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Biomass Energy Service-based Rural Energy Entrepreneurship

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Biomass Energy Service-based Rural Energy Entrepreneurship

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I.1 The challenge of rural energy enterprise in a developing country

Providing energy appliances and energy supply in rural areas is economically and technologically challenging. Reasons include:

- The low energy demand per consumer;
- The low density of energy consumers;
- The low-paying capacity of consumers;
- The remote locations of consumers from manufacturers and/or service support.

Decentralized energy generation from locally available, often renewable resources addresses some but not all challenges. From a sustainability perspective, it makes more sense if energy generation and supply are provided by a local entrepreneur rather thanthrough a donor-driven programme. However, economic sustainability of such an enterprise often becomes difficult, because of the hurdles mentioned above. Ideally, a rural energy enterprise should provide an ongoing energy service based on a locally available energy resource.

The entrepreneur needs to think carefully about the business model of selecting energy service and service delivery mechanisms in order to ensure long-term customer satisfaction and financial viability of the enterprise. The entrepreneur must identify energy services desired or aspired to by the target population and assess what energy services are possible based on local conditions, including technological development. Additional considerations might include legal, safety and environmental requirements that must be met even if end users are unaware of them. Ideally, energy service delivery should be commercially viable but, given the challenges mentioned above, service quality and sustainability often depend on support by donors and/or government policy, so it is important to determine the optimum type of support required.

Consider the example of an entrepreneur wanting to introduce, as a consumer product, a solar lamp in a rural community. A needs assessment could reveal that customers are more willing to buy a bright light to illuminate their stalls during night markets, rather than buy a dim light that provides domestic illumination only. However, the high cost of the brighter light could be a barrier to market penetration. Such an insight could lead the entrepreneur to develop a business model based on renting out solar-charged portable lights to vendors in night markets. This shift from one-time product sale to daily rental would most likely ensure greater financial sustainability for the enterprise and a better energy service delivery to the end user. Such an enterprise would be on a more sure footing if it received some initial financial and technical advice in setting up the solar-charging facility based on the most appropriate technology available from the most reliable vendor able to provide good service and maintenance.

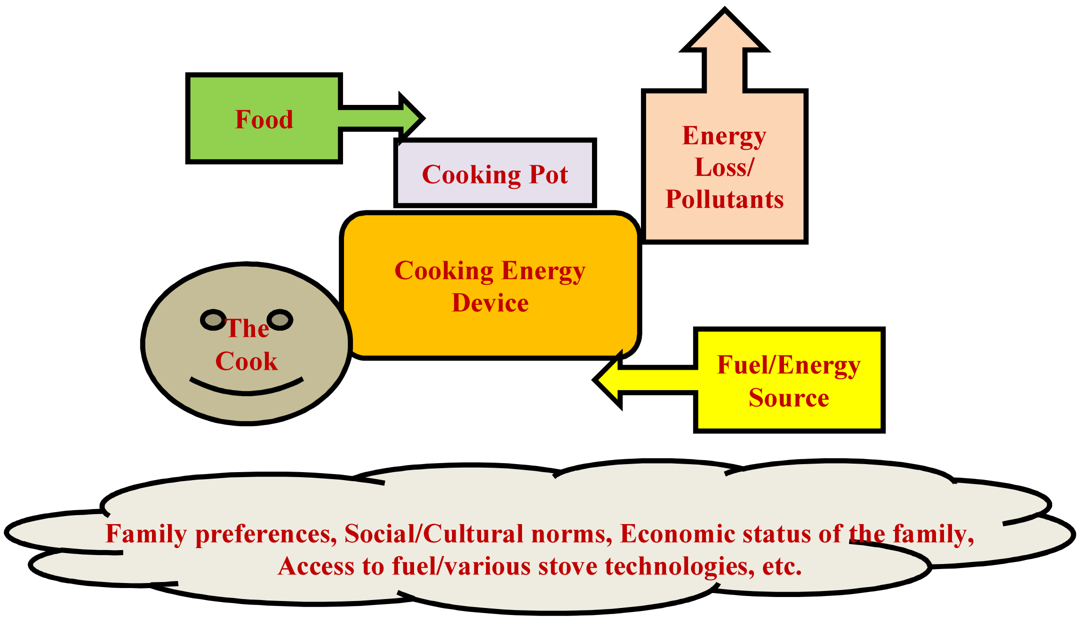
It is possible to develop decision-support tools to gain better insights into service delivery needs, and to choose the right product/service delivery model that provides the best compromise regarding end-user needs, strengths/weaknesses of available technology, and legal/safety compliance. The sections below describe, as an illustration, one such decision-support tool.

I.2 Cooking energy service delivery challenge for rural areas in developing countries

The discovery of fire and the ability to cook food were landmark developments in human development. Even today, most people living in rural areas throughout the world continue to use biomass-fuelled fire as the energy source for cooking. The traditional biomass fuels used for cooking include wood, woody biomass, charcoal, and animal dung cakes.

The advantages of using traditional biomass fuels for cooking are easy availability and no or very low cost. However, major concerns include pollution caused by traditional cooking and the resulting health impact, especially on women and children. During the past 15 years or so, the World Health Organization (WHO) has identified exposure to smoke produced while cooking as a serious health issue facing rural populations in the developing world. Because of increased awareness of smoke inhalation hazards, many governments have specified efficiency and emission standards for cooking stoves and space heaters. In recent times, the climate change impact of black carbon emissions from traditional wood stoves has become an additional concern. However, regulatory emphasis on health and environmental concerns lessens the overall service delivery aspect of energy appliances for cooking. Of what use is a clean burning stove if it cannot handle the meals end users wish to cook?

Figure 1. Factors contributing to cooking energy service delivery



Service delivery from cooking depends on fuel type, size, geometry and moisture content and is also a function of stove design and cooking area ventilation, plus the cook's skill in tending the fire and following cooking procedures. This is shown in figure 1.

Combustion is a chemical reaction that requires high temperature and a constant oxygen supply. Oxygen-rich air must mix properly with burning volatile gases. Ignition of a solid biomass fuel at room temperature cannot occur without the help of an "igniter" such as kerosene. Being volatile, kerosene ignites as soon as its temperature reaches ignition point after a matchstick is struck. The burning kerosene raises the temperature of the biomass fuel, which starts burning and using up the oxygen in the air surrounding the fuel stack. While the air loses oxygen to the fire, it also heats up. The hot air rises, creating a draught that feeds the fire with fresh oxygen-rich air. However, the new air coming in is cooler and sometimes extinguishes the fire. The air needs to mix with all the hot volatile gases emanating from the fire stack in order to burn without leaving behind aromatic compounds and carbon particles. Thus, maintaining a steady smoke-free fire requires maintaining an optimal and turbulent airflow through the fire, supplying an adequate amount of oxygen without cooling the fire.

In some cases, it is possible to lessen if not eliminate the ill effects of cooking-related pollution by modifying the stove to improve combustion quality or ensure a properly ventilated cooking area. However, maintaining air quality that meets World Health Organization (WHO) standards requires combining a standardized fuel or energy source and an appliance designed to use that fuel or energy source with maximum efficiency and minimum pollution. The cleanest cooking options are electricity and gaseous hydrocarbon fuels, but these options often are not economically or logistically viable in rural areas. This is where modern biomass fuels become crucial.

With advancing technology, several modern biomass fuels have emerged and are used as cooking fuels in some areas. These include solid fuels like biomass briquettes, pellets and char briquettes; liquid fuels like plant oils and alcohols; plus gaseous fuels like wood, gas and biogas. These fuels are relatively cleaner provided that they are used with appropriately designed cooking stoves. Gaseous fuels, able to mix thoroughly with air, are cleanest, followed by liquid and solid fuels.

The other renewable energy option for cooking and heating is solar thermal energy. It is cleaner but less user friendly. Developing a heat battery would address some limitations of solar thermal technology for cooking and heating applications, but such technology is in a nascent state.

There are entrepreneurial opportunities to provide clean cooking appliances as a one-time sale and to produce and/or supply clean fuels to power those appliances as an ongoing service. However, contrary to what most researchers and regulators believe, social, economic and cultural variations in cooking and eating habits affect usage patterns of various types of stoves even in the same kitchen. As a result, modern appliances that meet WHO standards and comply with legal and safety regulations often end up being rejected by consumers or used as secondary stoves for special or extra cooking.

For a long time, in many developing countries, the distribution of clean cooking technologies was donor driven. Many people believed that the total shift to modern and cleaner cooking was not happening because people did not value what they received for free. The entrepreneurship model in the cooking energy sector has been pushed in the developing world since the early 2000s, yet end users often still consider the appliances as secondary devices in their kitchens, even when they have bought the appliances themselves.

The low economic and decision-making status of women in large parts of the world also needs to be considered when understanding and untangling the behavioural issues related to cooking energy appliances, because cooking is regarded mainaly as a female domain.

In 2012, Dr. Priyadarshini Karve, an independent researcher in the cooking energy sector, approached Ashden India Renewable Energy Collective (AIREC) with a suggestion that a service-delivery focus would improve the situation. With financial assistance from The German Society for International Cooperation (GIZ), the AIREC team developed a definition of cooking energy service and a decision-support tool to help rural enterprises in selecting appropriate products and service delivery approaches for specific target customer segments.

The Tool comprises three MS Excel files and one MS PowerPoint file:

1. A printable set of data sheets for collecting data from various stakeholder respondents, assuming that data will be collected in areas where it might not be possible to use electronic appliances.

2. The data file where collected data is keyed in. In some locations, the data could be directly inputted while surveying/interviewing respondents.

3. The analysis file, which generates conclusions in the form of graphs and tables.

4. A printable set of survey cards in the form of a PowerPoint file.

5. A set of sample data and analysis files for reference.

The output of the Tool is useful in answering the following questions:

Which technology is more likely to be acceptable as a primary cooking energy technology in a given area or community?

How ready are people to accept a particular cooking energy technology?

What needs to be improved in a given cooking energy technology to make it more acceptable to the target group?

What needs to be highlighted in marketing a given technology in order to change the perceptions of the target group?

How do various available technologies rank in meeting cooking energy service requirements from the perspective of various stakeholders?

What new technologies need to be developed or sourced to deliver better cooking energy service in a given geographical area?

The following sections describe the Tool in more detail. The set of Excel files that comprise the Tool are also provided as in the List of Enclosures.

I.3 Cooking energy service parameters

We have identified the following cooking energy service parameters that address the various concerns of cooks and other stakeholders in the cooking energy sector. These are shown in table 1.

Table 1. Cooking energy service parameters

Characteristics		Sub-characteristics		Description	Addresses concerns of
A	Versatility	A1	Boiling Performance	Time taken to bring water to boil from room temperature, with recommended usage procedure.	Cook
		A2	Roasting Performance	Time taken to increase the temperature of a griddle to 200 degrees Centigrade starting from room temperature, with recommended usage procedures.	Cook
		A3	Frying Performance	Time taken to increase the temperature of oil in a frying pan to 200 degrees Centigrade starting from room temperature, with recommended usage procedures.	Cook
B	Convenience	B1	Ability to modulate heat input to cooking pot	Ability to regulate/control the flame, for example.	Cook
		B2	Ability to cook multiple items simultaneously	Number of items that can be cooked at the same time.	Cook
		B3	Ability to deliver non-cooking thermal energy services	Number of heat-based non-cooking services available as byproducts of cooking, including hot water, space heating and food drying.	Cook
C	Economics	C1	Operating Expense	Cost of fuel/energy source for one day's cooking.	Buyer

Characteristics		Sub-characteristics		Description	Addresses concerns of
		C2	Capital cost	Capital cost of the product paid by the end user.	Buyer, Distributor/Project Implementer, Regulator/Funder
		C3	Possible earning from use	Does the recommended usage process of the device produce any saleable byproducts? Does the device get carbon credits the income from which is passed on to the user? Does the device have a non-zero scrap value after being used as a primary cooking device during its expected lifetime? Does the manufacturer offer a discount on new appliances upon the return of used or scrapped ones?	Cook, Buyer
D	Safety	D1	Smoke and Soot Emissions	Measurement in terms of national and/or international air-quality standards and corresponding test protocols applicable to the technology.	Regulator/Funder, Cook
		D2	Stability	Stability can be assessed by placing the device with the cooking vessel size recommended by the manufacturer on a tiltable platform. The angle of tilt at which the assembly topples over is a measure of stability.	Regulator/Funder, Cook
		D3	Temperature of Outer body	Measurement of the temperature of the device's outer surface, in terms of national and/or international standard test protocols applicable to the technology.	Regulator/Funder, Cook
E	Device Supply & Support	E1	Durability as expected life in years	How many years the device is expected to be used without major repairs, according to the manufacturer.	Cook, Buyer, Distributor/Project Implementer, Regulator/Funder
		E2	Support provided or not	User training or sufficiently detailed training manual – pictorial and/or multi-lingual, service and maintenance support, replacement warranty, credit, instalment or other user-friendly payment options.	Cook, Buyer, Distributor/Project Implementer, Manufacturer/ Technology Developer
		E3	Manufacturing capacity	How many units can be manufactured per month?	Distributor/Project Implementer, Manufacturer/ Technology Developer, Regulator/Funder
F	Environmental Impacts	F1	Energy Efficiency	Energy efficiency tests to be conducted in terms of national and/or international standards for device type.	Regulator/Funder
		F2	Carbon Emission Reduction Potential	How much greenhouse gas emission is avoided by replacing the traditional technology with the given technology, calculated using standard methodologies recommended by the United Nations Framework Convention on Climate Chanage or other bodies.	Regulator/Funder

Characteristics		Sub-characteristics		Description	Addresses concerns of
		F3	Carbon footprint over lifecycle	Greenhouse gas emissions resulting from manufacture, wear and tear of the device during use and disposal at the end of useful life.	Regulator/Funder
G	Fuel/Energy Source	G1	Multi-fuel or not	Can the stove be operated using various fuel types or does it require a specific, standardized fuel?	Cook, Buyer, Distributor/Project Implementer
		G2	Availability of fuel/energy source locally	Is the fuel/energy source recommended by the manufacturer available locally or not?	Cook, Buyer, Distributor/Project Implementer
		G3	Fuel processing required by user or not	Can the available fuel be used directly or does it require prior processing by the end user?	Cook

I.4 Using the AIREC Cooking Energy Service Decision-Support Tool

(a) Choosing stakeholders and other specifics

The Tool has a provision to select the stakeholders relevant to the question being explored. If a government agency is using the Tool to gain more insights into the sector, it is important to get opinions from all stakeholder groups. However, if a potential rural entrepreneur is doing the analysis, only the preferences of COOKS and BUYERS are relevant. In this case, it is possible to blank out the parameters that do not address the direct concerns of COOKS and BUYERS by putting 0 in the cells corresponding to those parameters in the data file.

The Tool provides the ability to skew the data in favour of a particular stakeholder group. If the Tool user wants to attach more importance to the opinions of COOKS, the preferences of the COOKS can be enhanced by a multiplier factor. The Tool user can select the SKEW value for each stakeholder group in the analysis file.

The Tool user can select other features, as explained below.

(b) Preference mapping

The first step of the Tool involves identifying the priorities of the service parameters for each stakeholder group. The data is obtained through surveys, focus group discussions and interviews. Each respondent, whether as an individual or as a group, is given 10 tokens and asked to distribute the tokens between the three sub-characteristics in each of the seven sets. Afterwards, the respondent is given 20 tokens and asked to distribute them between the seven main characteristics. The Tool provides printable pictorial survey cards that can be used in this process, avoiding potential problems of low literacy levels.

In each case, respondents should assign more tokens to parameters valued more highly and fewer token to parameters considered less important. It is acceptable to assign zero tokens to completely unimportant parameters, but all given tokens must be used for each set. The Tool provides a set of printable data sheets to record the number of tokens assigned by respondents for each parameter for each set.

As COOKS and BUYERS are the most crucial stakeholders, their opinions must be taken into consideration. Data from these two stakeholders should be collected by surveys of individuals as well as through focus groups. Our field studies show that data collection using both methods is able to capture the nuances of the energy services that COOKS and BUYERS desire.

The field data collected can be inputted into the data file, called AIREC_CESDST – DATA.xlx. This file is linked with the analysis file, called AIREC_CESDST – ANALYSIS.xlx. The output of this step is provided in the form of tables and graphs that show the relative preferences of various stakeholder groups and a collective regional preference map.

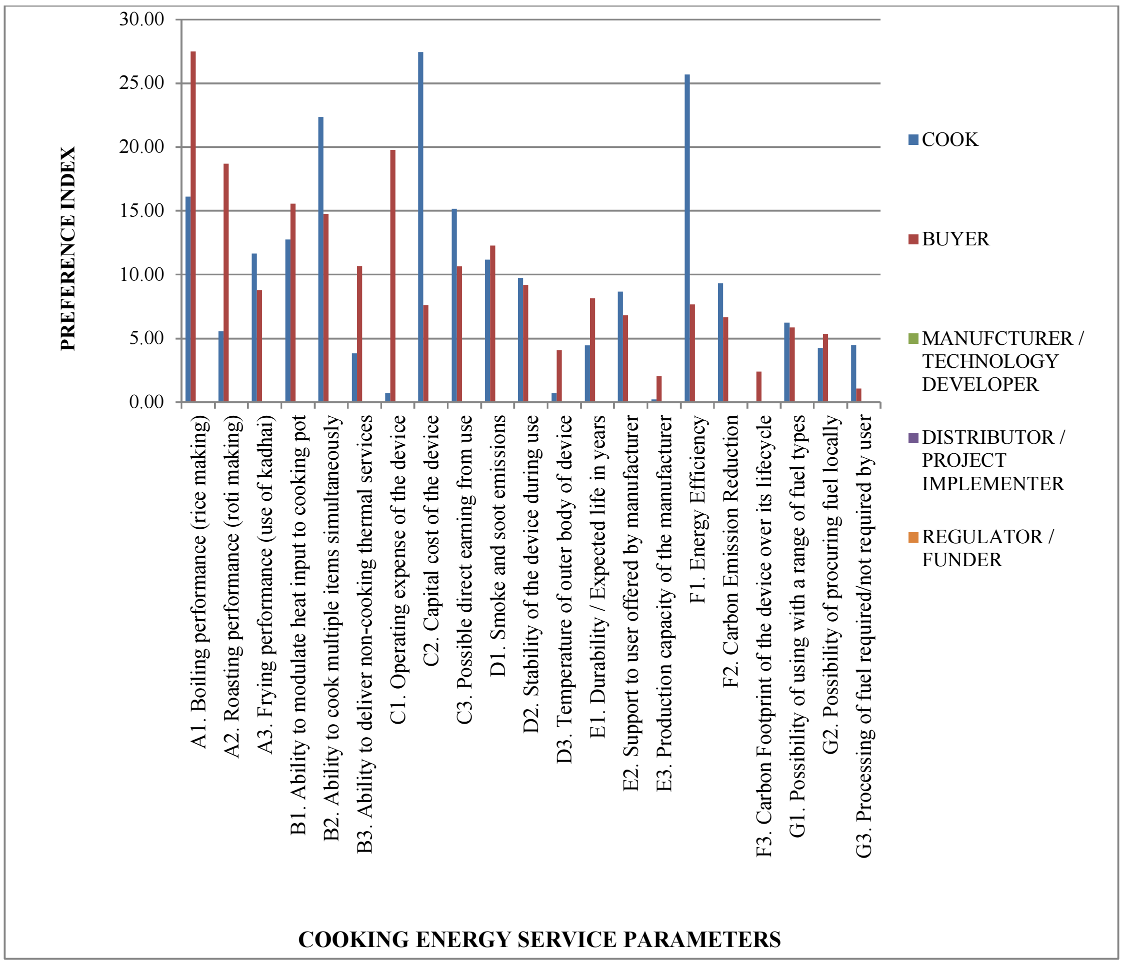
(c) The Tool

Figure 2 provides an example of the type of data that the Tool can generate. In this example, only data from COOK and BUYER stakeholder groups have been used.

The absolute values of the preference indices, shown as numbers on the Y-axis, do not have any significance except that they provide a useful measure of how various parameters are scored with respect to one another. The Tool user can choose an acceptance threshold as a percentage of the highest value of preference index, determining which parameters are most important for a stakeholder group. For example, in figure 1 the highest preference index value is 27. If the Tool user determines the threshold as 50 per cent of the highest preference index, all parameters that have a preference index value above 13 would be considered non-negotiable or HIGH preference for the respective stakeholders. Parameters for which the scores are below 13 would indicate relatively unimportant or LOW preference. At this threshold in the sample COOKS value a stove's boiling performance more highly than the stove's ability to perform other cooking operations. Understanding such preferences would allow Tool users to select the optimum appliance to introduce to the target population.

The Tool user might want to analyse and understand variations in preferences by playing with the SKEW value in addition to setting various thresholds. Such variations could provide additional insights into possible marketing strategies and research needs.

Figure 2. Preference mapping – Example



(d) Performance assessment of various cooking energy technologies

In most countries, government regulatory bodies set standards for fuel use efficiency, harmful emissions, safety and durability. However, these are just four of the 21 service parameters that we have identified. The second part of the Tool focuses on analysing cooking energy technologies against all 21 service parameters. The test protocols and the marking scheme, described in the product scores datasheet of the analysis file, are defined in such a way that various cooking energy technologies can be compared on the same footing. Each technology can be given a scorecard, based on its service delivery as envisaged by various regional stakeholders. For example, an LPG stove, a box-type solar cooker, a biogas plant plus stove, and a forced draught biomass stove can be assessed on a scale of 0 to 10 for ability to modulate heat input to cooking pot. LPG and biogas stove score highly on this parameter, because of the relative ease of controlling instantaneous flames in such stoves. A forced draught biomass stove scores less highly because there is a noticeable time lag between reduction in the stove's fan speed and reduction in heat output. The box-type solar cooker scores 0 on this parameter, because it does not provide any manual mechanism to control the heat input to the cooking pot. However, the same four stoves rank in differently when assessed using different parameters. In terms of operating expense, for example, a solar cooker, for which the daily fuel cost is zero, will rank highest. An LPG stove, which incurs high daily fuel costs, will rank lowest.

The output of this part of the Tool matches preferences obtained in the first part with performance as reflected in the scorecard of each technology, as shown in table 2.

Table 2. Interpreting the match of preferences with performance

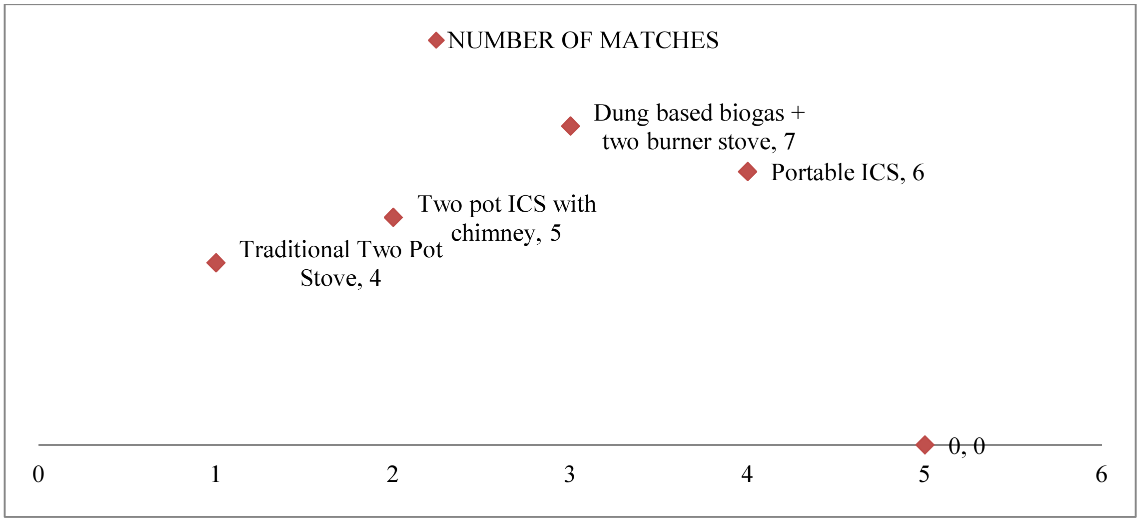
Sr. No.	Preference	Performance	Implication
01	HIGH	HIGH	A good match. The product can be marketed successfully for valued parameter
02	HIGH	LOW	Need for technological research to improve product performance for valued parameter
03	LOW	HIGH	Product possesses required attribute but stakeholder assigns it a low value. Can be rectified by advertising and raising awareness
04	LOW	LOW	Unimportant

The type of technology that has more HIGH-HIGH matches would find maximum acceptance in a given geographical area with very little effort from the entrepreneur.

While the performance scorecard of a product might remain more or less the same universally, with some exceptions where performance is judged on the basis of a local reference point, the preference map might vary from region to region based on cultural as well as socio-economic aspects. As a result, matching preferences with performance for each target region could give different outcomes. For example, a stove suitable for one geographical area or market segment could fail in other geographical or market segments.

Figure 3 illustrates the type of result that might be obtained. The graph shows that the maximum number of HIGH-HIGH matches in the particular region is found for a biogas plant. Therefore, a biogas project is likely to be successful in replacing the traditional cooking technology in that region.

Figure 3. Matching between preferences and performance for four technologies – Sample



I.5 Advantages of the service-delivery approach

Table 3 provides a hypothetical example of conclusions derived from using the decision-support Tool described above.

Table 3. Illustrative example of utility of the Tool

Stakeholder	Top-priority parameter	Stove 1	Stove 2	Stove 3
COOK (rural woman)	Roasting performance	HIGH	LOW	HIGH
REGULATOR (local government)	Smoke and soot emissions	LOW	HIGH	HIGH

In the case above, a government in its role as sector regulator could provide equal incentives for enterprises to promote Stoves 2 and 3. However, the likelihood of a COOK using Stove 2 is low because, from her perspective, the stove is not capable of performing the most important function. Stove 3 is likely to be more acceptable to the COOK, while also meeting the requirements of the REGULATOR. The service-approach analysis provides this insight and makes Stove 3 more eligible for marketing than Stove 2.

Entrepreneurs can use similar tools for any energy service, helping select the right product-service combination and delivery mechanism. The Tool will also highlight what issues to emphasize during awareness raising and marketing campaigns.

The AIREC Cooking Energy Decision-Support Tool is an open-source knowledge resource. Organizations and groups across the world are invited to try out the Tool in their own geographical area and/or target communities. The Tool can be tailored to suit the specific demands of a particular project/study/assessment. AIREC would be happy to collaborate in customizing the Tool, training analysts and helping interpret the data.

II. Biomass Energy

Renewable energy sources hold great potential for providing vital energy services to rural areas, helping improve quality of life and creating income-generating opportunities. Biomass energy has some unique features among renewable energy sources.

Using firewood for cooking and space heating is one of the most traditional ways of energy use and continues to be the predominant means of obtaining those two energy services in rural populations across the world.

Use of biomass energy cannot automatically be deemed renewable or sustainable unless the energy generation cycle is carefully managed. For example, overemphasis on biofuels has led to destruction of biodiversity through the plantation of oil palms in Malaysia. However, judicious harvesting of biomass from natural wilderness, plus innovative use of waste biomass generated from agricultural activities, can lead to renewable or sustainable biomass energy.

Biomass is the only potentially renewable resource that can provide us with fuels equivalent to non-renewable fossil fuels. The technologies developed and perfected during the past couple of centuries, which rely on fuels to run various machines for producing heat, electricity and mechanical power, can continue to serve us with renewable fuels in a world that wishes to reduce its dependence on fossil fuels.

Illustrative examples of potential rural energy-service entrepreneurship based on biomass energy are discussed in the sections below.

II.1 Conversion of waste biomass into char

(a) Potential benefits of char/charcoal

Charcoal making has been deemed polluting and environmentally damaging but charcoal is a fairly user-friendly and clean-burning fuel. It is easier to ignite, provides heat rather than producing leaping flames and therefore poses less of a fire hazard. Charcoal also burns with minimal particulate-matter pollution. Charcoal does, however, pose the danger of carbon-monoxide emission, which can be life threatening if charcoal fires are not adquately vented. However, the issue can be addressed by using a properly designed stove.

Apart from its use as fuel, charcoal has many other applications.

Adding charcoal can help improve productivity of particularly acidic soils in a way far superior to using compost or ash as soil additives. Converting organic waste into char and adding it to soil is a promising approach in terms of carbon sequestration.

Charcoal is an excellent absorber of organic molecules. If charcoal is made under controlled conditions, it can result in activated charcoal that can be used as a filtering agent in many chemical industries. While production of activated charcoal might be beyond the capacity of rural enterprises, even ordinary charcoal can be used for such applications as deodorant in toilets, refrigerators and crowded closed spaces like offices and classrooms. Producing and supplying charcoal filters for such applications can provide a business opportunity for rural enterprises.

(b) The charring process

Converting wood or biomass into char essentially involves heating the biomass to drive out volatile gases, leaving carbon behind. Care needs to be taken that hot carbon does not come into contact with oxygen during the process. In a traditional charcoaling kiln, the material to be charred is arranged in a heap. Fire is started at the base and the heap is covered with mud. Part of the wood burns, producing heat for charring the remaining wood. However, during the process, volatile hydrocarbon gases are allowed to escape into the air. For a pollution-free charring process, it is imperative that the volatile gases emerging should come into contact with oxygen and burn completely.

Much cleaner technologies than traditional ones are now available for charring wood and woody biomass. Industrial-scale charcoaling machines have been designed and commercialized in different parts of the world.

However, for rural enterprises focused on renewable energy, there is another consideration involved when choosing technology.

The natural choice of raw materials for charring in the context of a rural renewable- energy enterprise is such agricultural and garden waste as dry leaves, twigs, grass, palm fronds and paddy waste, plus such food-processing wastes as coconut and peanut shells, corn cobs after kernal removal, date seeds and rice husks. Typically, such raw materials would be scattered across farms, gardens and small processing units. If an industrial-scale charcoaling machine capable of handling tons of biomass per day is erected at one location, the low-density biomass must be collected and transported to the site. Each day biomass is likely to be transported across longer and longer distances. The energy spent on transportation soon would exceed the energy generated by the unit, causing the business to fail.

Samuchit Enviro Tech has developed a system involving portable kilns that can process char at the point of available waste, with further processing centralized. Because charcoal or char powder, depending on the raw material, is heavier and has a higher energy density than the raw material, transporting it is less energy intensive. This model is low tech and relies more upon labour, which is better suited for a rural enterprise.

The charring process is based on the Top Lit Up Draught, or TLUD concept. The kiln design and the charring process are shown in the accompanying video.

The inner space of the kiln is filled with raw material to be charred. The material is ignited at the top, and the lid is closed. The air inlets are at the bottom of the kiln. The air pocket between the lid and the ignited layer feeds oxygen to the flame and also heats up. The hot air along with the flame rises and escapes through the hole in the top lid. The holes at the bottom suck in external cold air because of the drop in air pressure, resulting in an air current rising through the biomass from bottom to top, called an updraught. Some of the air gets sucked into the space between the two walls of the kiln and becomes hotter as it moves up towards the hole in the lid. This hot air continually introduces fresh oxygen to the flame exiting at the top, ensuring that all combustible hydrocarbon gases burn before air leaves the kiln.

As the top layer of the loosely packed biomass burns, the layers below are heated, releasing combustible gases. The gases burn by using oxygen within trapped air pockets. The flame front moves downwards, seeking fresh oxygen. Layer by layer, the flame front moves from top to bottom, consuming oxygen in the air rising from the bottom. As a result, only oxygen-less air passes through the char layers left behind by the flame front.

When the flame front reaches the bottom, all combustible gases are totally burnt. The flame visible at the opening in the lid disappears. At this point, the kiln is lifted up and the smouldering heap quickly cooled by dousing it with water. The heap now contains char.

The basic kiln we designed, as shown in figure 4, has an inner volume of 100 litres. It is designed so that a single worker can handle one kiln. A group of three workers can operate two kilns in tandem more comfortably. The kiln is constructed from steel sheets that can be transported as a flat bundle and assembled on location with the help of nuts and bolts provided.

Figure 4. Samuchit Trashflasher Charring Kiln

The size of the kiln is not critical to the charring operation, but the relative dimensions are important. The kiln can be scaled up in size depending on the quantity of raw material available per day. The basic idea is to ensure that air inlets are at the bottom only and that the structure is double walled, so that preheated oxygen-rich air can be available just below the lid in order to ensure clean burning of exiting combustible gases. For larger-sized kilns, loading and unloading could require some level of mechanization.

(c) Additional processing required

Depending on the raw material and the intended final product, some additional processing could be required before and after charring.

The raw material to be charred needs to fit into the inner compartment of the kiln. In the case of wood or woody biomass, some re-sizing could be required. However, having air pockets and channels through the material in the kiln is essential for the updraught to work. The size and shape of the raw material, therefore, should not lead to tight packing. For example, this technology does not work with fine sawdust, the particles of which tend to pack tightly.

The raw material must be dry, ideally with not more than 10 to 15 per cent moisture. Sun drying for a few days is essential. The drying period will depend on the moisture content to start with, plus the shape and size of the raw material.

If the raw material is hard wood, the output is lumpy charcoal that can be used directly as fuel. However, if the output is to be used as biochar for mixing with soil, or for other applications, it could be necessary to grind it into fine powder. For this purpose, any industrial dry grinder can be used.

If the raw material is loose biomass or low-density wood, the output of the charring kiln crumbles easily into small char particles and can be used directly as biochar for soil improvement. For other applications, it is advisable to grind the char into fine powder, thereafter using a mould or press to shape it into the desired shape and size for intended use. The mould/press can be hand operated or electric, depending on the scale of the operation.

A hand-operated mould used for producing beehive briquettes is shown in figure 5. Moulds can be designed to produce briquettes of various shapes.

Figure 5. Components of mould for producing beehive briquettes

Figure 6 shows a hand-operated extruder-type briquetting machine, which is basically a meat-mincing machine with a modified outlet. The machine can be hooked to an electric motor, as shown in figure 7, to increase output.

Figure 6. Hand-operated briquetting machine

Figure 7. Electricity-operated briquetting machine

The overall operation, with some of the equipment mentioned above, is shown in the accompanying video.

(d) Possible business operation and economics

Let us consider a potential business with a production capacity of 100 kilograms of charcoal/char powder per day. The economics of each operation will depend on local conditions. The following discussion outlines the factors that must be considered for economic viability.

To produce 100 kilograms of char per day, the business needs to access about 300 kilograms of biomass per day. Let us assume an area of a 10-kilometre radius from which this biomass is to be accessed. The biomass could be in the form of agricultural waste, tree waste and waste from processing agricultural produce. It could be in the form of other types of waste, including from crates, cardboard and furniture. Depending on the location and availability of raw materials, it might or might not be possible to operate the business throughout the year. For example, such activity cannot operate during the rainy season. Agricultural waste is available only during the harvesting season for each crop. Such constraints must be considered when deciding the type of product, its end use and price, and the optimum target market.

Let us assume that the operation will use portable kilns with inner volumes of 100 litres. Typically, with hard wood, one charge of the kiln might contain 10 kilograms of wood. Charring might take 45 minutes, resulting in about 3 kilograms of charcoal. With loose biomass like leaf litter or straw, one charge of the kiln contains about 3 kilograms of biomass. Charring takes about 10 to 15 minutes, producing about 1 kilogram of char. The actual performance will fall somewhere between these two extremes, depending on the type of biomass used as raw material.

A group of three workers can operate two kilns in tandem. If the group works an 8-hour shift, moving from location to location charring the biomass available at each, the team's daily output could be about 30 kilgrams of char. Four such teams could produce a total of about 120 kilograms of char daily.

The char is brought back to the central facility on a daily basis, where it is further processed if required.

The processing might involve grinding, mixing with a binder, compaction into desired shape and size, drying over a period of 2 to 3 days and packaging. The processing operation could be handled by three labourers and a supervisor.

The total manpower involved in manufacturing would be 15 labourers and one supervisor. There could be additional sales and delivery people, with the entrepreneur acting as general manager.

Capital expenses would comprise:

1. The charring kilns. These might need to be replaced every year, as the iron sheets corrode due to constant heating and cooling in contact with biomass.

The rest of the equipment would be required only if specifically shaped char balls/briquettes/bricks were required for specific applications. The depreciation for all equipment could be estimated as 10 years.

1. Grinder. Any industrial-type dry grinder could be used. An electric motor or diesel engine would be required to operate the grinder.

2. Mixer. An industrial blender could be used to mix the char powder with binder.The best binder is waste grain flour from the sweepings of a flour mill floor. For every kilogram of char powder, 100 grams of waste grain flour is required as binder. The grain flour is boiled in water to produce a paste and then mixed with the char powder.

3. Mould/Briquetting machine. The simplest option is to use an electrically operated meat mincer, as shown in figure 7. The blades should be removed. The nozzle should be modified the same way as for a hand-operated briquetting machine.

4. Trays for drying. The shaped char briquettes will dry more quickly if spread out on chicken wire mesh trays rather than placed on the ground.

5. Additional costs, including land, a working shed and vehicles for transportion.

Daily recurring expenses would comprise:

1. Remuneration to the owner(s) of the biomass used. Even though the business would be based on waste biomass, the material would cease to be considered waste by its owner(s) as soon as the business started converting it into saleable products. It would be best, therefore, to offer a price for the waste at the beginning of the enterprise.

2. Payment for binder, packaging material and other consumables like gloves and masks.

3. Transport of kilns, char and final product.

4. Wages and salaries.

5. Servicing, maintenance and contingencies.

The least income would be obtained by selling the charcoal/char briquettes as fuel in local markets. Such value-added products as an organic deodorant for toilets, for example, might sell in nearby towns and cities at higher prices.

II.2 Biogas from green organic waste

(a) Basics of biogas generation

Methanogenic bacteria are the oldest living organisms on earth. Free oxygen in the air or that dissolved in water is poison for such bacteria, which can live only in the stomachs of animals and humans, where they get food without having to go out into the air. The biogas system is an artificial stomach created to feed the bacteria in a protected environment. In return, the bacteria release a high-energy gas.

Because the bacteria are conditioned to live at an animal's body temperature, the system works best when the ambient temperature is between 30 and 40 degrees Celsius. During the winter, the system will have access to less food waste and produce less biogas than in summer.

Food waste/high calorie organic waste-based biogas plants for households and institutions can be constructed from Low-Density Polyethylene (LDPE) water-storage tanks and Polyvinyl Chloride (PVC) plumbing materials. The feedstock needs to be 100 per cent organic, uncontaminated by inorganic waste like plastic, metal or glass. It needs to be pulped before being put into the biogas system. The effluent is watery and should be recycled into the biogas plant, to avoid the need for adding fresh water daily.

Biogas plants do not require any input of dung or fecal matter on a daily basis. They take food waste or other similar high-calorie organic waste as feedstock. Feedstock could be in the form of kitchen waste, plate waste other than hard bones, leftover food, green vegetable waste, fruit and flower waste, slaughterhouse waste other than hard bones, spoilt grain, non-edible fruits and rhizomes, oilcake, wet waste from food-processing units and waste from herbal-medicine production.

The technology provides an excellent means of dealing with organic waste in an environmentally friendly manner while providing a renewable gas for cooking. The system can be a means of shifting people away from using firewood for household cooking towards a clean cooking technology, even when petroleum gas is not available or accessible.

(b) Household biogas system

A typical household of four to six people uses about 250 to 300 grams of Liquefied Petroleum Gas (LPG) daily and generates about 400 to 500 grams of organic waste daily. Typically, 500 grams of food waste, when available, can generate about 100 grams of biogas, capable of replacing about 30 grams of LPG daily. The amount of biogas is not sufficient, therefore, to fulfil the total cooking energy needs of the household. However, it is always possible to augment the in-house food waste with other materials, including waste from neighbourhood vegetable and fruit vendors and waste grain flour from a nearby flour mill. If it is possible to collect about 4 to 5 kilograms of organic waste daily, it could be possible to generate about 1 kilogram of biogas, sufficient to cook all main meals for four to five people

The household biogas plant developed by Samuchit Enviro Tech is constructed from LDPE tanks and PVC plumbing materials, as shown in figure 8. The accompanying video shows how to assemble the plant. All the required components are typically available in hardware shops selling plumbing material supplies. No construction is involved. The plant can be installed on the ground or terrace of a house, or even on a suitably located balcony.

An entrepreneur with plumbing knowledge could assemble the biogas plant and provide service/maintenance support. The capacity of the plant is based on the amount of feedstock available on a daily basis. If a household can access only its own organic waste, the plant could be constructed from plastic tanks with a capacity of 500 litres for the digester tank and 300 litres for the gas holder tank. If a household can access 5 kilograms of organic waste daily, a plant could be constructed with a capacity of 1000 litres for the digester tank and 750 litres for the gas holder tank. When selecting tanks, care needs to be taken to ensure that there is a gap of not less than 5 cm and not more than 10 cm between the radii of the outer digester tank and the inner gas holder tank.

Figure 8. Samuchit Household Biogas Plant – 500 litre digester tank, balcony model

The waste going into digester tanks needs to be ground into a paste. Therefore, a food pulper or blender, either electric or hand-operated, is an important system component. Another important component is the stove. A biogas stove is similar to an LPG stove but with a higher gas-flow rate. Biogas stoves might be available in local markets. If not, an LPG stove could be converted to a biogas stove by removing the nipple in the gas inlet of the stove. A stove thus modified cannot be used for burning LPG.

This system, designed to operate only on food waste, does not produce any solid spent slurry. As the effluent is only a brown-coloured liquid, it can be collected in a bucket or drum. It is recommended that the effluent be recycled into the plant while putting in the next day's feedstock. This would avoid the need for daily fresh water and would prevent the plant from losing nutrients that the bacteria requires. Occasionally, the effluent could be used as liquid fertilizer for the garden or potted plants.

(c) Operation and maintenance issues

Starting a new biogas plant

After all leaks in the digester tank have been secured, cow dung should be added to the tank, about 40 kilograms per cubic metre of the tank's volume. When gas generated in the digester raises the gas holder, which could take two to five weeks, depending on ambient temperature and dung quality, the gas generated might not burn initially. In that case, the gas should be released after the gas holder rises for the first time and then checked for combustion from the second time onwards. Dung contains a large variety of micro-organisms. If the gas does not burn, it is likely that the methanogens have not yet attained a sufficiently high population density. The gas should be released until the gas holder rises. If the gas burns, it is a sign that the methanogens have established themselves in the substrate and that feedstock can be introduced into the system.

Operating a biogas plant

Overfeeding should be avoided because food that methanogens cannot consume increases the number of undesirable microbes in the system. The rule of thumb for the daily feed rate is 1 gram of dry digestible matter per litre of digester capacity. To estimate the dry weight of feedstock, cooked food like boiled rice can be assumed to contain about 80 per cent water, while uncooked food waste like vegetable waste can be assumed to contain about 90 per cent water.

When starting the operation, it is necessary to introduce feedstock gradually because the number of methanogenic bacteria in the system is low. The feedstock input should be increased slowly until the maximum limit for a given size is reached. In the first week, only 20 per cent of the recommended daily feedstock should be added. The gas should be used up before adding new feedstock daily. In the second week, feeding can be increased to 40 per cent daily. Full capacity should be reached in the fifth week.

Grinding the waste into a paste before introducing it into the digester is necessary because the microbes evolved in animal stomachs, in which the bacteria were exposed to matter that the animals chewed.

Every day, feedstock should be mixed with a bucketful of water to pour into the biogas plant. Fresh water should be used the first time. Thereafter, the effluent water can be collected and reused.

Water vapour is generated in the system, along with biogas. It is, therefore, necessary to have the gas outlet in the shape of a T junction. One arm of the T is connected to the gas outlet from the plant, the other connected to the biogas stove. The lower arm can be connected to a cock that is normally shut. Once a day, the cock should be opened to remove water accumulated in the gas outlet.

Adjust the pH of the substrate in the digester

Non-methanogenic micro-organisms produce acetic acid under anaerobic conditions. Methanogens convert the acid into methane and carbon dioxide. If more acetic acid is produced than the the methanogens can process, it accumulates in the substrate, which turns acidic. That generally results from overfeeding and it inhibits methane production. The power of hydrogen (pH) of the substrate can be restored by neutralizing it with calcium hydroxide solution. Restoring the neutrality of the substrate usually also restores its ability to generate methane. The pH of the effluent should be checked periodically, using a pH paper.

Avoid accidents

If biogas is mixed with oxygen, the mixture can be explosive. An explosion can occur in a newly set up biogas plant if the gas holder still has air from outside in it. Therefore, it is advisable to let out all the gas accumulated in the gas holder when the gas holder rises for the first time. When the gas holder rises again the next day, there is no danger of oxygen being present in the gas holder.

The main steps for starting and operating a biogas plant are shown in the accompanying video.

(d) Potential entrepreneurial opportunities

There are already enterprises supplying dung-based biogas systems in rural areas. The same agencies could take on food waste-based biogas plants as an additional product.

Biogas systems could be assembled for restaurants, residential educational institutes, old-age homes, orphanages, community kitchens and other enterprises. The system size and component capacities would be decided by the amount of organic waste available daily. For such systems, the economic saving accrued through replacement of petroleum gas could be an added incentive for the client, allowing the entrepreneur to earn more profit than would be possible from selling biogas plants only to households.

Entrepreneurs could explore a rent-based business model because biogas plants can be dismantled and shifted from one location to other relatively easily. To lease rather than sell biogas plants to end users would require capital investment but ensure ongoing income from a limited number of customers.

The uptake of biogas plants with individual kitchens attached for household or commercial/institutional use could be increased if banks designed consumer finance options to enable it. Accessing carbon finance or Corporate Social Responsibility (CSR) funding also could be explored.

(e) Two-step biogas system

Household biogas plants based on kitchen or food waste have not been used widely in the developing world even though such systems have been available for more than 10 years. Waste available from one home is not large enough for it to be converted into a primary cooking energy source. Most people in the developing world are not concerned about managing their waste scientifically and, therefore, do not appreciate or value the potential of a household biogas plant.

Attempts to set up community-based biogas systems in which organic waste is collected and used as feedstock for one large biogas plant have met with only limited success, the main reasons for failure being :

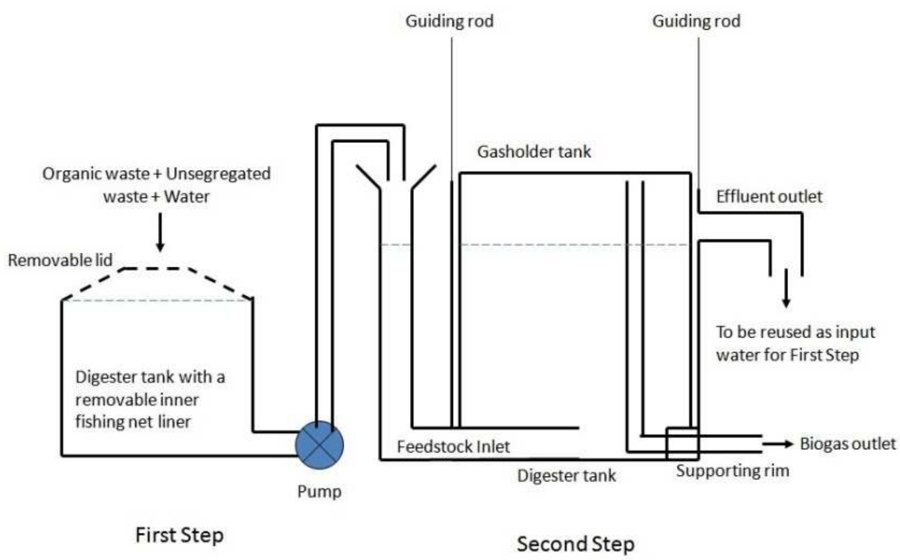
- Difficulty matching available biogas with a community's energy need;
- Logistic challenges in waste segregation, collection and processing;
- Logistic challenges in distributing the end product to multiple users.

The solution commonly attempted has been to encourage people to segregate their waste to enable organic waste to be available separately for centralized biogas generation to be used typically for the generation of electricity to be sold to the electric grid. However, once the collection and transport costs of getting the waste to the centralized unit are taken into account, the energy consumed through diesel burned during transport, for example, plus biogas engine inefficiences, the overall process of waste to biogas to electricity often fails to provide an economically viable net-energy-positive system.

Samuchit Enviro Tech has developed a next-generation system in biogas technology that combines the advantages of a community biogas system and a household biogas plant, overcoming the problems inherent in each. The new technology creates an environmentally friendly, energy sevice-based entrepreneurial opportunity, especially in rural areas

The heart of the system is a two-step biogas plant, in which both steps are anaerobic. Figure 9 shows a schematic diagram of the system.

Figure 9. Schematic diagram of a two-step biogas system



The first step uses bacterial action to break down organic waste into organic acids that are water soluble. The acidic water is pumped into the second step, where methanogenic bacteria convert organic acids into biogas. The advantage of the system is that, even if the first step receives a mix of organic and inorganic waste, the inorganic waste will not interfere with the biogas-generation process.

The model operates along the following lines:

1. The total and organic waste generated in a community is estimated. Based on that, a two-step biogas system is designed and established at a suitable location. The land for the system might be provided by a village council, either free or at nominal rent. The houses and/or establishments interested in purchasing biogas will receive floating dome-type biogas storage containers of appropriate capacity and biogas burners of appropriate size. The biogas storage containers should be filled with water and placed as close as possible to the cooking stove.

2. The organic and inorganic waste generated in the community is collected from door to door. A public campaign should be run to motivate residents to segregate their waste. Typically, despite public awareness

campaigns, about 30 per cent of waste is unlikely to be segregated, which is why the model requires a two-step biogas plant.

3. The segregated recyclable inorganic waste collected door-to-door is sold to appropriate scrap dealers. Hazardous waste such as medical and sanitary waste is incinerated. Organic waste and potentially unsegregated waste is introduced into the first step of the biogas plant.

4. The anaerobic digestion of organic matter in the first step results in a liquid rich in organic molecules. The second step converts the liquid to biogas.

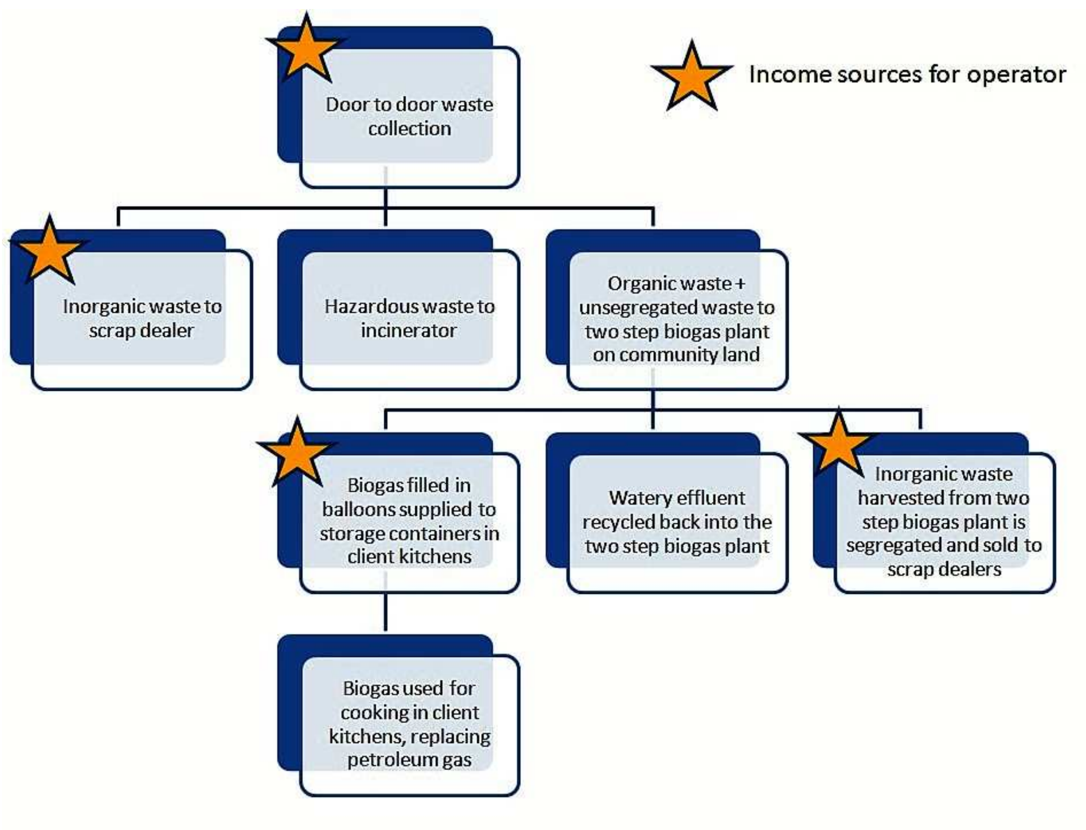
5. Each day, while the first step of the plant receives new feedstock, the biogas generated in the second step is collected in rubber balloons of 1 cubic metre capacity. Each balloon holds slightly more than 1 kilogram of biogas.

6. The biogas-filled balloons are transported to customer kitchens, where the appropriate quantity of gas is released into the storage containers. Ideally, the vehicles delivering biogas collect waste for the return trip to the cengralized plant.

7. The reactor in the first step of the biogas plant is lined with a fishing net, which is taken off every three to four months to remove accumulated inorganic wast. The waste must be segregated mannually and disposed of appropriately. With time, waste segregation becomes ingrained as common behavioural practice, reducing the inorganic load ending up in the centralized biogas plant.

Figure 10 shows the proposed workflow for the operation described above.

Figure 10. Workflow of the enterprise based on a two-step biogas system



(f) Economics of the business model based on the two-step biogas system

In the model outlined above, use of community land for the commercial centralized biogas enterprise is justified by the fact that the enterprise provides an important civic service in terms of waste management.

The entrepreneur needs to invest in the following capital items:

- Biphasic biogas plant;
- Vehicles for door-to-door waste collection;
- Rubber balloons for use as containers to transport biogas;
- Tanks and stoves at customer sites;
- Incinerator for hazardous waste.

The running expenses are mainly for labour, vehicle fuel, plus sundry repair and maintenance costs.

The revenue is generated through several possible ways, including:

- Waste-management service fee received from the village council/community;
- Price received for recyclable inorganic waste sold to scrap dealers;
- Price received for biogas from end users.

The enterprise might receive additional support in the form of tax rebates, low- interest bank loans, carbon finance, plus financial support through CSR and donor agencies. Donor, CSR and government support is justified because the enterprise provides social and economic benefits through scientific waste management, livelihood generation and supplies of a locally produced renewable and clean energy source for cooking. There is carbon finance potential because the system avoids methane generation through landfill and replaces a fossil fuel, petroleum gas, with a renewable fuel, biogas.

II.3 Conclusion

The two case studies above demonstrate the potential for rural energy enterprises based on locally available biomass resources and targeted at real service needs of rural comminuties. Biomass in some form is always available near human settlements because humans have always settled in areas where some water is available and food can be grown. Biomass can be viewed as a natural store of solar energy that can be used in innovative ways to fulfil some of the energy services required for daily life.

III. List of Enclosures

1. AIREC cooking Energy Service Decision-Support Tool: Three MS Excel files plus Survey Cards in the form of MS PowerPoint.

2. Schematic video showing operation of aSamuchit Transhflasher Charring Kiln.

3. Video showing the total operation of a renewable charcoal-production unit.

4. Video showing the assembly of a Samuchit Household Biogas Plant.

5. Schematic video showing initiation, operation and basic troubleshooting for a Samuchit Household Biogas plant.

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