Export Potential Assessment of *Biochar-Producing* Canadian Thermoelectric-Generating TLUD Stoves to Nepal

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1 - Introduction

In contemporary society, the concept of the world as a globalized, integrated community is commonplace and through various technological advances and developments, individuals of all cultures are able to encounter and interact with one another without having to physically meet. Unfortunately, even though technology has allowed for the destruction of many physical and social barriers, economic disparity between nations and individuals is still a detriment to the continuation of this technology fed process. Considering this, established countries should look out for those countries that are developing, and aid with guiding and shape their development for efficiency and the benefit of the populace.

This paper will discuss the potential for an economically beneficial relationship between Canada and Nepal through the manufacture, distribution and use of thermoelectrical gasification stoves. This will be revealed through the overall benefit to Canadian industry, the benefits and opportunity provided by the Nepalese market, the overall sales and marketing strategy, and a critical analysis of possible alterations for future investors.

2 – Information Relative to Biochar-Producing, Thermoelectricity-Generating TLUD Stove

i) Overall Product – Brief Summary

The unit proposed for export is a lightweight, inexpensive Top-Lit Updraft (TLUD) gasifier stove with a thermoelectrical-generator (TEG) attached. Explained in further detail below, gasification stoves basically utilize a biomass as fuel from which volatile gases are extracted and burnt separate from the parent material in a combustion chamber, and are identified through the route of the gasification air (Kirch, Medwell, & Birzer, 2016). As the name states, the TLUD unit is lit from above to create a downward migrating pyrolytic front, the products of which are liquids and gases that are utilized as fuel instead of the solid matter from which they originated (Kirch, Medwell, & Birzer, 2016). Utilizing the upwards of 600^{o}C temperatures achieved inside the combustion chamber, a thermoelectric generator will be retro-fitted to the stove that will use the waste heat created to produce power that can be exploited for a multitude of uses (Campeau, 2016; Lavoie, 2016).

Upon assessment of similar projects undertaken in other impoverished areas, such as the United States Agency for International Development (USAID) under Translating Research to Action behaviour change communication (BCC) exercise in Uganda, it has been concluded that the only way for successful adoption of these stoves is through complete involvement with the local community to create a product specific to their needs (Namagembe et al., 2015). Taking this into account, and due to large lapses in the current scientific understanding of TLUD manufacture, use, and the resulting qualities of biochar, a specific unit for manufacture and distribution has not been recommended, although Thermoelectric Gencell Technology (TEC) TEG, an Aurora, Ontario based TEG manufacturer is currently working with multiple conceptual units (Campeau, 2016; Namagembe et al., 2015; Kirch, Medwell, & Birzer, 2016). Ultimately, the gasifier itself must be a very simple, straightforward design, meant to be lightweight and maximize utility throughout the regions of Nepal, which for the most part are difficult to traverse due to the mountains/hills, which make up 77% of land mass yet comprise half the population (Lavoie, 2016; Malla, 2013).

ii) TLUD Gasification Stove

Relative to the overall unit, the most important aspect is by far the TLUD stove and the process of gasification it utilizes to achieve the touted benefits. Through analysis, it has been concluded that the safest, most efficient type of improved cooking stove (ICS) are gasifiers, in particular TLUD stoves (Anderson & Reed, 2004). Gasification is the process of converting solid hydrocarbons like biomass into gas for fuel within a low oxygen environment, with high efficiency and negligible emissions (IBI, 2016).

To save on costs it was attempted to create a unit out of standard aluminum cans, but unfortunately the unit was not as efficient at pyrolyzing as a TLUD stove, and the aluminum unfortunately was unable to withstand the roughly 600^{o}C temperatures created by the interior stove (LaVoie, 2016).

iii) Biochar

Biochar, the main byproduct of gasification, is a carbon-negative innovation that has been used for a long time throughout the world, mainly as a soil amendment but also can be utilized for its water filtration properties (IBI, 2016). Upon inspection, it varies greatly dependent upon production but is generally high in carbon, decay resistant, as well as very porous, allowing for sorption (adsorption/absorption) of water contaminants and fertilizer/pesticide run-off (Smith, 2016). As well, it has a quantitative impact upon removal of greenhouse gases, and with an addition to soils suffering degradation of one tonne biochar per hectare, yields could potentially increase between "0.5 kg ha^{-1} (cowpeas) to 40 kg ha^{-1} (wheat)", in addition to better soil tilth and nutrient/micronutrient capture (Smith, 2016). It can be produced through either pyrolysis (quantity) or gasification (small scale), yet for the utilization of these units as cook-stoves, gasifiers will thus be the focus.

iv) Thermoelectrical generator – Explanation

Although the stove by far is the hero out of the duo that combined make the TLUD-TEG stove as it provides the most benefits to the consumers, the real push for sales will be provided from the generation of power through thermoelectricity (Lavoie, 2016). The TEG unit proposed for retrofit to the TLUD stove is a special order, and is the equivalent TEG to that is featured in the IPowertower offered by TEC TEG of Aurora, Ontario (Campeau, 2016). The TEG proposed offers 96% efficiency relative to power conversion, and offers two spots for power generation; a 5V USB port for charging as well as a 4-port screw terminal, simultaneously capable of being wired to a 1.2V-12V battery for charging, which with sufficient heat would be able to power LED lighting in addition to charging a cell phone. (Campeau, 2016). The benefit to the consumer is unquestionable, as the power provided could be utilized for a variety of means, from charging cell phones and computers to providing lighting (Lavoie, 2016). In the case of the TEG stoves Airterra and the African Christian Organization Network of Kenya have created, consumers are selling the electricity to neighbours, helping in addition to the money saved from the stove's high efficiency to quickly pay off the modest cost of their stoves (Lavoie, 2016).

v) Manufacture/Production

In regards to the economic viability of the proposed product, one of the most integral factors is the costs accrued and saved through stove manufacture and the production of the completed unit. To simplify explaining production, the unit shall be separated into the gasifier stove and the TEG attachment. For just the stove alone, the cost to manufacture, assemble and ship units from Canada to Nepal would be exponentially more expensive compared to having them fabricated on the ground in Nepal, using local materials and local tinsmiths. Even if the units were fabricated in Nepal from materials shipped from Canada, it would still not be economically viable as any shipment from Canada drastically increases the cost of finished product to the Nepalese consumer (Lavoie, 2016).

The machinery required throughout the manufacturing process varies dependent upon the scale of production. To complete assembly, the unit can be fabricated by individuals aided with hand tools or it can be accomplished by a metal shop, with the latter obviously faster yet exponentially more expensive (Lavoie, 2016). In hopes of saving the target market as much money as possible, every conceivable avenue should be explored to cut overall costs in hopes of lowering the finished price of the stove. This fabrication approach is adapted from the work done by the African Christian Organization Network (ACON) in Kenya, where a similar TEG gasifier stove is manufactured within the country by volunteers and sold to individuals by a co-operative (LaVoie, 2016).

vi) Competition/Inspiration

Currently, the only known organization on the ground in Nepal involved with a similar product is the Clean Cookstove Project created by the Global Peace Foundation (Namagembe et al., 2015). Although striving to combat the same issues as other groups involved with ICS, the Foundation is teaching Nepalese women how to create a clay rocketstove instead of selling a unit, that accomplishes similar improvements in air quality but not to the same standard as a gasifier (Lavoie, 2016). The clay stoves are straightforward, inexpensive, utilize local resources, and the fabrication process is easily taught to others (Namagembe et al., 2015). Albeit similar, the proposed export differs greatly in that it is a gasifier, produces viable biochar, and has the attached thermoelectric generator, yet in comparison consumers might have issues relative to the cost as the proposed market has very little disposable income, an issue that has kept more from adopting the stoves relative to Airterra and ACON's work in Kenya (Lavoie, 2016).

Outside of Nepal, the number of organizations, companies and groups involved in attempting to convert constituents of developing countries from traditional (usually open pit) cooking methods are numerous. Although many are involved, the practical everyday adoption of the stoves sadly is still met with resistance, whether it be relative to cost or the proper knowledge and understanding of the stove's application (Namagembe et al., 2016).

vii) Logistics

In hopes of increasing Nepalese market share by offering the lowest possible price, any avenue will be explored to cut overall manufacturing costs, especially in regards to transportation. Shipping costs are drastically reduced by shipping the units prefabricated and unassembled (tools provided), opting to assemble in Nepal on site or before distribution, preferably by volunteers. For a rough estimate of potential savings, according to competitors with a similar product, RocketWorks of South Africa, "a 40ft/12m shipping container would accommodate 2880 assembled stoves, it will now accommodate 10 000 in component form," or disassembled, with production of over 250 units possible with a 5-man workforce (RocketWorks, 2016). Based upon the prototype in use by Airterra regarding their combined project with ACON in Kenya, the unit will weigh ~1.5 – 2 kg, and burns most gases from fires before they are released, with a 97% efficiency in combustion (Lavoie, 2016).

3 – Critical Analysis of Potential Benefits to Nepal

i) Nepal – Brief Summary

Before delving into the proposed product and the economic viability of the relative logistics and sales, first the conditions of Nepal shall be examined to assess the potential market. Nepal is a country land-locked on both sides by China and India, making transportation quite difficult, further exacerbated by the mountain and hills regions which comprise 77% of the country overall (Chapagain, 2004). Currently, 96% of Nepalese peoples utilize biomass burning for fuel, with "Almost 94% of urban- and 99% of rural- household energy consumption is used for cooking activities in 2010" (Malla, 2013). The clear majority of detrimental gases created are thus emitted, where they negatively influence respiratory and overall health of individuals (Malla, 2013).

ii) Benefit to Nepal

Primarily, the potential benefit for this product is exponential for many Nepalese constituents, particularly those in rural communities (Sapkota, Yang, Wang; 2012). Roughly 2.7 billion people worldwide still utilize traditional cooking practices which produce noxious gases, resulting in the death of 4.3 million each year due to household air pollution causing illnesses, including but not limited to increased child mortality, eye disease, and respiratory issues (Kirch, Medwell, Birzer, 2016; Sapkota, Yang, Wang, 2012). As a result, investment in the production of TEG gasification stoves is beneficial to not only Nepal, as the units could be retro-fitted and repurposed for use in a variety of geographical locations, all with different parameters effecting use (Lavoie, 2016).

In Nepal, around 83% of the population are in rural areas, and within these areas 86% of Nepal's expended energy is consumed, mainly as biomass, which of the overall energy consumption comprises 87% (Sapkota, Yang, Wang; 2012). Utilized mainly for cooking, 75% of this biomass burned in rural areas is firewood with consumption rates that are unmaintainable, and the heavy reliance upon firewood as a main fuel source is the most significant factor in the deforestation rate of 1.7% in Nepal annually (Sapkota, Yang, Wang; 2012). Considering that traditional cooking methods in Nepal require a large investment of time, energy, and labour relative to set up and use, this prevents the mainly women and children involved in the activity from participating in society and education to the point of impeding the countries development (Sapkota, Yang, Wang, 2012). In addition, the push to implement ICS would lead to other returns, including improved safety through no open flame, household improvements, a reduction in the reliance upon fossil fuels, and assisting to combat global warming (Lavoie, 2016; Anderson & Reed, 2004). Regarding the potential for implementation and financing, there are many possibilities that are beneficial, including the savings to the family by burning low-value local biomass while requiring less firewood, and the potential for the generation of CDM Carbon Credits through the production of charcoal, which tilled into soils effectively sequesters carbon (Anderson & Reed; 2004).

With the implementation of ICS in Nepal, which as of 2012 was numbered at 415 649 households, the carbon mitigation potential was found to be 8.37% over the lifetime of the unit, as well as annually having saved 262 ha of forest and the combustion of 420 tonnes of biomass (Sapkota, Yang, Wang, 2012). Considering that the TLUD stove can utilize any dry biomass for gasification, waste-wood and other detritus that usually would either be burnt as waste or composted would instead be actively sought as a source of fuel (Anderson & Reed, 2004). These sources can include (but are not limited to) community waste, including dried sewage, cardboard, paper, and other combustibles; organic wastes, including fronds, twigs, sawdust, etc.; and agro-wastes, including husks, stems, roots, and any production by-products (Anderson & Reed, 2004). With the addition of thermoelectricity, the gasification stoves have the potential to further mitigate carbon by removing the need for generators and other high fuel required implements (Campeau, 2016).

iii) Future Studies Required/Unknowns

Although the adoption of the TEG TLUD stoves should be widespread and immediate, other studies relative to the acquisition and proper, consistent use of TLUD stoves have found that there still unfortunately are some barriers relative to day to day implementation (Namagembe et al., 2015). An excellent example is the aforementioned study conducted by USAID and PATH, the Berkley Air Monitoring group in Uganda, which would make for a starting point relative to a similar assessment in Nepal. Albeit there have been examinations of the use of ICS in Nepal, such as the 2012 paper by Sapkota, Yang, and Wang referenced in *Environmental Science and Technology* issue 47, the examination was based upon ICS units only.

4 – Recommendations, Analysis and Conclusion

At this point in time, the credible benefits of introducing TEG TLUD Gasification stoves to Nepal is arguable. Considering that the technology varies greatly upon the biomass consumed and the unit itself, definitive evidence relative to the best unit for Nepal (or overall) currently is inconclusive. Albeit the potential benefits of a product of this manner would be exponential, the costs incurred in shipping the thermoelectric generators and stoves from Canada would be inefficient and not cost effective when assumedly materials and TEG equipment is cheaper and more readily available in China and India (Lavoie, 2016; Campeau, 2016).

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