DUEL INPUT
HIGH-EFFICIENCY ROCKET STOVE

ENERGY ACCESS | LPG CYLINDER PRIZE WINNING SOLUTION (5/7)
ABOUT IDEAS TO IMPACT

Ideas to Impact is an action-research programme designing, implementing and testing innovation prizes, to induce innovative solutions to development challenges in Climate Change Adaptation, Energy Access and WASH. A five year, £10.9m programme, funded by the Department for International Development (Dfid) that supports research and development in climate change, energy and WASH through a variety of innovation prizes. The prizes are designed to stimulate and incentivise development of technologies for low income consumers that will improve poor people’s access to affordable clean energy, safe drinking water and resilience to climate change.

ABOUT THE ENERGY ACCESS: LPG CYLINDER PRIZE

As part of the Ideas to Impact the Energy Access: LPG Cylinder Prize launched on July 7, 2015, focused on inducing innovations for recycling liquid petroleum gas (LPG) cylinders across sub-Saharan Africa. Applications were received from more than 180 solvers, from over 40 countries, proposing solutions to address the problem of how to maximise the value of large numbers of aging and unsafe LPG cylinders that might need to be retired in the event of market reforms. No readily available solution which could be implemented at scale was identified. However, seven winners were selected, who offered solutions which in the view of the judges had potential to address the challenge subject to further research and development.

Here we share one of these winning solutions.

ACKNOWLEDGEMENTS

The Energy Access prize is led by Simon Collings at Energy 4 Impact, and collaboratively designed with Jonathan Slater from The Blue Globe.

Ideas to Impact is managed by IMC Worldwide Ltd. With special thanks to the independent panel of judges who judged the winning solution, and to Michael MacKay, (hagesensei@hotmail.com) for submitting the winning solution.
EXECUTIVE SUMMARY
The design for a novel, affordable and easily manufactured home-use cooking stove is presented. The stove can burn biomass or LPG at high thermal efficiency and low emissions. Several potential social, environmental and economic impacts are described, and possible public relations and marketing considerations offered.

MANUFACTURING TIME: 1-2 hours
TOTAL COST: 6-12 USD
DESIGN FEATURES:
high thermal efficiency
fuel choice flexibility
low emissions
wind and rain resistant
reduced burn danger

SUMMARY
Described below is a novel LPG/biomass-fed high efficiency cooking stove suitable for home use in those parts of the world still dependent on open-fire or traditional cooking methods. Such people, thought to number 3 billion, many living in sub-Saharan Africa, can benefit immediately from this hybrid technology, and in the long term as they transition to LPG. The rocket combustion chamber technology used here has been extensively researched and implemented in numerous developing countries, but (to this author at least) this is the first description of a hybrid LPG/biomass high efficiency stove.

A well-designed rocket stove can improve fuel efficiency, decrease cooking time and significantly improve indoor air quality and human health.

The hybrid design allows for greater flexibility in fuel choice and a better ability to respond to unforeseen changes in the energy market, such as variable resource availability, price spikes or supply disruption. Such stoves can be introduced into homes still reliant on traditional cooking methods and unserviced by LPG networks. For those with access to this new hybrid technology, family health and economics will be immediately impacted; and in the long term, as LPG networks spread, such families will be well placed and more amenable to transition to LPG.

SOLUTION REQUIREMENTS
IRREVERSIBILITY
Cylinder top is cut off.

VALUE
A healthier, more efficient, more economical stove is produced.
An entrepreneurial ecosystem providing jobs and business opportunities is created.

GEOGRAPHICAL CONTEXT
The stove is appropriate for areas still using traditional cooking methods, including large parts of sub Saharan Africa and South Asia.
ENVIRONMENTAL IMPACT
Reduction in deforestation, carbon emissions.
Improved indoor air quality.
Increased, higher value LPG cylinder recycling.

SOCIAL IMPACT
Improved health and life expectancy, particularly women and children.
Reduction in food preparation and fuel collection time.

ECONOMIC IMPACT
Reduction in fuel wood expenditure.
Reduction in LPG expenditure.
Increased flexibility in fuel choice.

CAPACITY AND INVENTORY
Not dependent on cylinder size (above a minimum), material, or condition

LOCAL RESOURCES
Uses basic skills, technology, tools and raw materials readily available in most regions; specifically, metal working and pottery.

DESCRIPTION
Presented here is a theoretical design for a novel, dual input, high efficiency cooking stove for domestic use, utilizing recycled LPG cylinders. This design incorporates well established rocket combustion chamber principles and adds LPG capabilities in what is thought to be (by this author) the first description of a hybrid biomass-LPG appliance. Such a stove, when compared to cooking methods still in use today by 3 billion people (3-stone open fires, traditional stoves), can reduce fuel use by 33 to 41%, carbon monoxide (CO) by 50 to 75%, and particulate matter (PM) by 46 to 56% (1,2,5,8). The reduction in biomass use (wood, manure, agricultural waste) can save families money (if fuel is bought on the market) or time (if collected by hand), in addition to having a non-trivial impact on forest resource sustainability and regional CO2 budgets. Improvement in indoor air quality has significant health implications, especially for women and children as they spend much of their time in the home. At present, poor indoor air quality contributes to 1.5 million premature deaths per year due to respiratory illnesses, and as much as 2.7% of total global disease burden (3,4). The hybrid design provides maximum flexibility in fuel choice, allowing families to respond quickly to unexpected changes in resource availability, price shocks, and supply disruption. In LPG mode, the rocket combustion chamber should (theoretically) confer the same benefits it does when using biomass; a hotter, cleaner burn with fewer emissions and lower fuel use. The steel casing and attached handles provide portability and ruggedness, solid wind and rain protection for outdoor use, and greatly reduced burn danger as the outer shell does not get hot.

It is suggested here that such a stove is especially suited to communities not yet connected to LPG networks, as families in possession of such a high efficiency, versatile appliance would be more amenable to the transition to LPG when it becomes available, and more inclined toward the LPG provider branded on the stove given to them. It is further suggested here that initially, several hundred (or thousand) such appliances be provided free of charge to targeted communities to foster rapid dissemination of awareness of the new technology, and to provide valuable feedback on usability, functionality and esthetics in order to fine-tune the design. Such generosity on the part of
the stove provider would have a considerable impact on public relations and brand recognition, at minimal cost. After an initial period, stoves could be sold at a nominal price to foster an entrepreneurial ecosystem, and to encourage buy-in from customers. (People are more likely to use and care for something they have to pay for.)

THE ROCKET
First described by Larry Winiarski (Aprovecho Research Center) in 1982, a number of rocket stove designs have been implemented in various developing countries, including Honduras, Lesotho, Malawi, Uganda, Mozambique, Tanzania and Zambia. Stoves based on the rocket principle have won 3 Ashden Awards (2005 Sustainable Energy Award in Health and Welfare; 2006 Special Africa Award, and the 2009 Ashden Energy Champion Award).

A lightweight, low thermal density refractory ceramic chamber, using locally available clays and fillers (e.g., sawdust, vermiculite), of specific dimensions with sufficient air flow and an insulated flue gas path can result in almost complete combustion, greatly reducing emissions. In conjunction with an adjustable pot skirt, such a device can dramatically increase heat transfer and thus overall thermal efficiency regardless of fuel choice. Even when using LPG, thermal efficiency should improve from the 30 to 60% found at present using conventional burners, to 70% or more (theoretically) when using a combustion chamber, due to greatly reduced cooling of flue gases by ambient air (6,7).

THE HYBRID
The use of a gas burner within a ceramic combustion chamber has, to this author’s knowledge, not been described in the literature. It is suggested that a research project be established to examine the feasibility of such a setup, and to determine the most efficient design and most appropriate burner.

STOVE MANUFACTURE
A typical family-sized cooking pot (26-30 cm diameter) would require a stove with a 12x12 cm chamber necessitating a cylinder of 46 cm in height. Smaller cylinders can also be converted to stoves if the flue gas path maintains a constant cross-sectional area, with a chimney to diameter (or width) ratio of 3:1. The key design principles are extensively described in reference (8).

1. Cut off the top of the cylinder (at 46 cm mark).
2. Cut off a 3 cm ring to use as a mold for the chamber top and bottom.
3. Cut a 12x12 cm hole 10 cm from the cylinder base.
4. Attach simple handles
5. Make ceramic bricks, top, and bottom.
6. Assemble, and fill spaces with vermiculite.
7. Make fuel stand, LPG burner stand, pot skirt.

BIOMASS FUEL STAND
Any metal stand 16 cm high and long enough to support typical fuel of the region. The end must have a grate to allow sufficient air flow from underneath.

LPG BURNER STAND
A rigid support for an appropriately sized burner. Various burners should be evaluated. A simple Meker-Fisher burner for example, can provide 13,000 KJ/h of power; more than enough for a family cooking stove.
POT SKIRT
Thermal efficiency is greatly enhanced with the use of a pot skirt at an appropriate separation from the cooking vessel (generally 1 to 1.5 cm). An adjustable skirt can easily and cheaply be made from a 15 by 95 cm piece of sheet metal, or (ideally) a flexible, low thermal density, heat resistant material.

COMBUSTION CHAMBER BRICKS
Published research has suggested a tile density of 0.4 to 0.8 grams per cc. Several recipes have been promulgated, but the following has been highly touted (9).
vermiculite: 300 g passed through a #8 screen (2.36 mm)
clay: 900 g
water: 740 g
Fired at 1050 degrees C, this recipe produces a brick of 0.732 g/cc. Local knowledge should be used to determine the best firing techniques, type and source of clay, and brick dimensions.

TURNING CYLINDERS INTO COOKING VESSELS
Cylinder bottoms, cut to an appropriate height (for the region) can economically be converted into cooking vessels.
1  Remove the stand and cut off the bottom 20-25 cm of the cylinder.
2  Sandblast to remove all traces of zinc and surface contamination.
3  Attach a simple handle.
4  Coat the inside surface with porcelain enamel and fire at 1100-1300 degrees C. Porcelain enamel conveys excellent corrosion, heat, acid, alkaline, and thermal shock resistance. The unfired enamel mixture (frit) is best bought from a dedicated producer as the composition depends on the type of steel used.

TESTING PROTOCOL
Once built, the stove should be put through rigorous emissions and efficiency testing. Such testing can be carried out at the Aprovecho Research Center in Oregon, or by using standard published protocols; for example, the WBT (water boiling test). (5,8,9)

FIELD SURVEY
The stove should then be extensively field-tested for fuel consumption, usability, practicality, functionality and overall desirability. Hundreds of stoves should be given away to targeted communities and those families surveyed extensively over 1-2 months. The resulting feedback should then be incorporated into the final design.

MARKETING
Similar rocket stoves have been extensively tested in Uganda and Tanzania (2), and after several days of use 50% of cooks in those 2 countries said they would be willing to pay 10 USD for one. Our superior hybrid model can and should be sold for even less. After an initial giveaway of hundreds or perhaps thousands of units, and the subsequent 2 months of surveys, a distribution system of local retailers and dealers should be set up in such a way as to foster widespread dissemination of the technology. Even if sold at a small loss (to the LPG provider), the resultant entrepreneurial ecosystem would facilitate increased LPG network penetration in the long run, provide positive PR and extensive branding exposure, and, most significantly, provide immediate health and financial benefits to some of the most disadvantaged people on the planet.
COST BREAKDOWN

cylinder: free
chamber materials (clay, vermiculite): 1-3 USD
labor and kiln use: 1-3 USD
skirt and fuel stands: 1-2 USD
gas burner: 3-5 USD

SIDE AND TOP VIEW MINUS SKIRT

FOR 320 mm (outside) diameter cylinder:
Brick dimensions: long side: 222 mm
    short side: 120 mm
    width: 51 mm
    height: 330 mm

TOP AND SKIRT
Top dimensions: diameter: 314 mm
    height: 30mm
Pot spacers: width: 10 mm
    length: 25 mm
    height: 30 mm
skirt: circumference: 250-300 mm (adjustable)
    height: 150 mm
ADJUSTABLE POT SKIRT

FUEL STAND AND HANDLES

BIOMASS MODE

LPG MODE

FLUE GAS GAPS
chimney dimensions: 120x120 mm
c fuel gate dimensions: 120x120 mm
pot to skirt: 10-15 mm
pot to top: 30 mm
bottom of fuel gate to floor: 100 mm
skirt height: 150 mm
REFERENCES


5. Aprovecho Research Center; Test Results of Cook Stove Performance. 2006.


STATEMENT OF INTEREST
In principle, I am very willing to assist in your actualization of this project should you choose to pursue it. However I have no specific engineering or design credentials.

I have been interested in social justice and environmental issues from an early age, and have traveled extensively in over 30 countries, mostly in Asia. My university training was in biology (undergrad-Univ of Waterloo) and ethnobiology and Human nutrition (grad school-McGill). At present I am lecturing at an engineering university in Japan. I am applying to this challenge as an individual.