Science and Technology Department, Government of Uttar Pradesh

Project Proposal Research, Designed, Developed, Implemented & Submitted by

NEER Foundation
Meerut

Project Title

"A novel system for adsorbing and separating suspended impurities from effluent gases and hereby recovery of value added products from jaggery unit"

Project Type

Pilot Scale Demonstration

Focus Area:

Jaggery Manufacturing Industry

Principal Investigator:

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NEER Foundation, Meerut

Researched, Designed, Developed, Implemented

&

Submitted by,

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Objectives of the project

The project involves detailed groundwork study on the present jaggery manufacturing industry in India

Following are the major objectives laid down by Ministry of Environment & Forest for the project,

1. To introduce and demonstrate clean technology for the jaggery unit (*kohlus*).
2. Traditional jaggery unit (*kohlus*) will be replaced with the newly designed efficient units.
3. To develop a system or process for adsorbing and separating suspended gaseous impurities from effluent gases and thereby recovery of value added products.
4. To re---design the crushing unit for enhancing the sugarcane juice from 55% to 90%.
5. Maximum saving of bagasse for using it in pulp and paper industry as an additional source of income for the farmers.
6. Production of value added sugarcane juice with advanced packaging.
7. To develop value added jaggery products thereby creating additional healthy food (Vitamin A, Vitamin C, Vitamin E etc.).
8. To use sugarcane debris for producing briquetting/baling/bio fertilizer/compost which otherwise goes waste.
9. Cost effective and user---friendly technology.
10. Overall enhancement of income for the farming community.

Abstract

Inventa Infrastructure Pvt. Ltd proposes a self---sustainable, environment friendly and energy efficient jaggery---manufacturing unit. It does not require any external source of energy such as fossil fuel. The system has an improvised furnace design that ensures efficient combustion, which minimizes the particulate matter and poisonous gases exiting in the flue gas. The flue gas is passed through a scrubber where CO_2 is converted into valuable by---products making it eco---friendly. The process increases production by 25% over traditional units and produces export quality organic jaggery. While improvisation of manufacturing process, the workers safety and hygienic working conditions have been given equal priority. Simultaneously, Inventa & NEER have also proposed waste minimization solutions by utilizing sugarcane agricultural residue and combustion ash.

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1. Introduction

Jaggery also called "Gur" in India, "Desi" in Pakistan, "Panela" in Mexico and South America. India is one of the largest sugarcane producers in the world with about 4 million hectares of land under sugarcane, producing around 300 million tons of cane per year. The estimated sugarcane production as per the report of the Sugar Industry is 340 million tons for 2012---2013[1]. Of this about 60---70% cane is utilized for sugar production. India and Brazil are the major producers of traditional cane sugar sweeteners, *khandsari* (raw sugar) and jaggery. About 17% of sugarcane production in India is consumed for producing alternate sweeteners like jaggery *(gur)* and *khandsari*[1]. Currently around one---third of India's sweetener production of 26 million tons is in the form of these products.

In this era of automation, world evolves around machines. Agricultural field too, needs to be improvised technologically thus making it an attractive sector for investment and Jaggery is one of the principal agricultural products in India. In recent days, Jaggery making is done crudely which is more time consuming and tiresome work. Due to the inefficient processes jaggery making becomes difficult in present days. Making automatic mechanism increases the production rate and decreases manpower requirement. This process makes jaggery more hygienic. The objective is to benefit the rural economy and thereby increase the production rate. Adaptation of such new ideas in agriculture would enhance the present scenario and make India compete globally.

Unfortunately, the farmers face many issues during the process of jaggery making from these traditional jaggery---manufacturing units.

2. Jaggery Production

Jaggery is manufactured using two different processes. One is manual process and the other is through automated plants. Most of the Jaggery manufactured in India is done through the manual process. Although Automated Mills have been invented, but the manual jaggery manufacturing still remains the most widely used and most favored method for Jaggery manufacturing.

Manual Manufacturing Process

In India and neighboring countries, farmers make Jaggery predominantly in rural areas. It is the only method followed all over India. Manual method seems simple as no machine or electronics is involved in it, but it needs a lot of expertise and is very unhygienic for the workers.

[2]

The process of manufacturing Jaggery involves crushing sugarcane using a crusher and extracting juice out of it. The juice is then poured in a large shallow but thick iron vessels/pan called "kadhai" and made to boil over earthen ovens. It is continuously stirred using large ladles to avoid sticking at the bottom of the vessel.

Natural or inorganic (sodium bicarbonate, sodium metabisulphate) clarificants are added. The scum floating on the surface is removed via filtration. Lime is added to increase the pH. This boiling and stirring goes on for hours until most of the water from the juice is vaporized and the juice starts to thicken, as the concentration of sugar increases in it. Slowly it becomes super saturated and assumes a golden brown thick paste form. A lot of experience to decide the right moment when the Jaggery is done, because any under doing or over doing may ruin the taste and quality.[3]

The colors and taste depends upon the degree of boiling and the chemicals added. Now, the thick paste obtained is poured in various moulds. On cooling, the Jaggery solidifies and is taken out of the moulds, wrapped in paper and packed in jute or plastic bags. Thereafter, local agents or executives collect this Jaggery from farmers and sell in local market. The process for manufacturing Date Palm Jaggery and Palm Jaggery remains the same. These two types of Jaggery are invariably manufactured manually.

Jaggery making is a popular activity in several parts of India. However, the technology used by the manufacturers is quite outdated. There have been little improvements done in the manufacturing process to enhance the productivity of the process.

3. Project Overview

Inventa plans to set up a jaggery manufacturing plant having cane---crushing capacity of 1 ton per hour. Assuming this cane yields maximum of 750kg juice per ton, jaggery produced would be approximately 125kg per hour. The unit will be built in a closed well---ventilated shed, having separate storage and operations area. This unit will be powered by a steam engine, which utilizes waste heat to generate the requisite amount of steam. Much energy is required when the plant is starting up and shutting down. Doing this daily would impact negatively on the production efficiency, hence, we propose that this plant be run for 24hrs a day in 3 shifts. The plant will be closed for one day a week, for ash removal and cleaning. 8---10 unskilled workers would be required to run its various operations. 2 skilled workers would be needed for making jaggery. Dried bagasse/biomass is stored in the bagasse storage area in the night so as to prevent condensation of dew on the fuel. Sugarcane is also stored inside to prevent evaporation of moisture. Carbon dioxide generated in the combustion process will be scrubbed using alkali solution. The byproduct generated can be then sold to industries nearby. Paper, dye, glass industries etc. use the product as raw material. Inorganic nutrients will be extracted from the ash to enrich the sugarcane farms again. Inventa will explore three methods for ash utilization and the most economical and easy method shall be adopted. Sugarcane trash is a rich source of energy. This biomass is burnt in the field after harvest. Inventa has developed two mechanisms by which this biomass can be utilized as fuel for the jaggery unit. This would ensure significant saving of bagasse, which can be sold to paper industry. Thus it is doubly advantageous as wantonly burnt bio waste becomes fuel and the paper industry gets its raw material enabling it to reduce cutting of trees. Provisions have been made for producing and processing liquid jaggery. The product will be bottled at the plant and would be ready for sale. Molds of various sizes would be provided for making jaggery as per market requirements.

The technical details of the various improvements will be discussed in the proceeding pages.

4. Pollution Control in Jaggery Unit

The current jaggery---manufacturing scenario is inefficient and outdated. The methods and practices adopted in jaggery making are unhygienic. A jaggery---manufacturing unit has been using the same outdated technology from a long time leading to a lot of pollution & inefficiency. The above are the reasons that affect the people working in a jaggery---manufacturing unit.

Inventa has taken up this project and have come up with a solution. Inventa's innovative jaggery manufacturing unit along with integrated pollution control reactor "The O2 Box", which is a CO_2 reduction technology, is modified for jaggery manufacturing unit. The O2 Box is designed in a manner, which will help in putting a stop to all the environmental and polluting issues related to jaggery---manufacturing unit. The O2 Box will capture the harmful gases including carbon dioxide and emit environment friendly gases into the atmosphere. The captured harmful gases will be utilized to generate by---product that will act as an additional fuel or will serve as an additional marketable by---product for the unit. This technology will not only put an end to the unhygienic conditions/practices and pollution issues faced but also prove to be an additional source of income for the farmers and make jaggery---manufacturing process self---reliant.

Scrubbing Technology

Inventa's scrubbing technology will utilize alkali solution to capture CO_2 from the flue gas. Chemical absorption systems at present are preferred option for post combustion CO_2 capture. Flue gas is passed through a continuous scrubbing system where CO_2 is captured. The scrubbing process utilizes irreversible absorption chemical reaction of CO_2 with an aqueous alkaline solution. The solvent employed can also remove acidic gases such as SOx and NOx. A flow diagram for typical chemical scrubbing process is shown in figure below.

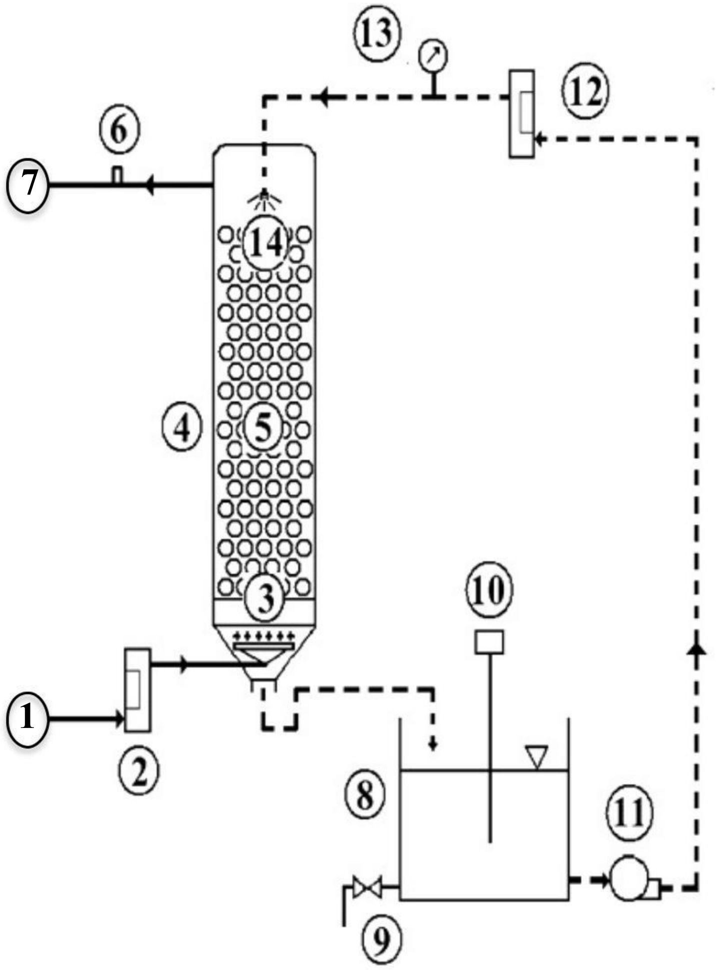


Figure. Scrubbing Process Layout.

(1) Gas inlet measurement point, (2) flow meter, (3) flow distributor, (4) packed column, (5) packing material, (6) outlet measurement point, (7) flue gas outlet, (8) solvent container, (9) drainage, (10) pH meter, (11) pump, (12) flow meter, (13) pressure gauge, (14) injector.

5. Drawbacks of traditional Jaggery unit and Solution by Inventa

A team comprising of engineers from Inventa has visited a number of traditional jaggery manufacturing units in the country. After visiting these units the team has noticed that the units are inefficient in their operations leading to an un---friendly working environment and producing non---export quality jaggery. The units were also a polluting source in the villages causing damage to the environment and making it non conducive for the worker to work and the residents to live. Following are the specific technical areas where the Inventa team has observed problems and proposed consequent solutions.

5.1 Crusher

Issues

Traditional jaggery units employ crushers that are based on obsolete technology.

a) Crushing efficiency is between 50---70%. To extract maximum amount of juice, the crushed sugarcane has to be resent through the crusher multiple times. There is a loss of time due to requirement of multiple crushing.

b) The rollers are made of mild steel and hence suffer from corrosion when not in use. They are also prone to high wear and tear.

c) As the design is obsolete, they require high amount of power. Many of these crushers do not have a gearbox, which means that they have to use high power to crush fat stalks

d) Constant maintenance and lubrication is required.

Solution

Inventa has co---developed an efficient sugarcane crusher in partnership with leading crushing technology company. This crusher specifically designed for putting in the jaggery unit extracts 95% of the juice in sugarcane in a single pass.

a) Crushing efficiency is increased to 95% resulting in a single pass. This translates to minimum of 185 kgs of juice extracted per ton cane.

b) The rollers are made of high quality stainless steel ensuring no corrosion and sturdiness

c) Gear box engineering by a German company, Nord has been employed for its reliability and performance. This gearbox provides excellent torque while requiring minimal energy.

d) The crusher requires no lubrication for upto 15000 hours and is virtually maintenance free.

5.2 Furnace

Issues

Considerable heat is lost because of crude construction, excess air input and inefficient combustion. This also results in black smoke fraught with CO and particulate matter exiting the chimney.

a) Traditional units have an open bagasse feed hole. This results in excess air entering the furnace. This excess air absorbs large amount of heat.

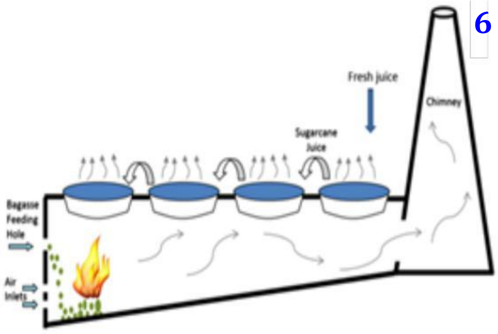
b) Air causing reduction in the heat available for extraction from the flue gas. This results in longer evaporation time and increased fuel consumption.

c) Combustion process is a sequence of three processes occurring: **i)** Drying of fuel **ii)** Pyrolysis or devolatilization **iii)** Oxidation[4]. In a traditional system all the actions are taking place simultaneously. So a part of the high energy of the oxidation of fuel ends up in drying the fuel and heating up of the air. This simultaneous combustion results in inefficient combustion and high amount of CO and un---burnt particulate carbon emission.

d) Many traditional units have no grate. This causes ash accumulation on the fuel resulting in incomplete combustion.

e) The furnace and flue gas path is mud lined. About 15% of heat is conducted to the earth.[5]

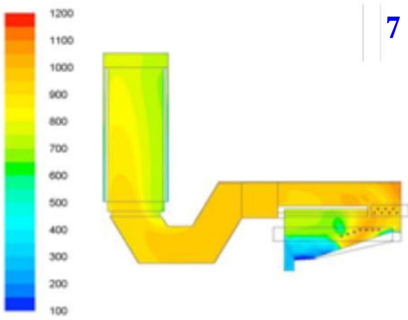
f) The flue gas path in a multi---pan system tapers up as it moves towards the chimney. As flue gas transfers heat to the pan, its temperature reduces causing it to require less volume to maintain the pressure and velocity. This tapering is done in a crude way, which causes expansion of flue gas resulting in a pressure drop and inefficient transfer of heat to the next pan.



[6]

Solution

Inventa has designed a furnace that tackles these problems resulting in efficient combustion and maximization of the heat available for evaporation of moisture from sugarcane juice.



[7]

a) A flap would be installed on the bagasse feed hole, resulting in more than 90% reduction in excess air input from this inlet.

b) A two---stage combustion furnace design where the primary combustion results causes complete drying and generation of volatiles and char particles. These volatiles and char particles will be burnt in the secondary combustion achieving a clean oxidation process. This two---stage process improves combustion efficiency considerable; CO and particulate emissions are reduced drastically. So maximum heat is extracted from the fuel.

c) A step grate would be employed for efficient fuel distribution in the furnace. Gravity and hot gases would constantly move the fuel causing the ash to fall down and get collected in the ash pit below.

d) Use of refractory bricks ensures the wall losses come down from 15% (in mud lined) to 5% making the furnace 10% more energy efficient.[5]

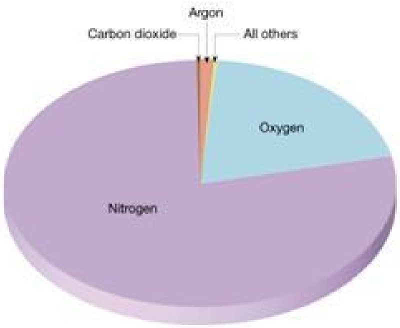
e) The flue gas path volume is critical in the flue gas energy transfer rate of to the pans. Inventa has optimized the path volume improving heat utilization ensuring pressure drop is minimized.

5.3 Energy Optimization

Issues

A traditional jaggery unit utilizes about 40---50% of the heat generated. This causes extra bagasse to be burnt and/or slow evaporation of moisture from juice.

a) Flue gas exits from the chimney at 350--- 500°C[5]. This is itself is 19---28% of energy loss.



b) Air consists of 79% of gases not participating in combustion (nitrogen, argon). These gases absorb about 50% of energy obtained from combustion. Huge amounts of combustion energy is utilized in heating the cold non---participating gases

c) Heat transfer rate is directly proportional to surface area. Traditional unit pans are not designed to extract maximum amount of heat from the impinging flue gas.

d) Juice extracted from cane is first stored in a cement tank. Once the first pan empties this juice is transferred to it. Fermentation ensues as soon as juice is extracted. Fermentation produces chemicals like organic acids, which reduce the quality of jaggery.

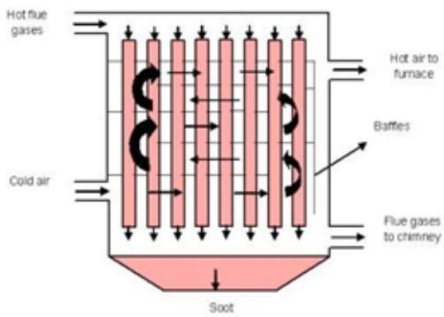
e) Bagasse is sun---dried over large patches of area. In case this area is unavailable wet bagasse would having lower calorific value would have to be used for combustion.

Solution

Inventa's technology utilizes 75% of the heat generated. The jaggery plant is entirely self---sustainable requiring no fuel other than generated in the process. This is achieved by various means.

a) A boiler is attached after the first pan to generate steam from the waste heat of the exiting flue gas. This steam is used to run an engine that powers the crusher, air blower and other power units. The diesel/electricity cost is reduced to Rs. 0. When it is not the jaggery production season, the same engine can be used to generate electricity for the farm requirements.

b) 100°C rise in combustion air inlet temperature results in 5% increase in heat availability for evaporation. An air heat exchanger will be installed after the boiler to extract 100°C heat from the exit flue gas to heat the cold combustion air before sending it to the furnace.



c) Fins are attached to the underside of the pan surface to improve the heat transfer area. A research conducted by

Prof. Anwar from IISR states an improvement of 9% in heat transfer.[8]

d) Juice extracted from the crusher will be stored in a pre---heater pan where it gets heated to near boiling temperature before transferring it to the next pan for evaporation. Such a process saves half an hour a day and prevents commencement of fermentation, ensuring good quality jaggery.

e) Inventa is also working on a bagasse dryer technology utilizing the heat of the steam exiting from the steam engine. This heat is exchanged with air, which passes over a closed chamber containing wet bagasse. The moisture is evaporated from the bagasse increasing its calorific value. The return on investment of this system is being studied in comparison with sun drying and may be an optional feature.

5.4 Process Improvement

Issues

Traditional jaggery units have very crude operations. Many operations are hazardous for the workers.

a) In a multi---pan traditional unit, boiling is transferred manually using large ladles. There is always a danger of this hot liquid splashing on his body. Many a times, the juice falls between the pans and flows down into either of the pans picking up dirt. This defeats the purpose of filtering the juice.

b) Workers use the large ladles to remove the scum floating at the surface and transfer it to a basket filter kept outside the pan. Once the basket is filled, the filtrate is poured back into the pans. Again this process can result in worker injury. This process is also cumbersome for the worker.

c) When the striking temperature is achieved in the final pan, four to five workers lift the final pan (which is directly above the furnace) and pour jaggery at 118°C into the cooling area/pan. Absence of even one worker means that this pan cannot be lifted and this would result in caramelization of the jaggery rendering it low in quality. The process is extremely dangerous as the workers get exposed to scalding liquid and a very hot pan. As this pan is directly above the furnace, flue gas at high temperatures escapes out of the outlet created by lifting the pan.

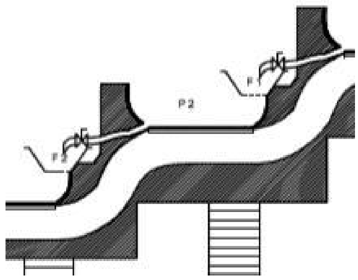
d) Workers are constantly exposed to hot flue gases and particulate matter exiting from the chimney. Severe health issues can result by constant inhalation of these gases

Solution

In order to improve the working conditions and safety of the workers involved in the jaggery manufacturing process, Inventa has come up with few simple modifications that ensure a great improvement in safety. These modifications also speed up the process saving time.

a) Valves will be used to transfer juice from one pan to the next. The worker does not have to manually transfer the juice. This method also eliminates contamination due to spillage.

b) A filter is placed before the crushed juice is transferred to the juice---preheater/storage ensuring larger fiber particles are removed. Filters have been placed on the interior walls of the pan. This ensures that the juice need not be ladled out of the pan to the basket filter. The filtrate will also fall back into the pan ensuring no wastage



c) Hot jaggery formed in the last pan is transferred to the cooling pan using a trough. A single worker does this operation. The cumbersome process of lifting and tilting the hot pan is eliminated. A trough is used instead of a pipe so that any liquid that cools on the trough can be easily removed.

d) The CO_2 scrubber and efficient furnace ensure the air breathed by the workers at the plant is clean.

5.5 Process Waste Minimization

Issues

Waste disposal is critical part of any process. In traditional systems, this source of revenue/benefit is often overlooked. Time is also an asset that is often disregarded.

a) Ash is thrown away after it is removed from the ash pit. Ash contains metal oxides and these can render the soil near the ash area to become highly alkaline. This ash contains micro and nano sized particles that fly into the air reducing the quality of air breathed.

b) Making 100kg jaggery results in evaporation of 400litres of water. This water is TDS free water.

c) Most traditional units are single pan systems where 3---4 batches are obtained in a single day.

d) In single pan processes, labor gets wasted. The juice is not crushed as the pan is in use. So the laborer sits idle during the evaporation.

Solution

Ensuring efficient and continuous process results in higher batches and consequent revenue generation. Wastes from jaggery unit can also turn into value products.

a) Bagasse/sugarcane trash ash has many soluble minerals and phosphates. These phosphates can be extracted and put back into the sugarcane fields. Thus the fields are not deprived of the valuable nutrients on harvesting. Another option is turning this ash into bricks. High silica content in the ash enables it to be an excellent material for brick making.

b) Water evaporated from the pans is recovered. This water is TDS free hence, the most suitable type of water for the boiler. This water can also be used for extracting nutrients from the ash.

c) Carbon dioxide in flue gas is scrubbed by alkaline solution to form value added by---product, which is an industrial raw material.

d) A continuous process entails higher number of batches in a single day. Considerable time is gained over a single pan process resulting in the higher turnover. Heat wastage is also minimized.

As the process is continuous, every laborer works continuously. So there is no drop in efficiency and productivity.

5.6 Storage

Issues

Around 5---10% of stored jaggery valued at about Rs.1000 crore is lost annually[9]. The main problems related to storage are liquefaction and color deterioration during storage[10]. Traditionally jaggery is in jute bags, earthen pots or covered in wheat straw.

a) This method allows moisture to enter reducing the quality.

b) Microbial action may also begin during monsoon deteriorating the taste.

Solution

Inventa will provide a plastic vacuum packaging machine.

a) Plastic packaging ensures that the jaggery will not absorb moisture.

b) Vacuum would prevent the action of microbes.

6. Sugarcane Trash Utilization

International Sugar Organization (ISO) states that, *Sugarcane is a highly efficient converter of solar energy, and has the highest energy---to---volume ratio among energy crops. Indeed, it gives the highest annual yield of biomass of all species.* Sugarcane produces two types of solid biomass: Bagasse and cane trash. While bagasse is used as fuel or raw material for paper industry, cane trash (leaves and cane tops) are left in the field to dry and later burned. Harvest of 1 ton of sugarcane stalk produces roughly 100kg of dried leaves and 200kg of cane tops. In India, and most of the world, this trash is left to dry in the fields and then set on fire. While this process reinvigorates some of the mineral nutrients, high fuel value biomass is converted to carbon dioxide without recovering its heat.

Bagasse equivalence of sugarcane residues [11]

Biomass	Availability (% cane)	Moisture content (%)	Bagasse equivalence
Bagasse	30	50	1
Cane tops and leaves	31.2	68	0.62
Roots	10.2	19.3	1.61

While roots have higher calorific value compared to cane top and leaves, it is difficult to collect it rendering it unusable. The dry cane trash (tops and leaves) has nearly the same calorific value of dry bagasse. So replacing bagasse with this waste can save about 70% of the bagasse used in jaggery manufacturing. Cane top and leaves are difficult to load as fuel due to their large volume and low mass. A technique is required to overcome this problem.

Inventa proposes two methods through which this cane trash can be used as fuel.

1. Manual baling of dry cane trash
2. Utilization as Briquetted Char from Sugarcane Trash

6.1 Manual Baling of Dry Cane Trash

Cane trash should be dried in the fields to remove the moisture. Then this trash is collected in the farm. Inventa has designed a portable manual baling machine that is taken to the farm. The trash is placed in the compression chamber. A person then mechanically operates a plunger/piston that will compress the biomass. Again more trash is added to the chamber and the plunger is used to compress it. When the desired length of compressed trash is achieved, two lengths of thread are used to tie it up for easy transport and to prevent the trash from decompressing. This system can generate bales of sugarcane trash continuously.

6.2 Utilization of Sugarcane Trash for Briquetted Char

Fuel briquettes prepared by Pyrolysing the trash can be utilized in jaggery unit. This fuel is advantageous when bagasse and raw trash are not sufficiently sun dried and contain high moisture.

The process of making briquettes is easy. 300kg of trash (dry leaves and can tops) obtained every ton of sugarcane is harvested. This trash can be collected and converted into charcoal in pyrolysis kiln. The fuel for kilns is trash itself. The char obtained is 30% of the initial biomass, i.e., 300kg will generate 90kg char[11]. Next the char is powdered, mixed with a suitable binder (wheat flour), and shaped, with the help of a machine into briquettes. The briquetted char can supply 55% energy required in jaggery manufacturing process, saving 55% bagasse.

100% Bagasse Saving

Sugar factories require huge amounts of sugarcane. Sugarcane trash after harvest is burnt in the fields. This trash can be baled for consumption as fuel in the jaggery unit. This would enable the unit to save 100% of the bagasse generated. The char briquettes made from the trash can be used as fuel for the jaggery unit or at the homes of the farmers. These char briquettes can also be sold as replacement for charcoal generating extra revenue for the farmer.

Sugarcane Trash Composting

NEER Foundation has developed a method of utilizing a excess sugarcane trash to be converted into compost. This compost can be utilized for sugarcane production thus converting waste into value.

7. Key Products

7.1 Value Added Jaggery

Vitamin C is an important constituent of our daily diet. Dried amla mixed in coarse powder form is best to be found[13]. Sugarcane can be crushed with sweet potato or carrot to fortify the jaggery formed with Vitamin A. Soy is an important source of Vitamin D and E and addition of soy milk during jaggery process would be enrich the jaggery with these Vitamins. Ginger is an Ayurvedic cure for stomach illnesses and enriching Jaggery with ginger will further increase its health benefits. The taste of jaggery can be enhanced by addition of sauf, black pepper or chocolate[14]. Other such additives can be introduced into the jaggery making process for improving its health quotient.

7.2 Liquid Jaggery

Liquid jaggery is a product that can be made by utilizing the same jaggery---manufacturing unit. It retails at the rate of Rs. 120/Litre in India. Liquid jaggery market is catching up due to its higher sweetness content and nutrition value. Ayurvedic medicines are also prepared using liquid jaggery as the base. The jaggery process has to be tweaked to obtain liquid jaggery. The temperature at which the hot jaggery is removed from the pan is different and the lime added is reduced. This ensures that the jaggery formed remains in the liquid state. The liquid obtained undergoes sedimentation in storage tanks. Here preservatives are added. After two days the liquid is removed for bottling.[15]

7.3 Export Quality & Organic Jaggery

This unit manufactures jaggery in a clean and hygienic manner. Harsh synthetic chemicals like sodium metabisulphite, sodium carbonate are not used. Only organic clarificants like ladyfinger mucilage, suklai etc. are used. The chimney will be outside the shed ensuring the quality of jaggery is not compromised. After production, the jaggery is stored in a clean room in vacuum plastic packaging to retain freshness.

7.4 Jaggery of various sizes and forms

Easy usable moulds have been designed for retailing jaggery in different forms. Granulated jaggery is in much demand as replacement of sugar for making beverages. Jaggery slabs can be designed such as required for exporting.

7.5 Trash Bales

The dried sugarcane trash bales can be utilized as fuel in jaggery unit. These bales can be made of any material. So grass bales can be made for easy storage, which can be later fed to animals as fodder. Leaves and other wastes of other crops can also baled for use as fuel in the jaggery unit.

7.6 Char Briquettes

We have suggested using sugarcane trash for making briquettes but any organic trash can be used. These briquettes can be made when it is not a jaggery---manufacturing season and can be used as fuel. Three workers can pyrolyse 300kg trash in one day by simultaneously operating two small---scale kilns designed by Inventa. So, a family unit of 3 persons can produce daily 90---100kg briquettes. The char briquettes have a good demand in towns and cities as cheap and clean burning fuel. If the briquettes are sold Rs10 per kg, family can earn Rs1000 daily. The retail price of char briquettes is in the range Rs10---20 per kg

7.7 Value Added By---Product From CO_2 Scrubbing

CO_2 from the flue gas is utilized to generate valuable by---product that is marketable as an industrial raw material.

7.8 Ash fertilizer

Bagasse ash contains minerals and phosphates essential for sugarcane growth. A culture has been developed that will extract these nutrients from the ash for utilization as fertilizer by adding it with manure. Or else a water wash can be given to the ash to extract any soluble minerals. This water should be mixed with irrigation water, thus giving back a part of the nutrients that were extracted by the previous crop.

7.9 Ash bricks[16]

Bagasse ash contains more than 78% of silica and alumina. These chemicals are essential for making bricks. Thus, this bagasse ash is directly used to make bricks. Silica and alumina are not water---soluble and a water wash to extract the soluble nutrients yield an insoluble sludge consisting mainly of silica and alumina and hence suitable for brick making.

7.10 Sugarcane Juice Beverage

Fresh Sugarcane juice obtained from mature cane is commonly used as a healthy and tasty drink in both urban and rural India. Sugarcane juice is rich in enzyme and has many medicinal properties. Sugarcane juice is a great preventive and healing source for sore throat, cold and flu. It hydrates the body and energizes quickly when exposed to prolong heat and physical activity. It is an excellent substitute for aerated drinks and cola.[17]

Sugarcane juice has a shelf life of 2 hrs. To extend its drinkability preservatives have to be added. The preservation is carried out using chemical preservatives such as potassium---metabisulphite or sodium benzoate or spices[17]. Potassium metabisulphite is a yeast and mold inhibitor and used widely as food preservative. The juice is heated for 15 minutes at 75°C for pasteurizing it.

The availability of fresh juice is very limited due to (a) Fast deterioration by microbial action, (b) Seasonal availability of sugarcane. A simple method of bottling the cane juice under hygienic conditions will ensure availability of cane juice at all times as a refreshing drink.

Procedure for bottling the juice

Sugarcane produced in normal soil using organic manures provides better quality juice. The canes should be harvested after reaching maturity to ensure maximum sucrose content.

The cane is crushed in a clean power operated crusher with stainless steel rollers. The juice is collected after filtration through muslin cloth into a clean satirized stainless steel vessel.

a) Juice Treatment

The filtered juice is maintained at 75°C for 15 minutes. The impurities in juice start coagulating at the surface that can be removed using scoop. After 15 minutes, the clear supernatant juice is filtered transferred to another vessel. The preservatives potassium metabisulphite and sodium benzoate are added in the juice. After this juice in warm condition is transferred in sterilized bottles and sealed with sterilized corks with the help of a corking machine.

b) Sugarcane juice beverage formulation

In the optimization of sugarcane juice beverage formulation mainly the quantity of salt, lemon and ginger in sugarcane juice are optimized based on sensory evaluation. The sensory evaluation was based on three parameter flavor, appearance and overall acceptability. Other flavors or nutrients can be added to enhance the juice.

c) Storage Period

A good quality beverage from the sugarcane juice has satisfactory storage stability of 60 days on refrigeration. This is achieved by heating sugarcane juice at 70°C for 15 minutes after addition of 3 ml lemon as a flavor enhancer and source of citric acid (anti oxidant) and 1gm salt as flavoring compound, 0.6 ml ginger extract as flavor enhancer per 100ml of sugarcane juice[17]. The lemon extract increases the pH of sugarcane juice to 3.01, which give a preservative action and inhibit the growth of microorganism during storage.

d) Economics

The cost of packaging 300ml bottle is Rs. 2---3 approximately. The data has been taken from the reports obtained from Sugarcane Breeding Institute, Coimbatore.

Institute Working On Bottling Of Sugarcane

a) Agricultural Engineering College & Research Institute, Tamil Nadu Agricultural University, Coimbatore.

b) Sugarcane Breeding Institute, Coimbatore.

c) Central Institute Of Post Harvest Engineering & Technology, Punjab

8. Comparative Performance of Improved Jaggery Unit

Evaporation percentages from each pan have been calculated for 125Kg/hr. Jaggery Production such that steady state is achieved. The heat transfer rate is a function of viscosity, temperature, thermal conductivity, pan area and other factors. Considering these factors, a model has been prepared for a continuous process for Jaggery manufacturing. The evaporation percentages and energy transfer for the 4 pans obtained from the model have been shown below. These calculations have been done for a cane that yields maximum of 750Kg juice/ton sugarcane. The sugar content also varies between cane varieties and an average amount i.e. 0.18 kg sugar/liter juice has been assumed.

	Pan 4	**Pan3**	**Pan2**	**Pan1**
Water Evaporation	43%	35%	22%	Preheating
Approximate Heat Required for evaporation	5125 KJ/Kg Jaggery	4100 KJ/Kg Jaggery	2562 KJ/Kg Jaggery	1404 KJ/Kg Jaggery

Furnace Improvements

	Traditional	**Inventa**	**Improvement**
Refractory lining to avoid heat loss due to conduction and radiation	No	Yes	10% reduction in heat loss
Flap system to optimize fuel to air ratio	No	Yes	Improved combustion conditions by optimizing excess air utilization in furnace for combustion
Primary and secondary combustion	No	Yes	Efficient combustion of Volatile compounds and unburnt carbon resulting in less emission of Particulate matter

	Traditional	Inventa	Improvement
Step Grate for Better combustion of bagasse	No	Yes	Prevention of ash accumulation on bagasse thus resulting in efficient combustion of bagasse
Efficiency	40%	75%	35%
Energy spent on evaporation	33000 KJ/Kg Jaggery	17600 KJ/Kg Jaggery	15400 KJ/Kg Jaggery
Bagasse Consumption in (Assuming C.V of Bagasse as 13600 KJ/Kg)	2.4 Kg/Kg Jaggery	1.3 Kg/Kg Jaggery	45% saving in bagasse consumption
CO_2 in flue gas	4.22 Kg/Kg Jaggery	2.28 Kg/Kg Jaggery	45% reduction in CO_2 emission with compared to traditional unit
Particulate matter (P.M.)	P.M in flue gas is as high as 1686 mg/Nm^3	P.M in flue gas is very low	Improved combustion of bagasse
Pan Improvements			
	Traditional	**Inventa**	**Improvement**
Fins at bottom of pan	No	Yes	Increased heat transfer area resulting in an effective increase in useful heat transfer to the pan and juices.
Flue gas path optimization	No	Yes	Increased contact of flue gas with pan
Filters before each Pan to remove impurities in juice	No	Yes	Improved quality of Jaggery
Valves at inlet and outlet of each pan	No	Yes	Prevent manual transfer of Jaggery between pans so as to avoid loss of Jaggery during its transfer

Crusher Improvements				
		Traditional	**Inventa**	**Improvement**
Data for per ton cane crushed	Percent of juice extracted	50%---70%	95%	25%---45%
	Amount juice extracted (kg)	380---525	710	185---330
	Jaggery Produced (kg)	71---100	134	34---63
	Regular Jaggery @ Rs. 25/kg	1775---2500	3350	850---1575
	Organic Jaggery @ Rs. 70/kg	4970---7000	9380	2380---4410
Fertilizer from ash				
		Traditional	**Inventa**	**Improvement**
Ash to fertilizer		No	Yes	1) Reduction in requirement of chemical fertilizers 2) Organic cultivation of sugarcane
Hood and Piping for recovery of water vapor				
		Traditional	**Inventa**	**Improvement**
Recovery of vapors generated during boiling of juice		No	Yes	1) Vapors are condensed and heat from vapors are exchanged to preheat combustion air 2) Part of condensed water is utilized for fertilizer generation and rest is utilized in steam engine
		Traditional	**Inventa**	**Improvements**
CO_2 absorption		Flue gas along with CO_2 emission is vented into the environment	CO_2 is absorbed in Alkaline solutions	90% CO_2 from flue gas is absorbed in Alkaline solutions to generate valuable byproducts

	Traditional	Inventa	Improvements
Major components in flue gas			
CO_2	CO_2 untreated	90% scrubbed	The exiting flue gases to the environment are almost free from CO, Particulate matter and other major Greenhouse gases like CO_2, SO_2 etc.
CO	Yes	Negligible	
SO_x	Negligible	Negligible	
NO_x	Yes	Negligible	
Particulate Matter	Yes	Negligible	
O_2	Yes	Yes	
N_2	Yes	Yes	

ADDITIONAL IMPROVISATION			
Steam Engine (Optional)			
	Traditional	**Inventa**	**Improvement**
Utilization of flue gas heat to run steam engine	No	Yes	20HP power generation using flue gas waste heat with incorporation of steam engine
Energy required to generate steam to run steam engine **(KJ/Kg Jaggery Production)**	---	7100	Heat from flue gas is utilized for steam generation to run Steam Engine
Extra biomass required = 0.5 Kg/Kg Jaggery Production			
Utilization of exhaust steam from steam engine	---	Yes	Exhaust steam is condensed and is utilized to preheat combustion air or to dry bagasse
Utilization of Power generated to run Crusher and other gadgets	---	Yes	Saving of diesel @ 96 liters/day OR Saving of 360 KWh Electricity per day

A typical diesel engine requires about 200ml diesel per HP generated per hour. This translates to 96litres of diesel per day.

Or

Power per HP per hour is equivalent to 0.764 KWh, which is equivalent to 360 KWh of power requirement per day.

Utilization of Sugarcane Agricultural residue (Trash)

		Traditional	**Inventa**	**Improvement**
Data for 1 ton cane obtained in farm	Utilization of leaves and stumps from cane farm	No	Yes	Waste minimization
	Leaves and stumps used as fuel in furnace	No	Yes	70% bagasse saved per hr.

Liquid Jaggery

	Traditional	**Inventa**	**Improvement**
Liquid Jaggery production in the same unit	No	Yes	Apart from Jaggery (Solid Jaggery) production farmers can produce liquid Jaggery unit which is considered to be premium quality Jaggery because of it s high nutritive value

Costing Benefits due to Additional Improvisation is over and above the earlier improvised Jaggery manufacturing process

1. Extra Benefits due to Utilization of farm waste like sugarcane leaves and stumps in furnace for combustion
   - Bagasse consumption: 1.3 Kg/Kg Jaggery.
   - Using stump and leaves in furnace for consumption, 70% of bagasse can be saved which amounts to be 0.91Kg bagasse saved per Kg Jaggery production.
   - With 125Kg Jaggery production per hr the total bagasse saved amounts to be, 113 Kg/hr.

Value of bagasse saved @4 Rs./kg = 450 Rs/hr = 10800Rs/day

2. Incorporation of Steam Engine

- A typical diesel engine requires about 200ml diesel per HP generated per hour.
- Steam Engine will generate 20 HP per Hour. To generate 20HP power 4 Litres of Diesel is required per hour. Hence with incorporation of steam Engine, which will generate 20HP power from waste heat from flue gas, 96 Liters of diesel is saved per day.

Value of Diesel saved @ 60 Rs. per liter = 5760 Rs/day

- Steam engine will generate 20HP power per hour, which is equivalent to 360 KWh per day

Value of Electricity saved @ 3.5Rs/ KWh = 1260 Rs/day

Savings from additional Improvisation

Waste Utilization	Bagasse saved	10800 Rs./day
Incorporation of Steam Engine	Cost of Diesel Saved	5760 Rs./day
	Or	
	Cost of Electricity saved	1260 Rs./day

9. Environmental Impact of the technology:

Once Inventa's innovative jaggery manufacturing technology is adopted it will have the following positive environment impacts:

Atmospheric Impact

The jaggery---manufacturing unit emits hazardous pollutants into the surrounding environment due to inefficient burning of bagasse. Burning bagasse releases CO_2, CO and Particulate Matter. Bagasse as a fuel presents problems with high moisture content, further it is generally a non---homogenous fuel with heavy and light fractions and small particles intermixed. These properties are not conducive to combustion hence atmospheric pollution is associated with fallen out of incomplete combusted particles (smut) rather than true smoke. Bagasse is considered a polluting fuel in the jaggery manufacturing in terms of black carbon and other gaseous pollutants primarily due to incomplete and inefficient combustion. Black carbon particles cause dense/intense fog, haze and smog. Intense air pollution will persist throughout the year. An increase in the concentration of black carbon produces changes in the monsoon patterns and abnormal heating of the atmosphere, as black carbon is strongly absorbing in nature. Increase in such pollution in the environment will also affect on crop yield.

Burning bagasse emits CO, CO_2, and Particulate Matter leading to hazardous effects on the surrounding environment and the people working in a jaggery---manufacturing unit. The O2 Box wards off the above disastrous effects, which is a CO_2 reduction technology modified for jaggery---manufacturing units. The O2 Box reduces the emissions from the jaggery---manufacturing unit to a large extent by capturing carbon dioxide, other harmful pollutants and particles, thus reducing their harmful effects.

Geological Impact

The jaggery---manufacturing unit emits carbon dioxide, other pollutants and various particles like fly ash. Usually jaggery---manufacturing units are located on farmlands. Ash is dumped in some corner of the field as a form of disposal. The natural soil becomes more alkaline due to alkaline nature of fly ash. This alkaline nature of the fly ash may damage the agriculture soil. The efficient furnace design will reduce the amount of particulate matter and unburned particles from the flue gas by capturing it. Thus, not letting the harmful particles affect the agricultural land. The captured ash is utilized to generate fertilizer, which will be beneficial for agricultural soil or the ash can be utilized in making bricks.

10. Social & Economical Impact of the Technology

10.1. Human Health & Safety

Presently a great deal of effort is devoted to identification and control of atmospheric pollutants. But nothing has been done to control the pollution and other unhygienic activities in the traditional jaggery---manufacturing units.

High concentration of particulate matter in and around the jaggery---manufacturing unit affects the health of the workers and the people residing in nearby areas. Also increased concentration of carbon dioxide into the environment results in poisoning e.g. difficulty in breathing, rapid pulse rate, headache, hyperventilation, sweating and fatigue. Humans residing in the near by area of the jaggery---manufacturing units are largely exposed to the above health effects.

Inventa's efficient jaggery manufacturing process with integrated pollution control reactor "The O2 Box" proves to be the solution to avoid the above health effects on humans. Once integrated, the system will capture all the harmful pollutants thus avoiding all the harmful effects on the humans.

10.2. Waste Utilization

In India especially in rural areas, waste is a severe threat to the public health concern and cleanliness. Most of the form of waste generated in rural areas is biodegradable yet it is a major problem to the overall sustainability of the rural areas. Similarly, jaggery---manufacturing units are located in rural parts of India and these traditional units generate a lot of waste that is not efficiently utilized. There is no proper infrastructure or a mechanism in these rural areas to tackle/utilize the units waste in an efficient manner. Inventa's innovative jaggery manufacturing system makes it sure that any kind of waste generated from the unit is utilized for the benefit of the unit/workers and everyone associated with the unit.

Following are kind of waste which is generated from the jaggery unit that Inventa's innovative system utilizes.

1. Bagasse

2. Water vapor from the pan
3. Ash
4. Flue gas
5. Sugarcane trash

10.3. Additional source of income and cost reduced by the Technology

The traditional jaggery---manufacturing units in India overlook an opportunity for additional source of income. Also there is a lot of cost involved for producing jaggery, which can be brought down to generate more profits. Presently the only source of income is through selling of the final product (jaggery) and there is no reduction of the unreasonable cost. Inventa's innovative jaggery manufacturing unit creates an opportunity for additional source of income and helps in mitigating rising cost of raw material. Following are different sources of income generated and various cost reduced in the traditional unit by Inventa's innovative system.

1. Selling of saved bagasse to the paper industry.
2. Generation of fertilizer from ash that can be either used in the farm or sold in the market or the ash can be sold to ash brick manufacturers.
3. Waste heat from flue gas is utilized to generate power---using steam engine, which saves diesel and electricity cost.
4. Utilization of waste CO_2 to generate valuable by---products, which can be sold in the market.
5. Sugarcane trash bales and char briquettes as fuel.

10.4. Improved Working Conditions

Jaggery unit workers face harsh working conditions, as they have to constantly work close to hot furnace and boiling pans and smoke filled ambience. Unhygienic manufacturing process and conditions leads to uncertain quality of products with unacceptable impurities. Inventa's improvised design captures all the heat and vapor emitting from the pan, thus providing the workers relief while working close to the pan. The system also provides a solution for transferring the juice from one pan to another without the workers lifting the pan to transfer the juice. The crusher is designed to extract juice at 99% efficiency, thus the workers are not required to extract juice from the same cane again and again. The improvised design for jaggery---manufacturing units is designed in a manner that it not only gives a relief to the workers from harsh working conditions but also produces export quality jaggery. The system though being technologically advanced it is user friendly and can be operated by unskilled workers without facing any harsh working conditions

10.5. Reduced Fuel Consumption

Inventa's jaggery plant is self---sustainable requiring no fuel other than generated in the process. The steam generated in the process is utilized in a steam engine to generate power. This self---generated power is sufficient to run the crusher and other power demanding processes/equipment. This completely nullifies the diesel/electricity consumption of the unit. The dryer reduces bagasse moisture, which increases its heating value. While the unit is self---sustainable it still manages to save 20% bagasse.

11. NEER Foundation's Responsibility for the project

NEER Foundation plays an important role in educating and training the farmers and operation of the pilot plant.

This jaggery unit will be installed inside a shed, thus ensuring clean operations. An open jaggery unit will cause contamination of jaggery by dust. Proper ventilation has to be maintained for the plant. One of the factors influencing evaporation rate is the humidity. Continuous influx of fresh air and outflow of inside air ensures better rate of evaporation. The shed also provides clean storage of jaggery. Hence, installation of a shed is critical for manufacture of export quality jaggery. It is the responsibility of NEER to get the masonry and construction work executed at the site.

NEER will undertake the responsibility of training the workers and the farmers on the operations of the jaggery manufacturing plant, the utilization of sugarcane trash to produce usable fuel and using ash to prepare fertilizer. NEER will educate the workers at the plant on the best practices of preparation of export quality jaggery. The workers have to be properly trained in the operations of the plant. They also have to be taught how to manufacture liquid jaggery. NEER would also inculcate in them the need of maintaining hygiene during operations.

NEER has a widespread reach among the farmers and villages. NEER will train farmers on the use of the sugarcane---baling machine and the char briquetting machine. NEER will educate the farmers on the ill effects of burning this valuable biomass in the fields and demonstrate the benefits of these easy to use manual machines. NEER will encourage subsistence farmers to use these techniques as a source of additional revenue.

NEER will encourage small kohlu owners to come together to set up the jaggery manufacturing plant developed by Inventa. It would educate the farmers on the benefits of the new manufacturing unit. It would create self---help groups (SHG) of farmers and help them setup the jaggery plant.

NEER is recognized for its efforts in educating farmers for implementing best practices for agriculture. Organic jaggery would bring the jaggery manufacturer much higher revenues than regular jaggery. But a critical aspect of labeling a jaggery organic is that it should be manufactured from sugarcane farmed organically. NEER foundation has developed some techniques that would ensure that the sugarcane grown is organic while the yield per acre is not compromised.

The following are the techniques developed by NEER that farmers can adopt for cultivating organic jaggery:

a) Seed Cane Harvesting & Bud Sett Preparation

Harvesting seed cane with brush cutter minimizes manpower requirement. It also improves efficiency of labor. The seed cane is cut in to single budded setts using the seed cutter.

b) Bagging and Stacking the Setts for Germination

After loading single budded setts into gunny bags, they should be watered thoroughly every 12 hours and covered by thick polythene sheets to control temperature, humidity and airflow. After 6---7 days when the buds sprout, the setts are ready for seed nursery preparation.

c) Seed Nursery Preparation

For raising seed nursery, HDPE trays containing 50 cavities, filling material should be kept ready. To fill in the cavities of the tray a mixture coir pith, enriched press mud cake, neem cake, bio---fertilizers, Trichoderma viridae, vermicompost etc. can be decomposed for one month and used as filler material. Then the germinated single budded setts are planted in each cavity. The trays must be watered daily. After 30 days of planting these single budded setts grow into plantlets of 20---30 cms. length with five to six leaves.

d) Seedlings Plantation

After 30---45 days, these plantlets having shoot root are ready for planting in the main field. Appropriate amount of organic compost/manure needed per acre is to be applied in the furrows before the plantlets are planted. The plantlets have to be planted on the collar part of the ridges, so that the water, if any stagnated in the furrows may not damage the plantlets. Necessary irrigations have to be given within week intervals until the plantlets are established.

Sugarcane Trash Composting

Sugar factories are the largest consumers of sugarcane. Farms sourcing these factories have significant amount of sugarcane trash lying in the fields. This trash is unnecessarily burnt and destroyed. The quantity is more than what is required to run the jaggery unit. Thus after satisfying the needs of the jaggery unit, the trash can be composted using the LR Compost technique developed by Lalit and Raman of NEER Foundation This compost can be then utilized by the farmers to enrich their own soil.

Material required for the preparation of LR Compost:

- Sugarcane leaves of one acre Sugarcane field
- 30 quintals of Animal dung
- 30 quintals of Sand
- 30 quintals of field soil
- 1000 litres of water

Size of the LR Compost pit

Length---25 Feet, Width --- 9 Feet, Height---5 Feet

Method of preparation

To prepare LR Compost, the following steps have to be followed:

- 1st layer of Sugarcane leaves (of about 2 feet height)
- 2nd layer of Animal dung (of about 2 inches)
- 3rd layer of field soil (of about 1 inch)
- After spreading these layers, sprinkle 200 litres of water. After this, follow the same steps as NADEP and spread 8 to 10 layers of the same material. Now, cover entire structure (LR Compost) with the field soil (layer of 2 to 3 inches). According to the

season, sprinkle water on the above surface of LR Compost (after every 15 days) till the moisture content in the soil rises up to 30 to 35 percent.

After 120 to 150 days, there will be useful compost produced to cater to the nutrient needs for one---acre field. The compost produced will be approximately of 10 tons.

Organic farming requires use of organic pest and disease control solutions. This does not pollute water and the soil fertility does not reduce over time. NEER introduce farmers to various bio---pesticides developed in India and educate them on their correct usage.

The following are the activities NEER will undertake:

1. Building of a clean and ventilated shed for the operations of the jaggery---manufacturing unit.
2. Training the workers on the operations of the unit.
3. Educate the workers about making liquid jaggery and usage of the various molds
4. Educate the farmers/workers on using the nutrients in ash to develop fertilizer
5. Educate farmers about the harmful effects of burning sugarcane trash in the fields and teach them about using the trash by baling or briquetting. NEER will train the farmers on the working of the baling and briquetting machines
6. Holding initial meeting with the farmers and briefing them about the importance of proposed clean technology over traditional kohlus.
7. Improved agricultural techniques including single seed sowing technique, proper spacing technique and intercropping thus reducing cost of cultivation and labour requirement.
8. Increase the crop productivity, management of insect---pest and diseases through use of bio---control of pesticides thus developing organic sugarcane.
9. Organize the farmers in each block to form Self---Help Groups (SHG) so that they can come together for the implementation of the units in their respective villages.

10. Linking the SHGs with the banks.
11. Regular monitoring and counseling of farmers.
12. Regular monitoring of the operations at the pilot plant

NEER will also organize two one---day National Seminars, one after the installation of the unit and second towards the end of the project. This will enable the farmers to understand the technology and teach them the need of implementing it.

Media plays an important role in information dissemination. The local as well as national media has its own readership and is the only medium of sharing information even in the remote rural areas. Since the proposed project aims at farming community hence, it is essentially required that the activities of the project reach a wide area across the country both in regional languages as well as in English. It would be the focus of the organization to organize press conferences, invite press from the National Capital and to take them to the field so that they have first hand information about the work being carried out under the project themselves. Hence, this project's activities would be highlighted widely.

12. Duration Of The Project

The duration of the proposed project is twelve months from the date of initiation of the project.

13. Conclusion

Inventa's innovative jaggery manufacturing unit is a complete solution for the problems faced by the traditional jaggery manufacturer in India. The Juice extraction is improved to 95%, resulting in gain of 18kgs/quintal sugarcane at lower power consumption. The **emission of particulate matter is reduced** due to installation of an efficient furnace.

The waste heat generated is reused to generate power thus making the jaggery unit self---sustainable by **reducing the expenditure on diesel/electricity**. The unit owners will have a higher production rate at a lower cost due to increase in the number of batches per day. The unit will also prove to be a profitable center by producing **export quality organic jaggery** and fetch a higher price for it in domestic and international markets. **Safe and hygienic working conditions** and easy operations will lead to convenience of the workers.

Inventa also recommends briquetting of the agriculture waste/trash for the jaggery---manufacturing units that will have it own benefits. Once the innovative system is integrated, the jaggery unit will prove to be a **profit making center** and will revolutionize the jaggery making industry by **attracting private investments** which will benefit everyone associated with the unit thus **increasing the standard of living** of the people living in these areas and making

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