

TECHNOLOGY TRAINING GUIDE FOR MICRO AND SMALL ENERGY ENTERPRISES



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ACRONYMS

RE	Renewable Energy
ICS	Improved Cook Stoves
AC	Alternate Current
DC	Direct Current
VOLT	Voltage
PV	Photovoltaic
AWG	American Wire Gauge
KCJ	Kenya Ceramic Jiko

1.0 Introduction to Energy

Energy is important in everyone's life, whether you notice it or not. Without it people would have a harder time waking up and an even harder time getting anywhere. Energy is important whether it is solar energy, mechanical energy, nuclear power, or the energy your body makes that allows you to talk, move, and walk.

Energy does things for us. It moves cars along the road and boats in the water. It bakes a cake in the oven and keeps ice frozen in the freezer. It plays our favorite songs and lights our homes at nights so we can read a good book. Energy helps our bodies grow and our minds think. Energy is a doing, moving, working thing. Energy is defined as the ability to do work, and that work can be divided into five

main tasks:

1. Energy gives us light.
2. Energy gives us heat.
3. Energy makes things move.
4. Energy makes things grow.
5. Energy makes technology work.

Forms of Energy

you probably already have a good idea that energy takes different forms. Energy can light our homes or heat them. There are six forms of energy:

Mechanical

Mechanical energy puts something in motion. It moves cars and lifts elevators. It pulls, pushes, twists, turns, and throws. A machine uses mechanical energy to do work and so do our bodies! We can throw a ball or move a pencil across paper.

Kinetic energy is a kind of mechanical energy. It is the energy of a moving object. A moving car has kinetic energy. A stalled car does not; however, if it's poised at the top of a hill, it may have potential energy.

Potential energy is the energy an object has because of its position. Potential energy is resting or waiting energy. A spring is a good example of potential energy. Energy can be stored in the spring by stretching or compressing it. The sum of an object's kinetic and potential energy is the object's mechanical energy.

Chemical

Chemical energy is the energy stored in food, wood, coal, petroleum, and other fuels. During photosynthesis, sunlight gives plants the energy they need to build complex chemical compounds. When these compounds are broken, the stored chemical energy is released in the form of heat or light. What happens to a wood log in a fireplace? Burning the wood breaks up the compounds, releasing the stored chemical energy in the form of thermal and radiant energy.

Electrical

Electrical energy is a kind of kinetic energy. It is the energy of moving electrons. Everything in the world is made up of tiny particles called atoms. Atoms are made up of even tinier particles called electrons, protons, and neutrons. Electricity is produced when something upsets the balancing force between electrons and protons in atoms. We can use electricity to perform work like lighting a bulb, heating a cooking element on a stove, moving a motor.

Radiant

Radiant energy is commonly called light energy. But light energy is only one kind of radiant energy. All waves emit energy. Radio and television waves are other types of

radiant energy. So are gamma rays and x-rays. Light waves do work by wiggling the receptors in the back of our eyes.

Thermal

Thermal energy, or heat energy, is also a special kind of kinetic energy. It is the energy of moving or vibrating molecules. The faster the molecules move, the hotter an object becomes and the more thermal energy it possesses. Thermal energy can do work for us or it can be the result of doing work. Do this: Rub your hands together quickly. What do you feel? You should feel heat. When two objects slide against each other they produce friction which transforms into heat.

Nuclear

Nuclear energy is energy locked in the nucleus of the atom. It is the force that binds the nucleus of the atom together. The energy can be released when atoms are combined or split apart. Nuclear power plants split atoms in a process called fission. The sun combines atoms in a process called fusion. In both fission and fusion, mass is converted into energy, according to Einstein's Theory, $E = mc^2$.

Difference between Renewable and Non Renewable energy

Non-Renewable Energy commonly refers to 'conventional energy'. These are mainly fossil fuels such as coal and oil. These are produced over millions of years and cannot be replaced or replenished. These fuels are considered to be un-clean and harmful to the environment because they produce adverse smoke and gases when burnt. They are not sustainable fuels.

Renewable Energy (RE) is often known as a clean and modern form of energy. This is because it pollutes less than conventional fossil fuels. Renewable energy comes from

natural resources and can be replenished. Table 1 shows a brief overview of types of RE and their derivative sources

Types of renewable energy

Source	Description	Type of RE	Description
Sun	The source of all energy as heat and light	solar energy	Energy from the sun
		Hydro energy	Energy from flowing water
		Biomass	Energy from living of recently deceased natural and animal material
Rotation of the earth	The earth daily rotation leads to various processes (differential heating and changing inter-planetary forces) from which energy can be derived	Wind energy	Energy from the tides and current of the sea
		Tidal energy	Energy from the movement of air molecule
		Wave energy	Energy derived from the waves of the sea
The interior of the earth	Heat from the earth's hot core is conducted towards the surface	Geothermal energy	Energy from the earth's inner heat

earth			

Entrepreneurs do not have quality equipment to facilitate the production of quality briquettes. Those with equipment take too long to have them repaired once they break down. The machine fabricators available are few and have to serve an increasing number of entrepreneurs who are scattered across the county.

Briquette producers and ICS producers prefer to use cash from personal savings to start up their businesses. They are however willing to take up loans to facilitate the acquisition of bigger production space and equipment. Financial institutions do not have loan packages tailor made for briquette entrepreneurs.

The biggest concern for entrepreneurs remains identification of markets beyond the household level. Eateries and institutions still feel that briquettes would not fit into their fuel energy sources.

Standardization of briquettes will help in market penetration and increase consumer confidence as they purchase briquettes.

NB: The facilitator of this training is not limited to the trainer's notes. The trainer's notes are only for guidance through the whole training process.

1.1 Structure and Use of Training Guide

This trainer's manual has been developed to provide detailed and comprehensive set of guidelines for planning, implementing and evaluating the business and development services for the entrepreneurs.

The purpose of this trainer's manual is specific, rather than general, which prepares individual trainers to effectively implement a highly specialized developmental training, using a refined training methodology

1.2 Topics Covered

The three topics covered in this manual will provide potential entrepreneurs an opportunity to experience their strengths and weaknesses as entrepreneurs and to tap their potential for enhanced performance. This means looking at the entrepreneur's personal behaviour, identifying ways to improve it, developing key technological skills and guiding them in through the whole training programme.

1.3 Rationale

Rationale can be defined as the reason for something. In a manual for training the entrepreneurs, the rationale would explain why you need to do the behaviors that the guide is suggesting.

1.4 Training Objectives

The training objectives for this guide provides the clear guidelines and develop the training program in less time because objective focus specifically on need. It helps in adhering to a plan. It tells the trainee that what is expected out of him at the end of the training program. Training objective is of great significance from a number of stakeholder perspectives,

1. Trainer
2. Trainee
3. Evaluator

Trainer- The training objective is also beneficial to trainer because it helps the trainer to measure the progress of trainees and make the required adjustments. Also, trainer comes in a position to establish a relationship before objective and particular segment of training.

Trainee-The training objective is beneficial to the trainer because it helps in reducing the anxiety of the trainee up to some extent. Not, knowing anything or going to a place which is unknown creates anxiety that can negatively affect learning. Therefore, it is important to keep participants aware of the happenings, rather than keeping it surprise.

Secondly, it helps in increase in concentration, which is the crucial factor to make the training successful. The objective creates an image of the training program in trainee's mind that actually helps in gaining attention.

Thirdly, if the goals are set to be challenging and motivating, then the likelihood of achieving those goals is much higher than the situation in which no goal is set. Therefore, training objectives helps in increasing the probability that the particular will be successful in training.

Evaluator-It becomes easy for the training evaluator to measure the progress of the trainers because the objectives define the expected performance of the trainees. Training objective is an important tool to judge the performance of the participant.

1.5 Training Methodology

The training methodology in the manual gives the trainer time for expression and also it generates an active class. It is important for the trainees to be actively involved in the learning process.

1.6 Observation and findings

Once we passed through the total process of training, we arrived at certain conclusions.

The biggest barrier to distribution is transportation and the implicated costs. Raw materials for briquette production are becoming harder to come by as more charcoal dealers become aware of the value addition potential for the charcoal dust.

Entrepreneurs of briquettes are still not able to price their products to reflect changes in production costs.

2.0 TOPIC 1: SOLAR TECHNOLOGY

Module 1:	Solar Technology
Rationale	<p>By understanding that there is a notable growing need for countries to reduce their emissions and achieve greater energy independence while facing these factors</p> <ul style="list-style-type: none"> • Increasing volatility in fossil fuel prices • Significant increase in energy demand and CO2 emissions in emerging countries <p>Decreased nuclear generation in the energy mix of developed and developing countries</p>
Content	<ul style="list-style-type: none"> • Types of solar panel • How the solar system works • Instruction on how to use a solar panel
Objective	<p>By the end of the topic, participants will be able:</p> <ul style="list-style-type: none"> • To Define Solar Technology • To mention at least three types of solar technology • To pinpoint at least three characteristic for each solar panel • To explain how solar system works and its arrangements •
Duration	60MINS
Training Methodology	Case Study
Resources	<ul style="list-style-type: none"> • Flip charts • Flipchart stands • Marker pens

- | | |
|--|--|
| | <ul style="list-style-type: none">• Masking tape |
|--|--|

2.1: Trainer's Guide

Training Methodology

Case study

- The trainees are given the case study below to study
- The trainees are asked to discuss the elements of the case study e.g. the lesson learned.
- The trainees are asked to discuss the importance of having a home solar in relation to the case study.

2.2: Teacher's notes

Theory on Solar Energy

Solar Technology-Definition and importance

Solar panels convert sunlight to electricity as the sun's rays strike the silicon crystals in the panels. The electricity is channeled through wires into the electrical system of a building or home to reduce the need for traditional power. The solar panel use the sun's energy and light to provide heat, light, hot water, electricity and even cooling, for homes, and industry's (<http://bit.ly/1bQJp5A>).The importance of solar technology is found in the light of the following:

- Renewable source of energy: solar power or sunlight is a natural resource which is not going to end till the end of human race.

- Environment friendly: energy that comes from the sun is ecofriendly and carries no bad rays with it.
- Inexpensive and easy to get: As this is the natural power and we never used to pay for wind, water in the oceans, light from the sun and oxygen we get from the plants. We directly store this energy on solar panels which are very affordable and give work for years. Solar energy is not going to end soon; therefore we can use it as long as the planet exists.
- Easy to store: solar panels are the mediums through which we can convert energy into electricity and use it at homes and industries.
- Cheap way to produce electricity: Solar energy is now helping small business owners and household to generate electricity for themselves, at very cheap rates. Electricity that is produced with the help of this energy is used by them only, and they can cut their expense on utility bill easily. They can use it as a cooker, water heater, light and to operate much other equipment's at the houses or farms and small offices.

2.3: Types of solar panels

Monocrystalline panels: use crystalline silicon produced in a large sheet which has been cut to the size of the panel, thus making one large single cell. Metal strips are laid over the entire cell and act as a conductor that captures electrons.



Characteristics of monocrystalline solar panel

- It has a lifespan between 20-25yrs
- It is more than poly crystalline expensive
- It is very sensitive to light
- It has 3.5 watts

Polycrystalline panels: use a bunch of small cells put together instead of one large cell. Poly panels are slightly less efficient than mono panels. (<http://bit.ly/MrqQyK>)



Characteristics of polycrystalline solar panel

- It has a life span of 20-25yrs
- It is expensive
- It is very sensitive to light
- It has 20 watts

(<http://bit.ly/MrqQyK>)

(Diagrams from solar tech)

Amorphous panels: An amorphous solar cell is a type of solar cell that is relatively cheap to produce and widely available. They are named so because of their composition at the microscopic scale. Amorphous means "without shape". When the term is applied to solar cells it means that the silicon material that makes up the cell is not highly structured or crystalized. (<http://bit.ly/1f5nZrj>)



Characteristics of amorphous solar panel

- It has a life span of 7yrs
- It is cheap
- Requires a lot of sunlight because it has less sensitivity to the sun
- The base is black with brown lines cutting along

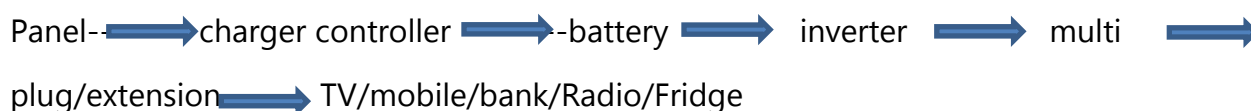
2.4: How the solar system works

The solar system is made up of; inverter, charge controller, battery and extension bar.

The inverter converts Dc (direct current) to AC (alternate current) current. The charge controller makes sure the energy from the panel is controlled and supplied to the battery, the battery stores the charge and the extension bar supplies AC current to bulbs and other components.

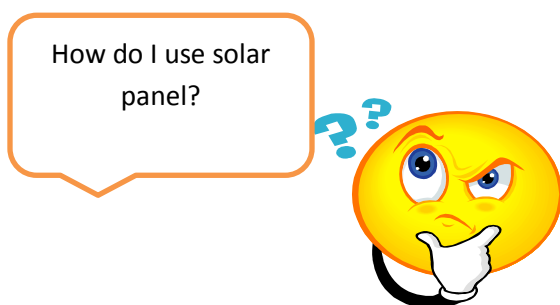
2.5: ARRANGEMENTS OF SOLAR ENERGY TO OTHER COMPONENTS

(Home solar system)



How the solar Panel works

A solar panel will generate direct current (DC) electricity when placed in the sun. This electricity can be used to power some DC appliances directly, but more often the electricity is run through wires to a charge controller and then to a battery where it is stored as 12-volt DC power. To use this electricity to power regular household appliances, an inverter is used to convert the 12-volt DC electricity from the battery to 110-volt alternating current (AC).



Instructions on how to use solar panel

- Inspect the back of the solar panel and note the maximum power voltage and the maximum power current produced by the panel. This information will also be in the installation manual that came with the panel when you bought it. Check that the panel produces a voltage less than 20 volts. This means that the panel can be used for a 12-volt system.
- Decide what kind of battery you want to use. There are batteries that are specifically designed for solar photovoltaic (PV) systems. They are called deep-

cycle batteries. A 12-volt car battery will also work, but it will not last as long as a deep-cycle battery. Many deep-cycle batteries are 6-volt. If you are going to use two 6-volt batteries, connect them in series by connecting the positive terminal of one battery to the negative terminal of the other battery with a battery interconnect cable.

- Decide where you are going to install the solar panel and the battery. The solar panel should obviously be in a place that gets plenty of sunshine most often on the roof of a building. The battery, on the other hand, should be inside the building in a well-ventilated space. But the solar panel and the battery should not be too far apart. Keep the connecting wires as short as possible. Measure and write down the distance in feet between the solar panel and the battery.
- Buy a charge controller for the 12-volt battery. A charge controller will ensure that the battery is not overcharged by the solar panel, which could seriously damage the battery. Go to a store that sells this kind of equipment or check out one of the many websites on the Internet. Select a charge controller for a 12-volt system that is designed for the maximum current generated by the solar panel.
- Determine the American wire gauge (AWG) of the wires that will connect the solar panel to the charge controller and the battery. Read carefully the instruction manual for the charge controller. It will usually tell you what gauge copper wire you will need to buy. Double the distance you measured between the solar panel and the battery and buy this length of wire.
- Cut the copper into two equal lengths with wire cutters. Take one of the wires and make a mark in red at each end of the wire on the insulation. This will be the positive wire. The other wire will be the negative wire. Cover the solar panel so it is not producing electricity. Connect wire to one of the terminals on the back of the solar panel. Connect the positive wire to the positive terminal.

- Install the charge controller on a wall close to the battery. Run the two wires from the solar panel down to the charge controller, attaching the wires to the wall at various points if necessary. Cut the wires so that there is just enough wire to connect to the charge controller. Set aside the remaining length of the two wires.
- Open up the charge controller and look at the instruction manual. The controller will have three sets of two terminals. One pair will be labeled "solar panel" or "PV," one pair will be labeled "battery," and one pair will be labeled "load." Each pair of terminals will have a positive and a negative terminal. Connect the positive wire from the solar panel to the positive terminal of the pair labeled "PV," and the other wire from the panel to the negative terminal.
- Take the length of positive wire that remains and connect one end to the positive terminal of the pair marked "battery" on the charge controller. Connect the other end of this wire to the positive terminal of the battery. Repeat this procedure for the other wire, connecting one end to the negative terminal on the charge controller and the other end to the negative terminal of the battery. Remove the cover from the solar panel.

Key questions

(Frequent asked questions)

- What makes a good quality solar system?
- What company do I select to install my solar system?
- What happens with my solar system at Night, in cloudy weather or during rain?
- How long will my Installation take?
- How will the system be maintained?
- How can I tell a water-heating panel from a solar electric module?
- How many solar panels do I need to produce enough electricity to run my house?

- Will a system produce enough energy to cover all my electricity needs?

Case study on home solar panels

Mohammed's family (*not the real name*) bought a brand new home in late 2010. After living in the home with their two young children for a year, the family recognized they had a large south-facing roof, the preferred orientation for a solar panel installation, and were curious to hear about cost and tax credits for a solar home upgrade. They were able to research online and then set up an appointment with a Solar Kenyan Energy Consultant who analyzed their power bill data and recommended a system based on individual need.

Challenges

Normally a combination of (**energy reduction + energy production**) is needed to eliminate a power bill. However, the family's power bills were lower than national averages, so one main challenge was which home energy solution(s) to recommend. Another challenge was what size solar panel system to recommend in order to maximize available tax credits. One final challenge was suggesting a solar panel and solar array design that would blend seamlessly into the dark asphalt shingle roof.

Solution

After analyzing the family's power bills and talking about different home energy improvement packages, a 22 panel solar array was determined to be the best solution to both maximize solar tax credits and cover a majority of energy costs. A 5.17kW solar array was designed using 22 235 watt Sharp solar panels with black frames, installed in 2 rows of 11 for a clean and symmetric look. The panels were positioned on the roof so that 1 final row of 11 solar panels could be added at a later date should the home owners desire to expand their home solar panel system.

Result

The **photovoltaic home solar panel array** was installed in October of 2011. The system was designed to offset approximately 77% of the annual home power bill with an average savings of around 172946 KES per month over the 40 year expected life of the system. In November of 2011 the Family paid for just 106 kWh and in many months since they have received a credit on excess power production including a 691.8 KES credit on their May 2012 power bill.

3.0: TOPIC 2: IMPROVED COOK STOVES-ICS

Module 2:	Improved Cook Stoves-ICS
Rationale	By understanding that improved cook stoves are more efficient compared to the traditional stove i.e. three stones.
Content	<ul style="list-style-type: none"> • Types of improved cook stoves • Types of jiko. • Testing of quality liners •
Objective	<p>By the end of the topic, participants will be able:</p> <ul style="list-style-type: none"> • To Define Improved Cook Stoves • To be identify a good quality liner • To mention at least two types of JIKOS • To mention materials used in ICS assembling
Duration	60MINS
Training Methodology	Group Work
Resources	<ul style="list-style-type: none"> • Flip charts • Flipchart stands • Marker pens • Masking tape

3.1: Trainer's Guide

Group work

Small groups may be composed of about three to five members who work together for a short time to complete packaging and labelling a task or to solve a problem. Through this group, the trainees can express their opinions freely and get actively involved in the discussions.

Group Work Instructions

- In groups, the trainees are asked to differentiate traditional cook stoves from improved cook stoves.
- In groups, the trainees are asked to mention the disadvantages of using traditional cook stoves.
- In groups, the trainees are asked to mention the advantages of using improved cook stoves

3.1: Teacher's notes

Improved Cook Stoves-Definition and benefits

Improved Cooking Stoves (ICS) are designed to be energy-efficient, which translates into the

Consumption of less fuel wood or charcoal, saving on time and resulting in less production of harmful

Smoke in comparison to the traditional stoves. The ICS is generally suited both to urban and rural Population. Specifically, consumers of ICS products are:

- Domestic charcoal users mostly in urban/peri-urban areas
- Domestic firewood users, mostly in rural areas

- Institutional users such as schools and hospitals
- Business users such as restaurants, hotels and street food vendors

The use of ICS leads to reduction of pressure on forest and energy resources. If the sector is well developed such as in Kenya, there is tremendous potential for skill development and job creation.

Improved Cook Stoves (ICS) are a mature energy technology for the efficient conversion of energy from biomass to heat. Benefits Improved cook-stoves can offer the following key benefits to consumers, over traditional stoves / 3-stone fire place:

- More fuel efficient: Money and time saved in acquiring fuel
- Reduced amounts of smoke and indoor air pollution

Furthermore, the following wider social benefits mean there is government support:

- Less pressure on forest and energy resources
- Public health: reduction of disease caused by indoor air pollution
- Skill development and job creation in the community.

3.3: Types of Improved Cook Stoves

The key feature of any ICS over a traditional stove is the use of an insulating material such as clay or mud (liners) to conserve heat and make it more efficient.

Two main parameters can be used to distinguish between

ICS types:

- The type of fuel used; e.g. charcoal or firewood and
- Whether the stove is portable or fixed.

A stove's efficiency can be determined by the ratio of useful heat produced to the amount of fuel energy going in. This will tell you how good an ICS is really is. Other important factor that can be considered is the appearance of the ICS and its ease to use.

Fixed Firewood Stoves

These types of stoves are mostly common in Uganda and Western Kenya. They are usually built up in situ and can be made very cheaply using local materials. They work by directing hot gasses from fuel -wood gasses.

Portable Stoves (charcoal/firewood)

The portable stoves are commonly across East Africa. Their portability makes them suitable for retail distribution as a take away product and mass manufacture away from the point of use

How the stoves are manufactured

Fixed Stove

- The main stove body is usually built up from the ground, around a simple mould (e.g. banana stem) that is removed to create the firebox and air passage cavities.
- They can be made with low-cost local material such as clay saw dust and lime mortar.
- Tools needed are also relatively inexpensive e.g. shovel, sieve, trowel, measuring tape

Portable Stove

- The ceramic liners for portable stoves generally require higher quality standards and are usually made using mould, left to dry and then fired in a kiln.
- The ceramic liners for portable stoves generally require high quality of clay which must be carefully prepared before putting into the mould. Moulds are relatively inexpensive.
- Likewise the requirement for kiln firing can make this a potentially capital-intensive venture unless access can be arranged to an existing kiln.

3.4: TYPES OF JIKOS

- Kenya Ceramic Jiko
- Uhai Jiko
- Kuni Mbili multipurpose
- Upesi Jiko
- Jiko poa
- Jiko banifu
- Rocket stove
- Shigela stove
- Kibwangu
- Tatedo stove
- Maendeleo jiko

The table below elaborates more about different types of Jikos and where in East Africa they are found

Country	Design	Type	Fuel type
Kenya	Kenya ceramic jiko (KCJ)	Portable	Charcoal
	Maendeleo/Upesi	Portable	Firewood
	Rocket stove	Fixed	Firewood
Tanzania	Tatedo	–	Charcoal
	Jiko bora	–	–
	Shigela	–	–
	Jiko Banifu	–	–
Uganda	Kibwangu		Firewood
	Rocket stove	Fixed	Firewood
	i) Lorena stove	Fixed	Firewood
	ii)Shielded fire stoves	Fixed	Firewood

3.5: Testing quality liners

Physical observation

- Look at the colour, it should be brick red in colour
- Look at the fire holes, it should be smooth without any cracks
- Measure the diameter of the fire hole, for any standard liner the diameter should be 3 ¼ inch.
- Look at the general smoothness of the liner.

- Sound test

A good liner will sound like a metal or a glass when tested. A bad liner will sound like a wood.

- Water test

3.6: Materials used in ICS assembling

These materials are also called insulators.

- Vermiculite +cement
- Sand+ Cement +Ash
- Rice husk +Ash +Cement
- Fired clay

Key Questions

(Frequent asked questions)

- Are improved cook stoves really saving on that much?
- Do modern stoves do not destroy cultural tradition?
- How long do the new stoves last?
- Its fuel wood a renewable energy resource?
- Isn't the smoke in the hut needed to drive mosquitoes?

4.0: TOPIC 3: Briquette technology

Module 3:	Briquettes Technology
Rationale	By understanding that, briquettes are renewable source of energy that is easily accessible and relatively affordable as compared to other energy fuels; because they are obtained from waste materials.
Content	<ul style="list-style-type: none"> • Waste Materials for producing briquettes • Commonly used binding agent • Types of Carbonized briquettes • Ingredient for making briquette
Objective	<p>By the end of the topic, participants will be able:</p> <ul style="list-style-type: none"> • To define what biomass briquetting is? • To mention at least six materials used for producing briquettes • To list at least the three types of carbonized briquettes • To describe production procedure for making briquettes using different binders i.e. cassava, molasses, pulped paper and soil.
Duration	60MINS
Training Methodology	Practical Exercises
Resources	<ul style="list-style-type: none"> • Flip charts • Flipchart stands • Marker pens

- | | |
|--|--|
| | <ul style="list-style-type: none"> • Masking tape |
|--|--|

4.1: Trainers guide

Practical exercises

This technique is used during training session, it permits students to acquire and practice the knowledge skills, and attitudes necessary to successfully perform more training objectives.

Practical exercise –Instructions

The trainer divides trainees into three groups'

Group one demonstrates how to make briquettes using cassava as a binder

Group two demonstrate how to make briquettes using molasses as a binder

Group three demonstrates how to make briquettes using soil as a binder

4.2: Teacher's notes

Fuel briquettes-Definition and Importance

These are charcoal made from waste products (charcoal dust, waste paper, forestry residue, saw dust and cow dung) that are used in household institutions for energy purposes. Briquetting technology is the process of adding value to waste products in order to be used for energy purposes e.g. in cooking and lighting.

The benefit of briquettes is found in the light of the following:

- Conservation of the environment-mean less rubbish in the streets.
- It is a source of income-you can make money from selling briquettes.
- Economical-it is cheap since the raw materials are at your disposal.
- Saves time-using fuel briquette means less firewood to chop and charcoal to buy



Waste Materials for producing briquettes

The materials used in producing briquettes are; Charcoal dust, Leaves, Maize stalk, Saw dust, Maize husks, Waste papers, Grass, Chicken Waste, Coconut waste and Rice husks.

Ingredients for making fuel briquettes can be classified under the following categories;

- (i) **Heat Fuels.** This is what provides the energy. About 90% of heat fuel material is required for good quality briquettes that will give you more heat. Always use materials that have less ash content in them. Examples of heat fuels include; Wood charcoal, Charcoal fines, Sawdust, Wood shavings, Waste paper, Coffee husks, Rice husks, Coconut wastes (coconut husks, fibers and shells etc.) and Macadamia nut shells
- (ii) **Binders for Producing Briquettes.** Binders are needed when the pressure produced by the compacting equipment is too low for 'self-bonding' or when the raw materials used do not self-bond, such as

charcoal. Charcoal is a material without plasticity and charcoal dust cannot hold into shape without adding a binding material. The effect of adding a bonding material is to enhance cohesion and reduce pressure requirements. Binders hold components by both mechanical and chemical adhesion, and occur when the binder molecules adhere to specific points in the molecular structure of the adherent.

4.3: Commonly used binding agents include:

- Starch from maize, cassava (manioc), wheat, sweet potatoes and certain plants like algae
- Sugarcane molasses
- red soil
- Gum Arabica
- Pulped waste papers

Cassava has unique properties such as high viscosity and resistance to freezing. Binders such as sugarcane molasses and vegetable starch (from maize, cassava, etc.) add to the calorific value of the briquette. Clay and/or red soil, and ash when used as binders inhibit combustion of the briquettes thereby producing more ash.

(i) Accelerants

Briquettes require materials to make them burn faster because unlike lump charcoal, their structure is more compact due to the compaction process used in making. As a result, briquettes cannot absorb sufficient oxygen for faster burning. Use about 1 – 2% of the accelerant. Examples of accelerants include:

- Sawdust

- Pulped waste paper

Remember that use of un-carbonized sawdust produces briquettes that produce a lot of smoke. To reduce the smoke from sawdust, partly ferment your sawdust for about five days by soaking in water.

Fillers

Fillers are materials that are added to briquettes during production to increase their weight, density or volume and to regulate the burning rate of the briquettes. That is, it slows down the burning rate of briquettes, which increases efficiency. Examples of fillers include red soil and ash.

4.4: Types of carbonized briquettes

Biomass briquettes can be classified into three main categories, these are:

- a. Carbonized briquettes: They are produced from densification/compression of loose carbonized biomass waste materials. Some of the loose carbonized waste materials that are easily found within our urban areas include charcoal dust. One can also compress raw biomass materials followed by pyrolysis (heating) to acquire carbonized briquettes.
- b. Non-carbonized briquettes: These are produced through agglomeration of loose raw biomass waste materials, such as sawdust; waste paper, leaves and wood shavings to acquire uniformly sized blocks.
- c. Semi-carbonized briquettes: Produced from compression of both carbonized and non-carbonized biomass wastes materials. A good example is making of briquettes from a mixture of charcoal dust and sawdust

4.5: Production Procedures for Briquettes

Making Carbonized briquettes

Tools and Equipment

- Wire mesh sieve: for sieving charcoal dust/binders/accelerator to separate dust from granules/particles. Also make it easy to remove impurities.
- Spade: moving/lifting materials required in the briquettes production.
- Mixing drum, trough or bucket; this is where mixing of different materials for making briquettes are done.
- Grinder: for grinding the big part particles into powder
- Weighing instrument/balance; for measuring the different proportions of materials used in making briquettes.
- Briquettes pressing machine (manual or motorized): for compressing of different materials to make briquettes

b) Raw materials/ ingredients

The raw materials are classified into heat fuels, binders, accelerators and fillers

- i) Heat Fuels: As explained above, these are the key materials in briquettes that produce energy or heat.
 - For carbonized briquettes, you can use already carbonized waste materials found within our environment such as charcoal dust. The alternative will be for you to carbonize the waste materials either using down draft pit kiln, drum kiln, controlled open charring, or use of gasifier stoves. This will turn the raw waste into carbonized materials.
 - If you are using charcoal dust, sort to remove the unwanted materials such as leaves, stones, and wood.

- Sieve to separate the charcoal dust from charcoal granules. Note that at this stage, the charcoal dust is known to contain some amount of soil in its composition. This is ideal for making briquettes to be used in poultry farms where warmth is required and not heat
 - Grind the charcoal granules separately into charcoal dust. This particular type of dust contains less or minimum amount of soil. This is ideal for making briquettes for use in households, institutions and hotel industry where heat is required
 - If your heat fuel is coconut wastes, saw dust, macadamia nut shells etc. Sort these materials to remove inorganic stuff like stones, nails, etc. then carbonize before using them to make briquettes.
- ii) Binders. These are the bonding materials used to enhance cohesion and reduce pressure requirements. They are used when the pressure produced by the compacting equipment is too low for 'self-bonding' or when the raw materials used do not self-bond, such as charcoal.
- These include cassava flour, spoiled maize flour, molasses, waste thick porridge (Ugali), waste sweet potatoes,
 - Select the binder of choice that is easily available in your area of operation

Preparing a cassava binder

- As mentioned earlier, a number of different binders can be used. Here we describe using cassava root to make porridge, but any starchy porridge is ideal.
- Peel and grate one large cassava root for each batch of charcoal.

- Mix it with hot water, to form a thick, gummy porridge. Approximately 1 cassava root and 1.5 liters of hot water are required to make enough porridge for one drum of charcoal.
- Mix the fine charcoal powder, with this warm porridge, in a basin. Mix it well so that all of the charcoal has some porridge on it.
- You can test if the charcoal mixture is ready for briquetting with your hands. Grab a handful of charcoal powder, and crush it in your palm to make a rough ball. If the ball falls apart when you let go, the charcoal needs more binder. If the ball keeps the shape of your hand, it is ready to make briquettes.
- If you have cassava flour; Mix 1 part of the flour with 10 parts of water and heat to near boiling i.e. raising the temperature to 90°C while continuously stirring to make thick porridge (gelatinization)

Preparing molasses as a Binder

Heat the molasses until boiling and leave to cool. This is to increase their binding characteristic

iii) Accelerators

Two accelerators have been mentioned above; saw dust and waste paper.

Preparation of saw dust

Sort to remove wood chips and twigs

Ferment in water for four to seven days

Preparation of Waste Paper

Sort to remove polythene and plastic materials

Shred into small sizes either using hands or paper shredder

Soak in water for two days. Pound using heavy stick into pulp

Drain the water and add clean water and let them soak for another two days, pound again until it becomes a smooth pulp,

Drain the dirty water, add more clean water and let it ferment for two more days

Preparing soil binder

When red soil/loam is used as binder then,

- Sort the soil to remove all impurities such as stones, leaves, humus, nails and papers.
- Carry out size reduction of the soil particles (grind the larger soil particles to finer particles)
- Mix the heat fuel (Charcoal dust) with the finer particles of soil using the following mixing ratio:
- Mix the composition until you get a homogeneous mixture before adding water

How do you determine if the materials you have collected for production will result in quality briquettes? This can be done by carrying out a simple test as follows:

Step 1: Soak organic material in water

Step 2: Take a handful of the soaked materials and press into a ball. If the paste retains the ball like structure, it means that it can be pressed into quality briquettes.

Step3: if the material falls apart, i.e. they don't take the ball like shape, and then add material

(Binders) that increase the binding capacity and repeat step 2.

What ratio do I use in the production of briquettes using different binders?



4.6: Maxing the materials/ ingredient and Making of the briquettes

a) Using Starch as Binder (Cassava flour or corn flour)

- Take 10 parts of the heat fuel + 0.2 parts of fermented saw dust
- Mix materials until you get homogeneous mixture
- Add the cassava porridge slowly while mixing until the mixture is wet enough
- Move the composition to the pressing machine and compress to briquettes (refer to section on moulding)
- Dry in direct sunlight for 3 to 5 days depending on the weather conditions

b) Using Molasses as binder

- Take 20 parts of the heat fuel + 0.4 parts of fermented saw dust
- Mix the materials until you get homogeneous mixture.
- Sprinkle water into the mixture to make it a bit damp
- Add 0.5 parts of heated molasses to the mixture
- Mix the materials thoroughly to achieve homogeneity
- Move the composition to the pressing machine and compress to briquettes (refer to section on moulding)
- Dry in direct sunlight for 3 to 5 days depending on the weather conditions

c) Using Soil as Binder

- Take 10 parts of the heat fuel + 0.2 parts of fermented saw dust
- Mix materials until you get homogeneous mixture
- Add 0.8 parts of red soil to the mixture and mix thoroughly
- Add water slowly while mixing until the composition is wet enough (refer to the section below)
- Move the composition to the pressing machine and compress to briquettes (refer to section on moulding)
- Dry in direct sunlight for 3 to 5 days depending on the weather conditions

d) Adding water:

- Add water to the mixture, little by little while stirring to make a paste. Test whether you have added enough water by taking a handful of the paste, squeezing and releasing. If the mixture does not loosen up, it implies that you have added enough water and you are ready to compress your paste into briquettes.
- Note: Some biomass materials like freshly carbonized charcoal dust require to be soaked in water for at least 8 hours to ensure that it is easy to work with. Other materials like sawdust and waste paper are soaked for at least a week to ensure that they are soft enough to work with.

e) Moulding/compaction into briquettes

- Compacting mixed materials into briquettes can be achieved using different techniques, including:

(I) you can mould the paste into balls or different shapes and sizes with your hands and leave them to dry in the direct sunlight

(II) You can mould the paste into shapes using empty tins or cans (containers of used products such as oil tins) and dry in direct sunlight.

(III) You can compact the prepared paste using a motorized or manual machine. In this case you need the briquette press, and a hammer, or wooden mallet.

- (Photo above shows the briquette press). With the ejector resting in the bottom of the cup, scoop up a full cup of charcoal powder.
- Place the plunger in the cup.
- Hit the piston hard with the hammer 3-5 times, to compress the powder
- Hit the bottom of the press on a hard surface (e.g. the surface of the hammering station). This pushes the ejector pin upwards, and lifts the briquette upwards.
- Repeat until you have made briquettes with all the material. A lot of charcoal mixture will fall on the ground during this process; if you put a plastic sheet or tightly woven cloth down where you are working, you can use it to collect the charcoal mixture to use it to make one final briquette, so it isn't wasted.

Drying the briquettes

These briquettes, now formed, will need to dry in the sunshine, to fully harden.

Leave the briquettes to dry in the sun for at least two days. If rain is likely, make sure they are protected from the water.

Hardening the briquettes (optional step):

After briquettes have dried in the sun, they may still be soft. To harden the briquettes, you can fire them in an oil drum, while making another batch of charcoal. Put the briquettes in a wire mesh basket, and gently toss the basket in a burning oil drum, just

before you put the lid on and seal it. When you open the drum after two hours, the briquettes in the mesh basket will have baked, and hardened.

Storage and Packaging

- Store your dried briquettes in a well aerated dry place. Avoid dump areas and leaking roof as this will make your briquettes return to paste form.
- Package your briquettes in an environmentally-friendly way, label and take to the market.

4.7: Making your own charcoal for carbonized briquettes (carbonization of Biomass materials using drum Kiln)

a) What you need

Carbonized materials are easily produced using simple tools and welding equipment; the total equipment cost is between KES1, 700 KES3, 400. A 250 liter steel oil drum (one full oil drum needs about 16kg of agricultural waste, and will produce about 4kg of charcoal) form the kiln

b) Requirements

- Drum Kiln
- A long, straight object likes a stick – to create a central chimney in the oil drum; it should be taller than the oil drum, and as wide as a fist in diameter.
- Three bricks or flat stones about the same size.
- Empty Rice bags or other large bags - to crush the charcoal powder in.
- Matches – to set fire to the agricultural waste.
- Sand, mud or dirt – to help create an airtight seal around the drum.

4.8: Preparing the equipment/ Making Drum Kiln

- Acquire the Oil drum:
- Cut one large hole in the top of the oil drum (this is a loading hole).
- Cut five holes of equal diameter at the bottom (these are air holes) of the oil drum.
- The drum kiln will be ready for use



Figure 1 and 2: holes at the base

Caution

- Do not use an angle grinder or any other tool that will create sparks unless you are certain that there are no flammable or explosive residues inside the oil drum.
- The drum should not contain any toxic or explosive residues.
- If it has safe residue (oil or food) a small fire should be made inside the drum to clean it out. Allow the drum to cool before starting to cut holes.
- Both flat ends of the drum must be intact.
- There must be no holes in the curved sides of the drum.

a) The cover

You need a lid, to cover the large loading hole in the top of the oil drum. The lid should be large enough to cover the loading hole in the oil drum, (figure 2) but small enough not to extend over the edges of the oil drum. An ideal lid is made from a piece of sheet metal. It is easier to place the lid on top of the hot kiln if a handle is welded onto the lid. If you can't make a curved handle, a

handle shaped like a short, flat 'T' has worked well. You can also use metal without handle

b) Making charcoal

Charcoal production requires experience to produce high quality charcoal, and to get high yields of charcoal from an oil drum. The method must also be adapted slightly for different materials. Whilst this manual provides general details, the time required at each stage varies. When conducting a charcoal burn, it is important that the weather is dry. It is possible to make charcoal when it is raining, but it is much harder to light a fire. The oil drum also cools down more quickly, so the yield is lower.

c) Filling the drum

- When filling the drum, it is necessary to allow air to flow through the drum so that the fire can burn hotly and evenly and produce high quality charcoal.
- Place a large stick, in the Centre of the drum and pack the bagasse, stalks or other material around it until the drum is full.
- If you are using corn cobs, or other material that is more difficult to light, create 4-5 layers of corn cobs, separated by husks or dried grasses. This allows the whole drum to get hot, and produce high quality charcoal.
- Carefully remove the stick, leaving a hole that goes to the bottom of the drum.
- Take a small amount of material and poke it into each of the holes in the bottom of the drum, leaving about 20 cm sticking out. This creates a wick, allowing you to easily ignite the material at the bottom of the drum. Refer to figure 4 below

Lighting the fire

- Before lighting the fire, place the drum on top of three stones or bricks, so that air can flow in through the holes in the bottom. Place the drum on the stones carefully, so that it will be easy to remove the stones while the raw material is burning, to seal the drum.
- Light the wicks at the bottom before you light the loading hole on the top. One good way to light the top is to light a long piece of the biomass on one end and then drop it in the central hole, made by the stick. Sometimes the fire catches fast enough that you do not need to light the top. Once the biomass is fully on fire, it will make a large, billowing plume of white smoke. Take care to stand upwind from all the smoke, to avoid inhaling it. After about 10 minutes, the smoke starts to get a bit darker, thicker and yellowish. As the drum gets hotter, volatile carbon gases begin to be formed.

These can be ignited to make the fire burn more cleanly, giving off carbon dioxide.

- Light a match and throw it into the top of the drum. If it is too soon, the smoke will not ignite. If the timing is right (volatile carbon gases are evaporating) the smoke will catch on fire and the fire will burn much more cleanly.
- Raise the drum on three flat stones, and light the wicks at the Bottom.



- Let the fire burn for another 10 minutes before sealing it. These times are approximate, and may vary depending on the material used, and the conditions of the burn.

Sealing the drum refer to figure 5 below

- In order for the material to carbonize, rather than burning away, it is necessary to seal the drum, preventing air from getting in. This step requires at least two and preferably three people.
- Place the lid on the drum. It is easiest to do this if the lid has a curved handle, so you can put the lid on with a stick. If flames shoot out from the edges of the lid or from under the drum, it is not yet ready to be covered, the lid should be removed and the material allowed burning for a little longer.
- Once the drum is covered, use the large stick to gently support one side of the drum, on the side of a stone.
- Kick away the stone under that side and gently lower the drum.
- When tipping the drum to be able to move the rocks or bricks from underneath, it may be safer for two people to hold each end of the stick and tilt the drum with the centre of the stick.
- Repeat this with each of the three stones until the drum is resting on the ground.
- Seal the bottom edges of the drum and edges of the lid with sand or soil until no smoke is visible.
- This means that there are no holes through which air can enter the oil drum.
- After sealing, the drum remains hot. Make sure that no one touches the drum for at least two hours after sealing.

- When the smoke is darker, carefully set fire to it.
- Place the lid on the drum

The agricultural waste will slowly carbonize inside the hot oil drum. After 2-3 hours, when you are sure that the drum has cooled, you can remove the lid. Before removing the material, sprinkle some water inside the oil drum. This will reduce the amount of charcoal dust that is thrown up into the air.





Figure 1 -carbonization of the materials

Charcoal

After 2-3 hours, the material inside the drum should be fully carbonized. This means the charcoal powder will be black throughout. If corn cobs are used; the cobs will be brittle and easy to break; the center of the cobs will also be black. If the drum was allowed to burn for too long before sealing; the yield may be low. In this instance, a lot of material will have burned away, and grey ash will remain. If, by contrast, the drum was not allowed to burn for long enough, or some parts of the drum did not get hot enough, the material will not be completely carbonized.



Figure 2 carbonised material

- If using cobs, they will still have a white core; bagasse may still be brown coloured. Uncarbonized material does not make good briquettes. Sort any uncarbonized material, and put it to one side. It can be used when filling the drum for the next batch, to avoid waste.

NON-CARBONISED BRIQUETTES:

- a) Tools and Equipment
 - Weighing machine
 - Drum/trough/bucket
 - Pressing machine
- b) Raw Materials for making non-carbonized briquettes are classified into two:
 - I) Heat fuels: such as saw dust. Ferment the sawdust by soaking in water for at least one week before use. Failure to do this results in briquettes that produce a lot of smoke.
 - II) Binders: such as waste paper.

When using waste paper as binder, the following steps are undertaken to prepare:

- Sort to remove plastics papers
- Shred/tear sorted waste paper into small pieces
- Soak them in water for two days; pulp/pound the soaked paper to make paper marsh
- Pour out the water from the pulped paper
- Ferment the pulped paper for at least three days by soaking in clean water

Mixing

Mix the heat fuel and binder using the following ratios:

- Fermented Saw dust: Fermented Waste paper

Fermented sawdust

Fermented waste paper

80

20

Briquette Making

- Press the mixed fermented materials into balls of different sizes and shapes using hands and dry in the direct sunlight.
- Using press machine compress fuel briquettes into uniform shapes and sizes and dry them in the direct sunlight

4.9: BRIQUETTE PRESSING MACHINES

There are four types of briquetting pressing machines commonly used in Kenya. These are piston, screw, roller and lever press.

I) **reciprocating ram/Piston press**

These machines are either manual or motor driven. Motor driven machines are relatively large and operate in such a way that the piston forces material through a narrow opening. Very high local pressures are built up as a result of the friction at the point of entry. This generates sufficient heat for the binding agent to flow, binding the material together. The area of the die tends to determine the output of a machine. For instance, a larger die (and correspondingly larger machine components) results in a larger output.

II) **Screw press extrusion**

Screw extruders use a screw action to extrude a briquette through a die. Material is fed into the machine from a hopper into the screw chamber. Powered by an electric motor, the screw forces the material through a die and out of the machine as a (typically) cylindrical continuous briquette. The heat enables lignin (binding agent) breakdown to occur, making the machine suited for briquetting non-carbonized feed stocks. Some machines use a conical screw that tapers from large (input end) to small (output end). This type of machine can achieve pressures of up to 100MPa, generating sufficient compaction for briquetting non-carbonized feed stocks.

iii) **Roller briquette press**

Roller-type briquette presses are commonly used to produce pillow shaped charcoal briquettes. They involve two adjacent counter-rotating rollers with indentations in the shape of the desired briquette. Powder is fed from above, falls into the indentations and is compressed as the rollers turn. The briquette then exits the machine as a single lump.

Briquetting of biomass using a roller briquette press usually requires a binder. Very often this type of machine is used for briquetting carbonized biomass to produce pillow charcoal briquettes.

iv) **Manual press and low pressure briquetting**

Manual presses are specifically designed for the purpose or adapted from existing implements used for other purposes. They are used both for raw biomass feedstock or charcoal. The use of a binder is imperative. Manual presses are very cheap (compared to motorized machines), but they have a low production capacity, they demand intensive labor and require the use of binders. The main advantages of low-pressure briquetting are the low capital and operating costs needed, and the low levels of skill required to operate the technology. The following are some of the manual briquetting pressing machines available in Kenya.