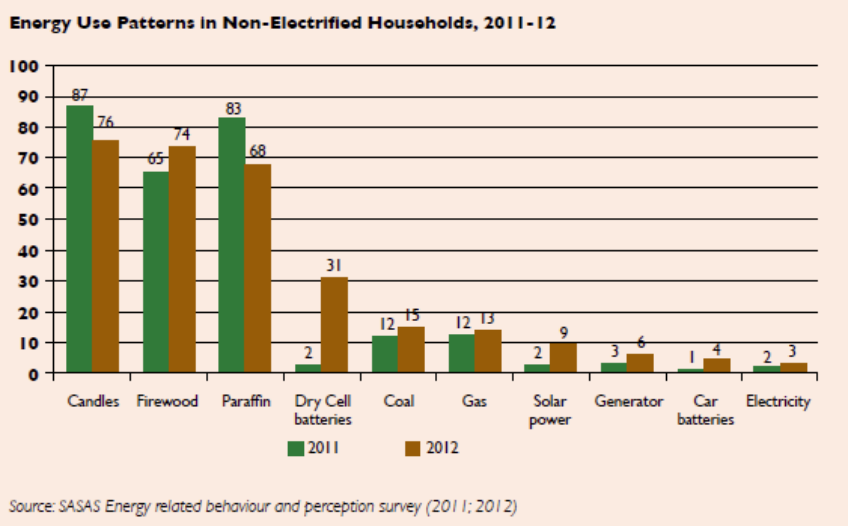
The Khaya Power Kettle Cooker

Khaya Power has developed a biomass TLUD gasifier stove to complement the Power Pack service initially planned for the Khaya Power Energy Hubs.

This document outlines the design criteria, the market viability and the operation of the stove.

Market Need for a Smokeless Biomass Cooker

Wood and charcoal are the primary biomass fuels traditionally used in Africa for cooking and heating. Some of this has been replaced with fossil fuels such as paraffin and gas (LPG).



Source: SASAS Energy related behaviour and perception survey (2011; 2012)

According to research done in 2011/12 two thirds of people with no electricity in their households in South Africa use wood or paraffin.

Solar power is useful for small appliances and lighting but not as useful and/or competitive for cooking / heating after dark.

Khaya Power has thus identified a need for a biomass stove/heater that can be used indoors in small living quarters.

The cooker should be:

- ***Energy efficient***
- ***Safe and not emit harmful gasses***
- ***Easily operated & maintained***
- ***Affordable to buy***
- ***Fueled inexpensively with readily available supplies.***

The Khaya Cooker

The Khaya Cooker is a Biomass Gasifier Stove that uses a small fan to control the burn of the pellets and produce a smokeless flame.

Advantages

- Costs less than paraffin to run
- Uses renewable fuel made from wood waste products
- High level of burn efficiency
- Easy to load and empty
- Cooling ring allows it to be used on any surface
- Safe for indoors use as it produces no smoke or harmful gases
- Can be run off battery or mains power

The Khaya Cooker has been designed for use in rural/ informal settlements. It can be used from a Khaya Power Juz Box or from backyard ("snake) power supplies in the shack areas.

It is intended to replace the use of paraffin and firewood in these areas, whose dangers are well documented.

Cooker Pricing and Running Costs

One objective when setting out our design criteria for the Cooker was to focus on a base price of $30 / R300. This is not a significant increase over existing paraffin and gas cookers in the market which are priced at between R120 and R250 and with the anticipated savings, the payback period on a cooker purchase will last no more than 12 months.

The cooker is fueled by wood pellets manufactured from wood waste, using about 500 grams per hour. Since the pellets retail at a price of R6.00 per kilogram, cooking/heating will cost approximately R3.00 to run.

Customer Running Cost Savings

Research indicates that on average people use not less than 20 Litres of paraffin a month (At R12.00 per litre, the average monthly cost is no less than R240);

In our model we assume that for cooking 2 hours per day, the Khaya Kettle Cooker will need approximately 30 Kg monthly, which results in a monthly expenditure of R180. A Saving of 25% or R60 per month! In fact, the monthly savings more than cover the six monthly payments of R50 for the stove (after the initial R200 deposit).

Modern Modular Design

The cooker has been designed using a variety of metal products. We have made sure that there is a balance between the durability of the product, the cost to manufacture and the completed look and design.

The product is to be a centre piece in the kitchen and thus has been designed to be stylish and have classic lines. The “kettle”- like look was intentional, as it will complement existing kitchen appliances and is easy to handle.

The component parts are completely modular and can be interchanged. This simplifies manufacture and improves the serviceability of the product in the field. For example, all electrical components are located in one simple part, the fan base.

The individual parts are as follows:

- **The Cooker Cook Top** is made from Stainless Steel. It is removable, fully washable and serviceable.
- **The Cooker Body** is made from a repurposed 5l plated can. It has an aluminum insulation layer to prevent excessive temperatures on the outside. To make it easy to handle, we have focused on making it light weight and have placed a “kettle” like handle on the side. It is easy to pick up, load and tip.
- **The Stove Base** is made from aluminum and houses the “engine” of the stove. A DC fan with speed control is used to forced air into the fire chamber. The air is directed through primary holes in the bottom of the chamber to assist in the release of the wood gasses which are burned off near the secondary holes. See next section for explanation of the stove operation.
- **The Fire Chamber** is currently a recycled food can that can be replaced on a regular basis. Serving as a pellet fuel chamber in the middle of the stove, the can reaches temperatures of 700 C, but is fully insulated by the body and is safe to use indoors.

Loading, Lighting & Cooking

The Cooker is easy to use and will operate with minimal attention for one hour at a time.

As the cooker is a batch load device, a decision needs to be made on how much fuel to load prior to lighting. Fuel CANNOT be added at a later stage and the only way to get heat for a longer period of time is to empty the residual charcoal in the cooker and to reload it again.

The combustion chamber can be loaded with up to 500grams of pellets but smaller amounts down to 150 grams can be used.

Once loaded, the cooker needs to be place on the base ring and the fan tested. Once this is done the cooker is ready to light.

To aid the (cold start combustion), a little turpentine, some ethanol jelly or some twigs must be to be added to the top layer of the pellets. Then light the fire. Please use long safety matches or a camping gas fire lighter.

When the fuel is first lit, there will be an orange flame. This is normal. The top part of the cooker will not operate until the bottom fire is hot and starts releasing the gases from the wood. This will take about 5 minutes.

After lighting, the fan may be turned on. It is best to turn it to low speed until the bottom flame is hot and pyrolysis is occurring. At this time, the top flames will become visible. They will be blue and orange in colour. See photo.

Once the top flames are visible, there will be about 10 minutes of cooking time per 100 grams of pellets loaded. This will also depend on the speed of the fan. By adjusting the speed of the fan, the flame can be set to low medium or high depending on the heat needed.

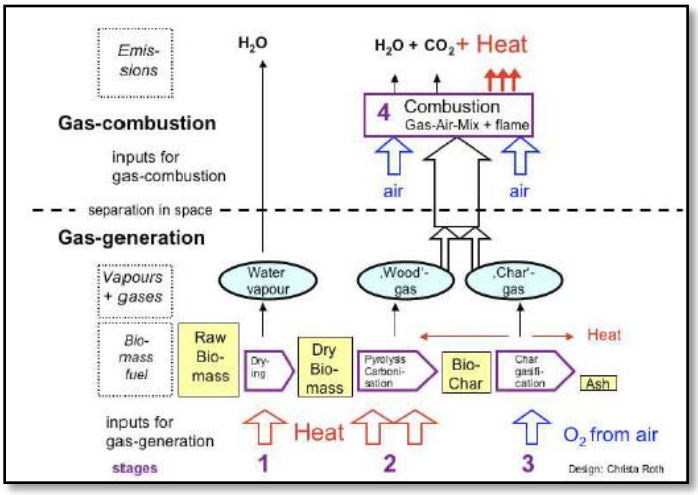
Once all the gasses are fully released from the pellets, the upper flame will die down or disappear. Hot coals will remain in the bottom of the chamber but the heat released will much lower at this stage.

If more cooking time is needed, the chamber must first be emptied – preferably (into a sand pit or a galvanized water bucket with water.) Then, new pellet fuel must be loaded for a new burn cycle.

DO NOT throw new fuel on top of the previously burned pellets (which are now char). If this happens, the fire will burn from the bottom up through the fuel, and all the fuel will be ignited simultaneously. As a result, the burn will be uncontrollable and the huge flames will only last for a short time.

Cooker Technical Design & Operation

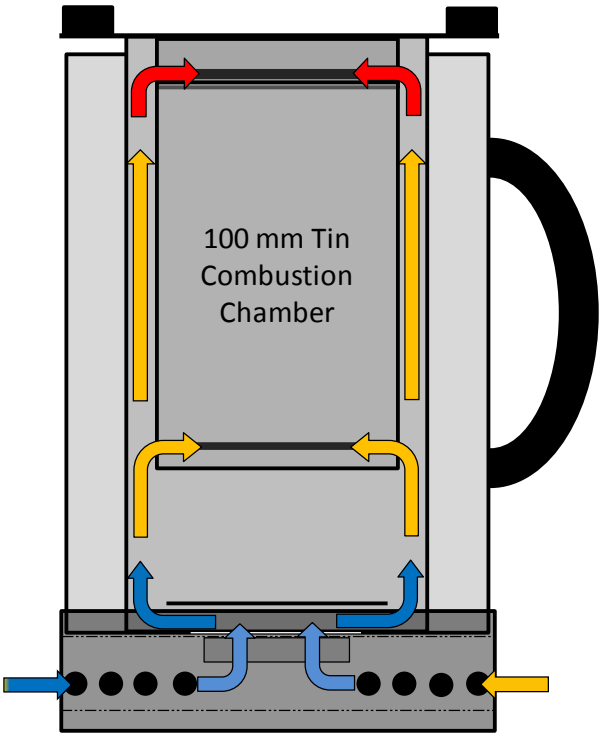
The cooker follows the design described in the document compiled by Paul Anderson and Thomas Reed. “Biomass Gasification: Clean Residential Stoves, Commercial Power Generation, and Global Impacts - 2004”. The design proposes using renewable biomass fuel and efficiently chars the fuel and burns the gasses released. See diagram for detailed information.



The wood pellets only have a 6-8% moisture content and there burn with high efficiency. The dry waste material has also been compressed and is 50% more dense than natural wood. It has a density of 650 grams / litre and energy of just under 20Mj / kg,- this fuel produces a slow steady burn at temperatures higher than raw wood. The dry material means process 1 shown on the diagram to the right has already been done by the time the pellet fuel reaches the consumer..

The cooker has a fan that forces air to provide 2 airflows to the Combustion Chamber.

- The **Primary Holes** at the bottom of the chamber provide oxygen to the fuel, which burns from the top down (in batches) thus called a TLUD (Top Lit Up Draft). The TLUD uses limited oxygen from the primary air holes to pyrolyse the wood pellets which releases the volatile components from wood as combustible gases and tars.
- The **Secondary Holes** at the top of the chamber provide oxygen to the hot gases and tars released. The air is heated as it travels up the outsides of the chamber. The hot air and gases are mixed by the pressure of the air entering the chamber - this produces a hot smokeless flame.



The cooker uses about 500 grams of pellet fuel per hour. The residual weight of the char is about 100 grams, thus 80% of the mass is turned into energy. The heat content of the gas is ~ 18kJ/g, so consumption of 4-10 g/m produces 1.2-3.0 kW.

The burn rate is controlled by the speed of the fan. The fan improves the efficiency and control of the fire by 40-60% and yet the fan consumes only about 1.2 Watts.

Test show that not only is the cooker, more efficient, but it produces the least CO (Carbon Monoxide) and PM (Particle Matter) of most available cook stove designs.

Our cooker is, therefore, both technologically advanced and cost effective in terms of initial purchase costs and ongoing fuels costs.

Cooker Design Philosophy and Practical Considerations

The TLUD design as set out by Paul Anderson and Thomas Reed in 2004 has been developed into many variants. Broadly the 2 most important differences is that one design is naturally aspirated and draws air through the stove, and the other that uses a forced air stream that is fed from the bottom of the stove.

Khaya Power believe that the power used to induce a draft is very small,l when compared to the control that is achieved, as well as being able to produce a stove that is far more compact. The forced air design has also been found to be more manageable in windy conditions.

We thus set out to design and build a stove using the principles described in the "Biomass Gasification: 2004" document, but applying some practical design principles in order to reduce the cost and improve the serviceability of the stove. The major design objectives were are follows:

1. **An all metal design**, using the appropriate materials for the different parts of the stove.
2. **Use existing but repurposed** volume manufactured **containers** for as many of the components as possible.
3. **Separate fan base:** Put all the forced air (fan and electrical components) into a separate unit that could be:
    a. Easily changed, repaired/swopped out.
    b. Manufactured in volume (large batches at a time) to bring down its cost and shipped in a kit form.
    c. Built in such a way it could be used for various domestic purposes. i.e. Blown air can be used as a insect trap, food drier, yoghurt maker, liquid chiller.
    d. Ship it with a variety of power options
        i. 5 or 12 volt
        ii. Rechargeable or stand alone
        iii. DC (battery/solar) or AC (grid) power source
4. **Create a secondary air supply / stove top sub-assembly** that would:
    a. Allow different primary/secondary air flow mixes depending on the fuel used
    b. Use recycled 100mm tin cans as the fuel chamber
    c. Be integrated into the stove top that is removable, rust free and washable.
5. Put a **single vertical handle** on the side which makes the unit easily picked up, and tipped after the cooking task is complete and the fire needs to be extinguished. (as opposed to many designs which have 2 horizontal pot handles.)
6. **A collapsible stove kit** that would reduce the volume shipped to be reduced by a factor of 4 (four) and allow final assembly to happen close to the point of use from easily available components. (5 litre can for outer casing and 100mm can for fire chamber)
7. **A price point of less than $30 US per stove.** Existing FA TLUD designs are coming in at price points that are too expensive for the markets intended. We want to ship a FA TLUD at the same price point as the very successful Rocket Stoves products in the market.

We believe that we have largely achieved the objectives set out above. Below is the detailed design of the 2 majored engineered components of the stove i.e. the detachable fan base and the stove top/secondary air supply assembly.

Detachable Fan Cooling Base

The fan base is designed to fit onto the bottom of the cooker body. The casing is manufactured from aluminium and houses a DC fan to provide the draft needed to control burn of the biomass and the air mixture.

The fan used can either be a 5 Volt or a 12 Volt fan as long as it produces an air flow of 12 CFM. The current design uses a 60mm x 60mm x 10mm unit from Sunon.

The fan is powered by either an external battery or an AC/DC power adapter. If the user is already using a cell phone, they will have access to a 1 Amp 5 Volt power adapter.

The basic design has a variable potentiometer, an external power connector and the fan only. Future designs will allow for:

- A PWM speed control
- A rechargeable battery and charge circuit so it can be used with a small solar panel.
- A variety of additional components to allow the base to be used for multiple purposes:
    - Insect/mosquito trap – UV LED and reversible fan
    - Food Drier / Yoghurt maker – Heating element and thermostat
    - Liquids chiller – Additional cooling fins and water evaporator

The ratio of the holes on the side of the unit to the fan opening is currently 1.5:1. This makes sure the fan can operate without any major friction, but the airflow through the holes has a cooling effect and can drop the temperature of the base by 3 degrees centigrade below the ambient temperature of the surrounding air.

The manufacturing of the base will be outsourced, and will be acquired as a complete unit. The metal work is standardized and will remain the same regardless of variant of the fan used, and whether the unit is rechargeable or not.

A targeted sub assembly price of $5 US is being investigated. We believe this could even drop further with large volumes.

We envisage that once multiple devices using the base are launched that each household will own more than one interchangeable base which will improve the utility use of the unit.

Stove Top / Secondary Airflow Sub-Assembly

The stove top is designed to fit onto the top of the cooker body, and secured with 3 stainless steel wing nuts. The casing is manufactured from stainless steel which makes it durable and washable.

The secondary air flow is controlled by a comb which is attached to the stove top. The comb has 30 slots/appertures which fit into the inside of the fire chamber.

Three of the legs of the comb are bent to extend down the outside of the fire chamber and are fixed to the ring /clamp on the outside of the fire chamber. The slots can be made bigger/smaller by adjusting the height of the comb in the fire chamber.

This height will change the mix of primary and secondary air depending on the fuel used. The mix can be adjusted from a 3:1 mix to a 6:1 mix.

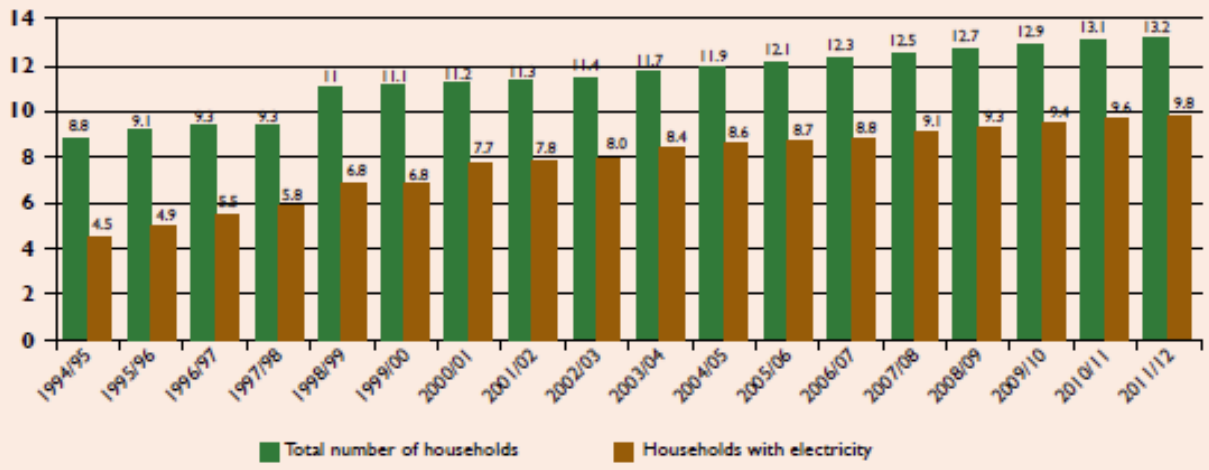



Once the fire chamber has been positioned and attached, the stove top is lowered into the stove body onto the positioning screws. The 3 wing nuts are then tightened ensuring that the secondary air flow from the fan rises on the outside of the chamber, heats up and then is fed through comb into the top of the stove where it mixes with the released gasses.

Total Market Sizing & Viability

4,8 million households in South Africa have no access to electricity. As was seen from the first section of this report about 2/3s or 3,2 million rely on paraffin or firewood for cooking/heating.

Figure 1: Total Number of Households and Total Number of Electrified Households in South Africa (Millions)



Source: DoE March 2012

The total paraffin market in South Africa is estimated at about 700 million litres per annum. We estimate that at least 1.5 million households rely on paraffin for daily cooking. At an estimated 20 litres per household per month, the cooking market is estimated at 360 million litres per annum or a retail turnover of 4,3 billion rand per annum. We believe that we can covert 5% of this base to using pellet cookers and wood pellets.

Our estimates are as follows:

- Targeted Households (5% of Paraffin Base): 75,000
- Monthly use of pellets per household: 30 kg (vs 20 litres of paraffin).
- Annual use of pellets per household: 360 kg
- Annual Pellet Sales of targeted base: 27,000 tons
- Annual Pellet Retail Sales or targeted base: 162 million Rand

Our distribution model is based on franchises called Energy Hubs. (Energy Hub business model document) These franchises are able to service households/communities that do not have access to grid electricity with their energy needs. We intend to do this by:

- Providing a Battery Power Packs and 12 volt electrical devices and appliances such as lights, cookers, TV's, cell chargers.
- Providing a Power Pack recharge service.
- Providing solar installations as upgrades to the recharge service to households that can afford it.
- Lastly but not least importantly ***providing cookers and wood pellets to fuel them***.

Our model is based on ***each micro-business/franchise servicing between 50 and 75 households***.

Annual Franchise Turnover & Gross Profit

Franchises will offer the cookers to their clients for purchase. This will be on a cash basis or a credit purchase with a deposit and a monthly payment.

We thus see each franchise selling about 75 cookers into their customer base, and then supplying them with pellets. For this we have devised a business plan and supply chain to service the customers who have purchased the cookers.

Each fully operational franchise servicing 75 customers will generate the following turnover:

- 75 stoves @ R500 = R37,500.00
- 2.25 tons of pellets per month = R13,500.00
- 27.0 tons of pellets per annum = R162,000.00
- Gross Annual Margin on pellet sales = R32,400.00

2015 Franchise Targets

- 3 regions (Eastern Cape, Western Cape, Kwa-Zulu Natal)
- 200 franchises

Manufacturing Plan

- 15,000 cookers (75 per franchise)
- Wholesale Unit Price: R320.00
- Total Cooker Sales: R4,800,000.00.

Pellet Sales at capacity above:

- Total Cookers: 15,000
- Pellets / Cooker / month: 30kg
- Monthly Pellet Sales: 450 tons per month
- Wholesale Pellets sales per month (excluding regional service fee):R1,755,000
- Regional Service Fees per month: R405,000