be a good place for such a pilot project because CFSP is already experienced in post combustion stoves designed with appropriated technology.

3.2- Project preparation in Kampong Chhnang

A global prefeasibility study about hospital waste management was done by three french students *(Cf. Rapport d'étude sur l'incinération des déchets biomédicaux dans les Pays En Développement, O.Enjolras-B.Crespo-A.Hérail, Licence STER Tarbes 2006)*.
An inventory of fixtures and management policy has been done in the Kampong Chhnang hospital according to the recommendation of this previous work.
The study done, focused on that hospital, is necessary to prepare and to discuss about the global project; Kampong Chhnang hospital would possibly become the place of the pilot project.

4- Personal conclusion

Being able to be part of an organisation with which I had no previous experience has been thoroughly enriching. Working for an NGO for the past 3 months made me realise that its way of functioning is virtually identical to that of any successful company.
However, there is the very positive possibility of a certain amount of freedom with regards to personal organisation, taking initiative and autonomy. In way, I think that this contributes enormously towards the happy working environment.

Working on the early stages of a project required much work and perseverance which, with hindsight, is very rewarding from a professional point of view. It is all the more rewarding knowing that the project is the foundation for future projects that will be developed.
I equally appreciated the technical expertise and communication with the population which was required during my work between the office and during the research.
This project also helped me realise how much time and personal investment is needed in order to see some and personal investment is needed in order to see some real results. It was very interesting to be part of such a project which, though technical, required taking into consideration the cultural and social aspects in order to achieve real results.

Regarding the contacts that I made during these 3 months; speaking english was extremely important within this international environment. Having to speak in english on a daily basis made me realise that my level is not as good as it could be and has motivated me to persevere and improve. This is undoubtedly essential in order to work on international projects.

Finally, working with the Khmer and other expatriates was an agreeable, enriching and productive experience based on an exchange of work knowledge and methods.
I was happy to apply these things to an environment that I didn't yet know and towards a cause that I consider important.
I would like to thank the GERES and all the local team for giving me this opportunity, the means to do carry out my work and their support.

BIBLIOGRAPHY

- **Roll press design—influence of force feed systems on compaction**
  P. Guigon, O. Simon
  Université de Technologie de Compiègne, France

- **Energy from Biomass in Cambodia**
  Freddie Verwoerd, *December 2001*

- **Survey of Cambodia Power Facilities,** JICA *2003*

- **Energy Master Plan Study,** NEDO

- **Study of Electric Power Technical Standards and Guidelines in the Kingdom of Cambodia**
  Takuya Takaoka, JICA *February 2003*

- **Technology Packages: Screw-press briquetting machines and briquette-fired stoves**
  S. C. Bhattacharya, S. Kumar, *2005*

- **ENERGIE ET BIOMASSE – LA DENSIFICATION**
  Pierre LEQUEUX, José Carré, Jacques Hebert, Ludovic Lacrosse et Yves Schenkel
  Presses Agronomiques de Gembloux, *1990*

- **RENEWABLE ENERGY TECHNOLOGIES IN ASIA**
  A Regional Research and Dissemination Programm Development Cooperation Agency (Sida)

- **National Energy Policy Review Cambodia**
  COGEN 3, *Decembre 2003*

- **Agro-residue-based renewable energy technologies for rural development**
  M. Shyam, Central Institute of Agricultural Engineering, Bhopal, India

- **Using Modern Bioenergy to Reduce Poverty,** SEI *2001*

- **Charcoal briquetting by agglomeration**
  RV Siemons et P Visser, BTG Biomass Technology Group B.V.

- **Theoretical and practical aspects on the use of LCV-gas from biomass gasifiers in internal combustion engines**
  Hubert E. Stassen, Harrie Knoef, BTG biomass technology group B.V.

- **Pyrolyse et gazéification de la biomasse pour la production d'électricité**

CIRAD, *Octobre 2001*

- **SMALL SCALE GASIFICATION SYSTEMS**
  H.E.M. Stassen and H.A.M. Knoef, Biomass Technology Group B.V.

- **RICE HUSK GAS STOVE HANDBOOK**
  Alexis T. Belonio with "Preface" by Paul S. Anderson, *2005*
  APPROPRIATE TECHNOLOGY CENTER
  Department of Agricultural Engineering and Environmental Management
  Central Philippine University, Philippines

- **RICE HUSK GAS BURNER FOR BAKERY OVEN**
  Alexis Belonio
  Central Philippine University

- **T-LUD Handbook**
  Paul S. Anderson, and Thomas B. Reed, *2006*

- **Biomass Gasification:**
  Clean Residential Stoves, Commercial Power Generation, and Global Impacts
  Paul S. Anderson and Thomas B. Reed
  Biomass Energy Foundation, USA.
  Prepared for the LAMNET Project International Workshop on
  "Bioenergy for a Sustainable Development," 8-10 Nov 2004, Viña del Mar, Chile

- **Sustainable Energy in Cambodia: Status and Assessment of the Potential for Clean Development Mechanism Projects**
  The Cambodian Research Centre for Development (CRCD), *2004*

- **Sustainability of Improved Cookstoves Production and its impacts in Cambodia,** CFSP

- **Potentiel bioenergie au Cambodge***, Dec2003*

- **An overview of the energy systems, renewable energy options, initiatives, actors and opportunities in Cambodia***,*
  Australian Business Council for Sustainable Energy *, August 2005*

- **Study On Quantity of Sugarcane Residue in Phnom Penh**
  Suon Sany*, 2001*

- **Modification of commercial briquetting machine to produce 35mm diameter briquettes suitable for gasification and combustion**
  R.N. Singh_, P.R. Bhoi, S.R. Patel
  Thermo chemical Conversion Division, Sardar Patel Renewable Energy Research Institute (SPRERI), India

- **COMMUNITY BASED RENEWABLE ENERGY PILOT-PROJECT,**
  SME Cambodia

- **SME Newsletter, issue 1 volume 1,**
  Décembre 2005

- **Feasibility Study for Community-Based Eco-Businesses from Renewable Energy Generation Systems (bio-fuel, bio-gas, hydropower, biomass, wind, solar)**
  Draft Report, GERES *April 2006*

- **Draft Cambodian Energy Sector Strategy,**
  SPM- IB, CFSP

- **Char Briquette Project Proposal**
  Ywan BOSKORO, CFSP

- **Woodenergy Baseline Study for Clean Development Mechanism,**
  GERES *2006*

- **Statistical Yearbook 2003 Cambodia,** NIS
- **Statistical Yearbook 2005 Cambodia,** NIS

- **Cambodia Socio-economic Survey 2004,** NIS

- **A Report of Household Fuel Consumption Test (HFCT) in Cambodia**
  Kayeswar M. Sulpya and Chen Cheth
  GERES-CFSP, *May 2005*

- **Potential of Char Briomass Briquettes Production in Phnom Penh**
  Kayeswar M. Sulpya, CFSP

- **Revue cambodgienne "Green fire", n°10, Mars 2005**
  Asia Regional Cookstove Program (ARECOP), Cambodia Fuelwood Saving Project (CFSP), Centre d'Etude et de Developpement Agricole Cambodgien (CEDAC)

- **"Biomass Briquetting: Technology and practices"**
  P.D.Grover et S.K.Mishra
  FAO, Bangkok, *avril 1996*

Visited web sites

- COGEN 3 : http://www.cogen3.net/aboutcogen.html
- Asean Centre for Energy : http://www.aseanenergy.org
- BTG Biomass Technology Group B.V.: http://www.btgworld.com
- Cambodia renewable energy & rural electrification: http://www.recambodia.org
- CDRI (Cambodia Development Ressource Institute: http://www.cdri.org.kh
- Centre National pour la Recherche Scientifique et Technique: http://www.cnr.ac.ma
- CIRAD – La recherche agronomique au service des pays du Sud : http://www.cirad.fr
- GasNet – Réseau Européen de la gazéification : http://www.gasnet.uk.net
- GRET – Association de solidarité et de coopération internationale : http://www.gret.org
- Ministry of Industry, Mines and Energy, Cambodia : http://www.mime.gov.kh
- Pyrolyse Institute: http://www.pyne.co.uk
- Asian Institute of Technology : http://www.retsasia.ait.ac.th
- Reseach Projects4 – ARRPEEC I (AIT Bangkok): http://www.arrpeec.ait.ac.th
- Solarch-Suisse: http://www.solarenergy-thermal.ch
- Wood Energy Network of Cambodia: http://www.wenetcam.net/
- Genentech – Environmental Programs, Data : http://www.gene.com
- CIAE – Central Institute of Agricultural Engineering, Bhopal : http://www.ciae.nic.in
- FoST - Foundation for Sustainable Technologies, Nepal : http://www.cityinside.com/fost/index.htm

- Hazardous Waste Clean-Up Information : http://www.clu-in.org/
- NEDO – New Energy and Industrial Technology Development Organization : http://www.nedo.go.jp/
- SME Cambodia : www.smerenewables.com
- Ministry of Environment, Climate Change Office, Cambodia : www.camclimate.org.kh
- Ministry of agriculture, forestry and fisheries : www.maff.gov.kh
- National Institute of Statistics : www.nis.gov.kh

Char briquettes manufacturer:

- Thailand Charcoal – Manufacturers, Suppliers : http://www.alibaba.com/countrysearch/TH-suppliers/Charcoal/2.html

Gasifiers manufacturers:

- Netpro Renewable Energy Pvt. Ltd : http://www.netprorenewable.com/NETPRO
- Ankur Scientific Technologies Pvt.Ltd : http://www.ankurscientific.com/
- DESI power India : http://www.desipower.com/
- Radhe Renewable Energy Development Associate : http://www.radhegroup.com
- TNAU – Technologies : http://www.tnau.ac.in/tech/index.html

Press-grinder manufacturers:

- AD Trading : http://www.adtrading.fr/
- C F Nielsen : http://www.cfnielsen.com/
- Reinbold : http://www.reinbold-gmbh.com
- Rictec : http://www.rictec.com.sg/
- Environmental Expert.com. Waste Management & Recycling Equipment : http://www.environmental-expert.com
- Leading manufacturers of fuel briquetting machines : http://www.wealthfromwaste.com/
- Machinery to produce coco charcoal briquettes from dust charcoal : http://www.thaisumi.com/en/charcoalextruder.php

Some of the people interviewed

United Nations Industrial Development Organization
Promotion of Cleaner Industrial Production
in the Kingdom of Cambodia
Va Chanmakaravuth
Project Assistant
Ministry of Industry, Mines and Energy
#45 Preah Norodom Blvd.,
Khan Daun Penh,
Phnom Penh, Cambodia
H/P 855-16-824 615
Tel/Fax 855-23-222 076
makaravuth@online.com.kh
makaravuth@ncdproject.com

United Nations Industrial Development Organization
Promotion of Cleaner Industrial Production
in the Kingdom of Cambodia
Nguon Narin M.Sc
National Project Coordinator
Ministry of Industry, Mines and Energy
#45 Preah Norodom Blvd.,
Khan Daun Penh,
Phnom Penh, Cambodia
H/P 855-12-918 878
Tel/Fax 855-23-222 076
nguon_narin@online.com.kh
narin@ncdproject.com

MINISTRY OF INDUSTRY, MINES AND ENERGY
DEPARTMENT OF ENERGY DEVELOPMENT
VICTOR JONA
Director
#45, Norodom Blvd.
Phnom Penh, CAMBODIA
Ph./Fax : 855 23 214304
Mobile Ph. : 855 12 918 401
E-mail: j.victor@mobitel.com.kh

MINISTRY OF ENVIRONMENT
Thy SUM
Chief of Climate Change Office
Ministry of Environment,
48, Samdech Preah Sihanouk Blvd.
Chamkarmon, Phnom Penh,
Kingdom of CAMBODIA
Tel/Fax: 855-23-218 370
H/P: 855-16-907 764
E-mail: cceap@online.com.kh
Website: www.camclimate.org.kh

Municipality of Phnom Penh
Phnom Penh Waste Management (PPWM)
SAO KUNCHHON
Governor of PPWM
Office : No. 22, St. 163, Sangkat Veal Vong, Khan 7 Makara, Phnom Penh
Tel : 023 991 077, H/P : 016 850 030
Email : kunchhon@hello016-gsm.com
: ppwm@camintel.com

TOCH SOVANNA
MBA & M.Sc. Renewables
Deputy Director
Department of Energy Technique
MINISTRY OF INDUSTRY MINES AND ENERGY (MIME)
#45, Preah Norodom Blvd, Phnom Penh, CAMBODIA
Mobile:+855-11 959 699
Fax: +855-23 990 602
E-mail: tochsovann@yahoo.com
tsovanna@hotmail.com

INSTITUTE OF TECHNOLOGY OF CAMBODIA
Dr. Thavarith CHUNHIENG
Ph.D., M.E., Ch.E.
Food Engineering and Bioprocess Technology
DEPUTY DIRECTOR
Academic Affairs
Blvd. Pochentong, BP 86 - Phnom Penh, Cambodia.
Tel : (855) 023 880 370/982 445 Fax : (855) 023 880 369/362 110
H/P: (855) 012 484 910 E - mail : thavarit@itc.edu.kh

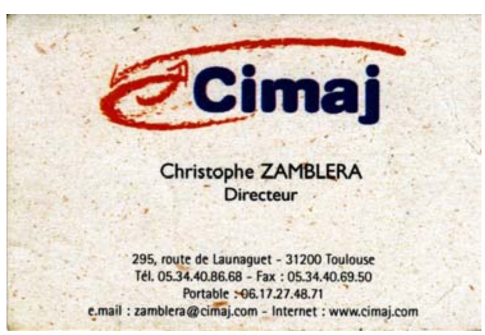
INSTITUTE OF TECHNOLOGY OF CAMBODIA
Dr. PHOEURNG Sackona
Director
Blvd. Pochentong
BP 86 - Phnom Penh
CAMBODIA
Tel : (855) 23 338 071
(855) 23 880 370
Mob : (855) 11 878 207
Fax : (855) 23 880 369
E-mail : sackonap@itc.edu.kh
sackonap@online.com.kh

Institute of Technology of Cambodia
Dr. Davin UY
Director of Research and Development
BP 86, Pochentong Blvd.
Phnom Penh, Cambodia
www.itc.edu.kh
Tel: (855) 12 213982
Fax: (855) 23 880369
E-mail: Davinuy@itc.edu.kh

INSTITUTE OF TECHNOLOGY OF CAMBODIA
CHREA Rada
Head Department of
Civil Engineering
Blvd Pochentong
BP 86 – Phnom Penh
CAMBODIA
Tel : (855) 023 880 370
Mob: (855) 011 816 169
Fax : (855) 023 880 369
E-mail: rada@itc.edu.kh

DEPARTMENT OF ENVIRONMENTAL SCIENCE
Va Dany
Head
Area of studies:
Environmental health and sanitation, water quality and supply, air pollution and climate change, environmental education, environmental monitoring.
Room 112, RUPP Main Building,
Russian Confederation Blvd.
Phnom Penh, CAMBODIA
Tel : 855-11-876-037
Email: vadany@hotmail.com
environment.rupp@everyday.com.kh


Cambodian Education and Waste Management Organization COMPED
Mr. CHAU Kim Heng
Director
Address : Phoum Rolous, S/K.Choeung Eck, Khan Dong Kor, Phnom Penh
P.O Box : 955
Phone : 012 842 387
E-mail : comped@forum.org.kh
: kimheng@forum.org.kh
Community Sanitation and Recycling Organization
Bo Sokhann
SWM Program Officer
Office:
No.39, Street 356
Sangkat Toul Svay Prey I
Khan Chamcarmon
Phnom Penh, CAMBODIA
Tel : (855-23) 211 152
H/P : 012 217 745
Mailing Address:
P.O Box 2015
Phnom Penh 3
CAMBODIA
E-mail : csaro@online.com.kh
: k_vannith@yahoo.com
Visit: www.online.com.kh/users/csaro
Small and Medium Enterprise Cambodia
SME Cambodia
Leuk Dana
BDS (Rural Electricity Specialist)
#593, National Road No 5
Gr. 12, Phum Rom Chek 4, Khum Rattanak
Battambang Province
P.O. Box : 614
Tel : (855-53) 730 244
Fax : (855-23) 218 652
H/P : (855-12) 862 400
E-mail : danaleuk@yahoo.com
SME Renewable Energy Ltd.
RENEWABLE ENERGY
#92K, St. Russian Blvd, Tóul Kork
Phnom Penh, Cambodia
P.O.Box: 614
Erik Middelink
Project Manager
Tel : (855-23) 882 354
Fax : (855-23) 882 354
H/P : (855-12) 304 334
E-mail : erik@smerenewables.com
Website : www.smerenewables.com
SKYPE ID : erikenbo
Association Supporting Disability for Development
Choeurng Choeurn
Executive Director
Tel: (855) 12 581 932
E-mail: asdp_cambodia@yahoo.com
Center Address: Thmey Village, Tameun Commune, Thmor Kol District, Battambang Province, Cambodia
CEDAC
WE Net CAMBODIA
Tong Chantheang
General Secretary
No. 39, Street 528
Sangkat Beung Kok I
Khan Tuol Kork
B.P. 1118 Phnom Penh
CAMBODIA
H/P : 855-12 725724
Tel : 855-23 880 916
Fax : 855-23 885 146
E-mail: chantheang@wenetcam.net
Website : www.wenetcam.net
grad. eng. Jürgen Stäudel
freelance graduate engineer
constructional engineering & project management
sustainable solutions for waste recycling & sewage treatment
P.O. Box 955
COMPED, Phoum Rolous,
Choeung Eck
phone 012 87 52 82
mail to: yu-len@web.de
www.wastepicker.de
Bridget McIntosh
CDM & Carbon Finance Consultant
East Asia
Cambodia
+855(0)12 452 795
Laos
+856(0)207773891
camclimate@online.com.kh


Cimaj
Christophe ZAMBLERA
Directeur
295, route de Launaguet - 31200 Toulouse
Tél. 05.34.40.86.68 - Fax : 05.34.40.69.50
Portable : 06.17.27.48.71
e.mail : zamblera@cimaj.com - Internet : www.cimaj.com