Development of Policy Framework and Business Model to Promote Sustainable Use of Biomass Briquettes in Nepal

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Executive Summary

Nepal has an abundance of biomass residues that can be used for the commercial production of biomass briquettes, which make them attractive in terms of higher density, heating value and ease of transportation and storage. Nepal can harness this opportunity and create an enabling environment for promotion and sustainable use of biomass briquettes. Asian Institute of Technology (AIT) was responsible for developing a business model and policy framework for Nepal.

Stakeholders have been interviewed to understand the current situation of bio-briquette sector in Nepal, existing business models and pressing challenges faced by the sector. An extensive desk review of best practises around the world also carried out, in terms of both business models and policies for biomass briquettes to draw practices that could be relevant in Nepal. In January,2018, AIT and Alternative Energy Promotion Centre (AEPC) jointly organized a two-day stakeholder consultation workshop. The workshop was funded by Climate Technology Centre and Network (CTCN) and supported by Ministry of Population and Environment (MoPE). The overall objective of the workshop was to gain an overview of the key issues and challenges in bio briquette sector, and how to address them.

On the technology front, key issues identified were inadequate knowledge of value of biomass, lack of value addition to biomass, inability to make efficient use of biomass, information gaps on resource potential and accessibility, affordability of technologies, product diversification, drying of products and end user technologies. The business model session focused on possible business models in the context of Nepal, including cash at gate policy, product diversification, 3rd party financing and build- operate- transfer model. Lack of investment support, market segmentation and consumer identification, marketing mechanisms and networking, demand creation and stove designs were identified as some of the challenges in current business models. Pertinent gaps in Nepalese policy scenario were also identified, including lack of consumer awareness, high upfront costs, market barriers, technology support, tax and tariff reform and institutional development, quality control and standards, low- interest loans, grants and other financing mechanisms for briquette industries, investment support via low- interest loans, grants or subsidies for combustion (e.g. pellet industries). Creation of an enabling environment, special protection for industry, fiscal incentives for market barriers, institutional development and risk management were identified as measures to address these policy barriers.

The AIT team also visited Centre for Energy and Environment- Nepal (CEE-N), Organic World Pvt. Ltd. And Himalayan Naturals Pvt. Ltd. to understand the issues faced in manufacturing process.

The stakeholder consultation workshop identified important aspects to be included for the policy framework and constructed the way forward for training program that was held in June 2018. Further desk reviews were carried out to make the policy framework more holistic and explicit towards bio-briquettes.

A three day stakeholder dissemination workshop and training was held in June in Kathmandu. The overall objective of the workshop cum training was to disseminate the key findings on business model and policy framework in bio briquette sector, and to train the stakeholders on how to address the key technological issues prevalent in the sector in Nepal.

The training focused possible solutions to the pertinent technology challenges in Nepal. The proposed solutions include recognizing suitable technologies, training human resources on operation as well as mixing ratios, cost effective drying options such as solar dryers or hybrid solar drying systems, proper binder selection and mixing ratios, and torrefaction.

The dissemination workshop addressed suitable business action plan and policy framework in Nepal. The business action plan should address the entire value chain, from supply security to demand creation and identify specific points of government intervention for facilitating successful operationalization of the business action plan. Several policy incentives could be operationalized in Nepal including financing, tax exemptions, accelerated depreciation, prioritizing bio briquette sector, focusing on research and development, creating consumer awareness and setting national standards and certification schemes. This requires a holistic approach from the government that encompasses the entire supply chain, from assessment of biomass potential raw material to demand creation. Realistic goal setting based on monitoring and evaluation results, quantification of biomass potential of raw materials in Nepal, collaboration between private enterprises and research institutions are other aspects that need to be further looked into. Overall, policies need to be revised to recognize 'briquette' and 'pellets' explicitly. Co- ordination between all the relevant agencies is imperative to successfully operationalize the business action plan, and establishment of a Special cell with AEPC, such as a "Bio-briquette Technology Support Facility" was proposed. Such a facility would be responsible for technology identification, trainings, and consumer awareness generation as well as information dissemination.

The stakeholder dissemination workshop and training identified important aspects to be included for the policy framework and constructed the way forward for the policy framework that would be presented to the Ministry of Energy Water Resources and Irrigation (MoEWRI) for operationalization.

This report consists of a main report providing summary of the project outputs and findings and six annexes with more details about the activities carried out under this project. The annexes are: Annex 1. Status of biomass briquetting industry in Nepal, Annex 2. Business action plan for promotion of sustainable biomass briquettes in Nepal, Annex 3. Policy framework on promotion of sustainable use of biomass briquettes in Nepal, Annex 4. Gender mainstreaming in biomass briquettes policy in Nepal, Annex 5. Report on stakeholder consultation workshop of sustainable use of biomass briquettes in Nepal, and Annex 6. Report on stakeholder dissemination workshop and training on promotion of sustainable use of biomass briquettes in Nepal.

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1. Introduction

Seventy-five percent of Nepal's population (4 million out of 5.43 million households) use solid biomass (firewood, cattle dung, or agro-waste) as their primary fuel. At the same time, Nepal wishes to attain economic growth that targets sustainably, without threatening the local environment and public health by using polluting and inefficient technologies, while dealing with serious threats to the local environment and public health. Indoor air pollution is one of the biggest health risks in the country, and much is attributed to cooking and indoor heating using solid biomass, mainly firewood. Excessive firewood consumption by traditional cook-stoves exerts enormous pressure on forest resources in Nepal. In addition, they require rural women to spend more time collecting firewood and cooking, in turn limiting their ability to participate in income-generating activities. Urban and peri- urban households in Nepal depend on imported LPG (provided at a subsidized rate) for cooking purposes, which is unsustainable in the long- term. Nepal must therefore pursue other avenues of efficient, affordable and renewable energy sources that can meet the increasing energy demands in a sustainable manner, given the high costs of grid connection, the low consumption rate, and the scattered population, especially in remote areas.

Many solar energy and micro/ pico- hydropower projects are already running successfully in several communities across Nepal. However, biomass energy is not yet being optimally tapped into, as the use of biomass energy is largely limited to traditional use (for household cooking). Biomass densification can lead to increased energy efficiency, provide a means for livelihood generation and reduce the dependance on unsustainable fossil fuels. As an agriculture based economy, Nepal has an abundance of raw materials for briquette production. This raw material base combined with forest residues provide a strong opportunity for bio briquette production.

As a renewable fuel, biomass briquettes and pellets are suitable for household, commercial (army and police canteens, hospitals, schools and colleges, restaurants and hotels) as well as small to medium scale industries such as paper making industries, food processing, textile and clay products.

The following sections contain the findings of the project divided into 5 topics: i) Technology Framework, ii) Business Action Plan, iii) Policy Framework, iv) Gender Equality and Social Inclusion, and vi) Stakeholder Consultation and Dissemination Workshop Reports.

2. Technology Framework

Many different types of biomass resources available and varies in size, shape, and characteristics. It is imperative to select suitable and feasible technological path to utilize each biomass resources efficiently. Utilization of agricultural and forestry biomass residues for energy applications is often difficult due to their uneven and troublesome characteristics. The process of compaction of residues into a product of higher bulk density than the original raw material density (loose density) is known as densification. Densification has stimulated a great deal of interest in all over the world in recent years.

2.1 Densification Technologies

Several types of biomass densification are present, based on dimension (briquettes, pellets), operating condition (hot densification, cold densification), mode of operation (batch densification, continuous densification), compression system (piston, ram, and screw- press), wet densification and co-densification.

Depending on the types of equipment used, densification could be categorized into four main types:

- Piston press densification
- Conical Screw press densification
- Screw press with heated die
- Pelletizing press

Mobile Densification

Mobile densification unit allows the user to set it up at any location reducing major problems of transportation and handling. The systems does not occupy permanent space which is the major advantage over fixed densification plant. Mobile densification systems usually perform the tasks of chopping, particle separation, compression, screening, cooling and packaging. Moveable pellet plant can better be used to produce pellets of 200kg-450kg per hour. Small pellet plant features high efficiency and energy conservation.

Binder Densification

Apart from commonly used densification processes, technologies for binderless densification are also available. This is possible only with decayed and composed biomass, where unused residues accumulated and composed over years, like mountains of waste bagasse, coconut husk etc. could be used. Fresh biomass can also be briquetted after pretreatment (aerobic and/or anaerobic fermentation after size reduction if necessary)

Co-densification:

The co-densification of different (two or more) biomass materials can help each other to improve the characteristics of their combined densified product (pellets/briquettes). Since biomass can be classified into two groups, poor & good biomass, based on volatile matter, fixed carbon, ash content and heating value. Example of a poor biomass: Rice straw & good biomass: sawdust and sawdust can act as binder also for rice straw densification.

2.2 Biomass Densification Variables

Some of the variables to be considered for biomass densification include:

- Particle size and particles size distribution (PSD): The density & durability of briquette is inversely related to particle size. Uniform distribution of different particle sizes is best for densification.
- Moisture Content: Moisture content plays an important role in densification that it:
  - (i) lowers the glass transition temperature;
  - (ii) promotes solid bridge formation; and
  - (iii) increases particles contact surface area
- Densification Temperature: In thumb rule, maximum strength is achieved at around 220^{o}C, however it depends on the presence of cellulose, hemicellulose & lignin content in biomass.
- Densification Pressure: Optimum pressure level is specific for each feedstock type that needs to be determined through experimental study.

- Dwell time: It is the time while feedstock pass through heated die (screw press system).It enhances bonding strength between particles, reduces tendency of particle disintegration, and increases compressive strength.
- Die geometry and speed: An increase in mold length increases densification pressure demand, whereas, an increase in mold diameter of die decreases densification pressure.

2.3 Binding Materials for Biomass Densification

Binding materials are also known as additives, binder or external materials which can be organic or inorganic & can be used in their solid or liquid form. The use of binders is imperative especially in cold densification process. Binders usage is highly depends on the type of biomass. Binders should:

- improve compressive strength & durability of the product
- reduce the temperature and compaction pressure demand
- reduce energy consumption
- increase stable density of briquettes/pellets
- improve water resistance capability
- increase heating value & reduce ash content
- improve combustion characteristics of the pellets/briquettes

2.4 Selection of Binders

In densification wide range of binders are used: molasses, starch, asphalt, proteins, modified cellulose, kraft lignin, inorganic clay minerals, waste paper pulp (kraft paper and newspaper), bamboo residue, sewage sludge, mesuaferrea L. seed cakes, Cassava paste, rice bran, sawdust, dry cow dung, wax, rapeseed oil cake etc. The availability & cost of binding material needs to be assessed before the selection of binding material. The competitive value of binding material needs to be assessed even if it is free & readily available. For example, cow dung is widely used as organic fertilizer, a replacement of inorganic fertilizer, hence the extensive usage of cow dung for densification negatively affects (indirectly) the sustainable development process & causes GHG emission.

2.5 Bio- briquetting Issues in Nepal

The project able to identify some of the issues pertinent in the case of Nepal in bio-briquetting sector and classify them as:

I. Feedstocks related issues
   a) Only few residues are usually used for briquette production (i. e., rice husk and charcoal from woody biomass)
   b) Lack of information on biomass resources availability (i. e., types, amount, characteristics and locations)
   c) Lack of data on cost and energy related to the collection and transportation of residues to the processing plant.
   d) Other issues/problems in utilization of forest biomass residues and resources.

II. Technical issues
   a) Technology mostly limited to rice husk and beehive briquettes.
   b) Highly focused on charcoal briquettes making and lack of facilities for pellet production.

c) Use of inefficient biomass carbonization technology.
d) Need to identify appropriate binding material.
e) Need to develop suitable biomass drying system.
f) Lack of holistic approach for using bio-briquettes as clean and efficient combustion fuel in residential and industrial sectors.
g) Mainly depend on machine suppliers for troubleshooting and
h) Selection of appropriate technology.

III. Social, economic and other issues

a) Lack of analysis on cost competitiveness of biomass briquetting technologies for each feedstock type.
b) Lack of specific funds for capacity building, research and development, training programs etc.
c) Lack of public awareness, knowledge dissemination, and strong supply chain.
d) Lack of access to credits and infrastructure, and inadequate recognition for biomass briquetting/renewable energy financing.
e) Lack of database for potential suppliers and users.
f) Lack of provisions, innovative financial models, policies, incentives, and entities related to biomass resources and products supply chain.

2.6 Possible Solutions Proposed for Nepal

Some of the prospective solutions include:

I. For feedstock related issues

a) Commencement of region-specific biomass resource availability assessment program which will provide necessary information for future planning.
    i. Residue-to-production ratio (RPR), growth rate and cultivation cycle.
    ii. Population density, household energy demand, and the form (heat and electricity) of energy demand.
    iii. Identify, estimate, and evaluate the potential of available biomass resources for briquetting in each specific region.
    iv. Create region-specific database for biomass feedstocks availability and analyze characteristics.
    v. Assess the ease of access and suitable mode of transportation requires to collect biomass feedstocks.
b) Involve communities in collection, preparation and supplying of densified fuel to the market or end-users (industries or households or commercials).
c) Disseminate the negative impacts of indoor air pollution to create public awareness.

II. For Technical issues

a) Adoption of hydraulic or mechanical press briquetting system that offers higher lifespan compared to screw press briquetting system.
b) Adoption of energy efficient carbonization system such as retort kilns.
c) Torrefaction of biomass is an energy efficient solution over slow pyrolysis.
d) Promotion of biomass pellet production which has huge demand in the global market of biomass solid fuels.

e) Co-densification is another solution that offers mutual co-benefits to two or more biomass residues.
f) Utilization of waste heat for preheating of biomass before compaction.
g) Integration of biomass gasification system with hot briquetting system to meet the demand of both thermal energy for briquetting and biomass drying.
h) A holistic approach is needed for designing and developing improved cookstoves.

III. For socio-economic issues

a) Conduction of financial analysis for Community scale system including direct and indirect benefits, investment costs and sensitivity analysis
b) Training programs (for communities) should be designed/developed considering each community as a part of the biomass briquette/ pellet supply chain.
c) Arrange workshops on:
    - Advantages & importance of modern solid biofuels usage over traditional biomass.
    - Technologies to produce modern solid biofuels (briquettes and pellets) at household & industrial scale.
d) Hands on training on feedstock collection, preparation, and storage, operation of biomass densification (briquetting and pelletization) system and quality testing of densified products.
e) Business models (feedstock supply chain).
f) Practice preventive measures for hazards from self-heating and fire, and occupational safety:
    - Avoid storage and transport of large volumes if the fuel's tendency of self-heating is unknown.
    - Avoid storing biomass with moisture contents greater than 15 wt.% (w.b.).
    - Avoid mixing different types of biomass fuels in same storage.
    - Avoid mixing fuel batches with different moisture contents.
    - Avoid large amounts of fines in the fuel bulk.
    - Measure & monitor temperature distribution & gas composition within the stored material.
    - Monitor both the storage compartment & adjacent spaces for CO and O2 to avoid entry into hazardous environment.
    - Limit storage time & follow the storage principle "first-in-first-out"
    - Control the delivery of fuel with respect to allowed maximum temperature.

More details of the status of biomass briquetting industry is given in Annex 1 of this report.

3. Business Action Plan

This section gives a brief overview of the global biomass briquette sector and proposes an action plan for Nepal.

The potential of biomass as a renewable energy source has been recognized globally. Progressive depletion of fossil fuels and global commitments to curb emissions have increased the interest in biomass energy in recent years. The global market shows an increasing trend for wood pellets for industrial (mostly power station) use and heating use. Europe is the largest consumer of bio-heat by region. Markets in Asia is still immature compared to the European market. However, Asian markets are emerging and show robust growth with large-scale power markets in East Asia rapidly picking up. Japan and South Korea are the biggest importers of pellets in Asia, while China, Thailand, Vietnam, Indonesia and Malaysia are exporters. The international market has also seen some promising development in biomass conversion technologies. Torrefaction of wood enables the production of pellets with a higher energy density and results in a product compatible with systems designed for coal.

Nepal's business action plan is guided by it's Biomass Energy Strategy 2017, which aims to reach the annual production of 20,000 metric tonnes of pellets and briquettes.

3.1 Goal

To increase the access to biomass energy and hence contributing to the environment conservation by transforming traditional biomass energy use into modern, sustainable and clean energy.

3.2 Objectives

- To contribute to energy supply and energy security by generating energy through management of agriculture forest residues and organic wastes from municipal urban and industrial areas.
- To support the employment and income generation through the entrepreneurship development in biomass energy; and to reduce the existing dependency on imported energy through effective, efficient production and utilization of biomass energy.

3.3 Actions

3.3.1 Setting and delivering on ambitious and achievable biomass energy targets

Nepal is looking to increase sustainable energy production in the country by utilizing agriculture, forest residues and organic wastes. The current production capacity of briquettes and pellets is estimated at 7,000 metric tonnes annually. BEST has set an annual target of 20,000 metric tonnes by 2030.

3.3.2 Streamlining biomass energy projects processes and approvals

The action plan calls for coordination among relevant agencies to ensure smooth, timely and efficient procurement of biomass briquetting related machinery and raw materials.

3.3.3 Creating an enabling policy environment

This action plan aims to develop a policy framework that not only encourages private sector investment in biomass briquetting, but also a public private partnership where government is involved in risk management in the sector. An enabling policy environment consists of provision for including biomass briquetting sector as a special protection/ priority sector, making it eligible for low interest loans. Likewise, tax and customs exemption on briquetting equipment as well as raw materials, and accelerated depreciation on machinery need to be carried out.

3.3.4 Standardizing mechanisms and certification schemes

Quality consistency in briquettes and pellets is still lacking. Therefore, this action plan calls for development of quality standards as well as certification schemes for both carbonized and uncarbonized solid densified biomass fuels. This needs to be done in close collaboration with the Renewable Energy Test Station (RETS).

3.3.5 Encouraging continuous R&D

Research and Development in briquetting needs to increase to increase technological and human capacity development in the sector. The action plan recommends that AEPC work in close collaboration with research institutions including universities, Centre for Energy Environment- Nepal (CEE-N) and National Academy of Science and Technology (NAST). R&D is required especially in terms of alternate raw materials, binder options and stove technologies. Mechanisms for technology transfer also need to be developed.

3.4 Business Models in Nepal

In the context of Nepal, two distinct types of bio- briquette industries are present: uncarbonized and carbonized briquettes. The fundamental difference between these two is that carbonized briquette production is carried out in close collaboration with community forest user groups (CFUGs) as the raw material is char produced from anaerobic oxidation of forest residues. Uncarbonized briquettes, on the other hand, is produced from agricultural residues. Because of this difference, the working model of these businesses are also different.

i. Business Model for Uncarbonized Briquettes

BOOM (Build- Own- Operate- Maintain) model is proposed for uncarbonized briquettes, with diversification of raw materials as well as products. In this model, the private enterprise manufactures briquettes not only based on a single raw material, but diversifies the raw material base depending on the price and availability, as previous studies reveal that different agro-wastes can be fed into the same briquetting system to produce uncarbonized briquettes. A cash-at-gate policy can be used to ensure strong supply chain and regular supply of varied raw materials. Product diversification, where there is production of briquettes, pellets, pillow briquettes as well as the stoves that these briquettes require, is also proposed. Production of briquette stoves can ensure that customers do not have to venture elsewhere to find suitable stoves.

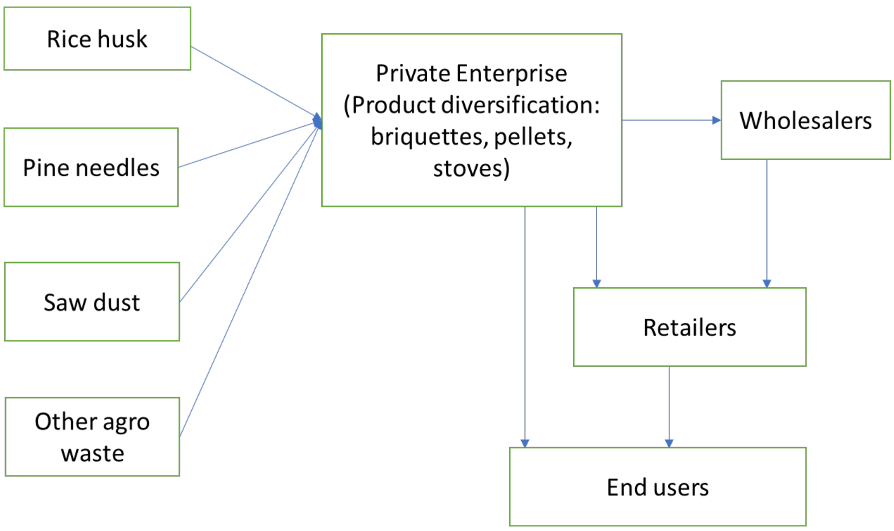

Figure 1: Proposed business model for uncarbonized briquette production

ii. Business Model for Carbonized Briquettes

The current business model comprises of a community- private enterprise model, working in collaboration with grassroot levels (CFUGs) who are responsible for forest management and collection of forest based residues for char production. Char making occurs in the forest itself, which is then transferred to the small community enterprises that are responsible for char storage, grinding, mixing, molding and drying of briquettes, quality assurance and wrapping and packaging. The role of private enterprises is to obtain the legal permits for transportation of char, transportation of raw material as well as end-product, storage of briquettes, advertisement and marketing, sales and distribution to wholesalers and/ or retailers. We propose that this model of business value chain can be replicated further with inclusion of micro finance institutions to support the small community enterprises in obtaining the necessary equipment for production phase, and to scale up production.

The private enterprise can assist high-potential community based enterprises (CBEs) further to access motorized machinery. The role of private enterprise also involves creating sales networks through improved branding and marketing, and help these CBEs form market linkages so that they can be sustainable in the long run.

Marketing and Distribution

Marketing and distribution of biomass briquettes, either carbonized or uncarbonized, needs to be effective. Distribution can be done via four channels:

- Channel 1: Producer →Consumer
- Channel 2: Producer →Retailer→ Consumer
- Channel 3: Producer →Wholesaler →Consumer
- Channel 4: Producer →Wholesaler →Retailer →Consumer

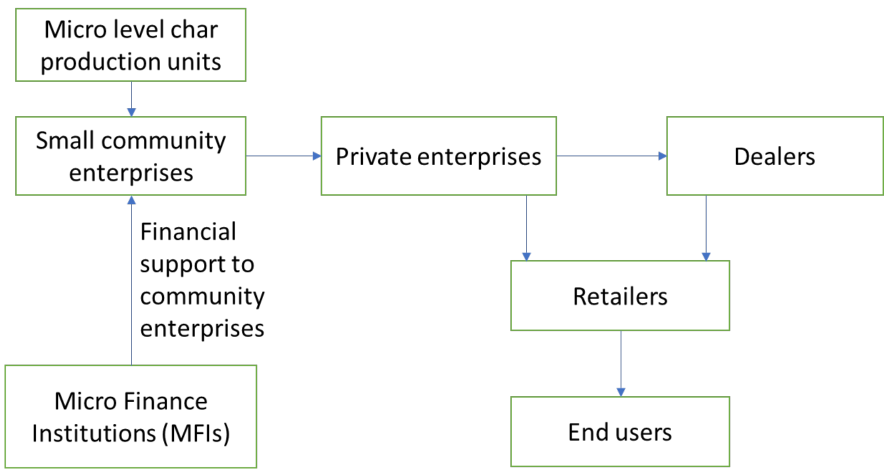

Figure 2: Proposed MFI- based business model for briquette production

Monitoring and Evaluation

Monitoring will be based on the specific outputs of the project. It will cover the intermediate outcomes, immediate outputs, the actions and inputs necessary to achieve the outputs and outcomes. More details about the development of business model and a comprehensive M&E plan is available in Annex 2 of this report.

4. Policy Framework

The regulatory environment can play a key role in both the deployment of and adoption of bio briquettes in Nepal. Many of the business models that are based on new and innovative revenue models or financing schemes are actually driven by incentive schemes initiated and financed by government. Therefore, a favorable policy framework is central to the promotion of sustainable use of bio briquettes in Nepal.

Biomass Energy Strategy, 2017, was formulated to address the need of an appropriate strategy for supporting the environment conservation through the sustainable production of biomass energy for proper and efficient utilization of available biomass resources. This policy framework is prepared in alignment with BEST, with the same vision, mission and long-term goal.

4.1 Vision To promote the biomass energy as reliable, affordable and sustainable energy resource to address the increasing energy demand of Nepal.

4.2 Mission To enhance the living standards of people by modernizing the use of biomass energy through research and studies on biomass energy; through creating public awareness; through market development, technology transfer and capacity development in biomass energy; as well as through efficient use of biomass energy.

4.3 Goal To increase the access to biomass energy and hence contributing to the environment conservation by transforming traditional biomass energy use into modern, sustainable and clean energy.

This policy framework is guided by the target to reach the annual production of 20,000 metric tonnes of pellets, briquettes by enhancing the production capacity by 2030.

4.4 Way Forward

A conducive regulatory framework for promoting sustainable use of biomass briquettes requires further policy support. Government's role in developing an enabling policy environment that promotes the use and fosters market growth of biomass briquette is crucial. A holistic policy framework that addresses strategic issues as well as entire value-chain of bio-briquette sector is desirable.

i. **Ambitious Target:** A target of annual production of 20,000 metric tonnes by 2030 has been set by the Biomass Energy Strategies. However, this target is based only from clean cooking perspectives in households. The realistic target that encompasses use of bio-briquettes in commercial and industrial use is yet to be determined.

ii. **Special Protection for Bio-briquette Industry:** There exists provision to include bio-briquette industry under 'national priority industries' category according to the Industrial Enterprise Act 2017. This provision should be made explicit and the industry needs to be given all privileges accordingly, including priority sector loan. In addition to this, public procurement and institutional use of briquette in government offices and others can also be encouraged by launching special programs in governmental organizations such as army, police, hospitals, prisons, orphanages and old age homes.

iii. **Renewable Portfolio Standards for Selected Industries:** A mandatory renewable energy portfolio for selected types of industries (such as brick, dye, boiler-based industries) that currently use fossil fuel can be made, such that these industries progressively have 5% of input energy mix to be biomass-based by 2025.

iv. **Technology Support:** Support for technology information, problems and assessments for:
   a. production of different types of bio-briquettes/pellets using different raw material
   b. Stove/burners for different types of bio-briquette/pallets
   c. quality assurance and standardization
   d. public-private R&D support, testing and sharing (equipment, raw materials), information sharing
   e. training for operators of technologies on ground (industry and commercial facilities)
   f. technology demonstration and exhibition
   g. enhance links between technical-experts and industry's real-life problems
   h. regular newsletter/info provision

   Creation of bio-briquette Technology Support Facility (BBTSF) under MoEWRI/AEPC with participation of stakeholders could also be done. This facility would then act as the chief technology support and dissemination centre.

v. **Industry Information and Education Campaigns:** Information gaps are still pertinent in the bio-briquette sector, where producers as well as consumers do not have full information about the sector. Therefore, industry information and education campaigns are required to:
   a. acquaint the public with the importance of bio-briquettes as well as, to incentivize industry and to keep industry informed of successful projects and emerging opportunities
   b. maintain a regular and frequent supply of information to ensure that the program has a high profile and to counteract any adverse publicity

   This can be accompanied by demonstration programs that focus on the use, handling and storage of briquettes as well as stoves.

vi. **Tax Reduction and Exemption:** Hydro, solar and bioenergy operators that start generating by mid-April 2024 will receive 100% corporate tax exemption for the first 10 years and 50% for five years after that. This reduction has not been extended in bio briquette sector. Although biomass briquettes are clean and renewable energy sources, carbonized briquettes are charged the same excise duty as charcoal, which is a non-renewable source of energy. The Financial Act of 2016 mentions excise exemption for VAT & Custom Duty in RE equipment as well as materials. These include only 1% customs duty for a range of solar, biogas and wind energy equipment. This should be made more stringent and carbonized briquettes should be exempted from excise duty. Likewise, exemption should also be made for the case of plant and machinery.

vii. **Electricity tariff support:** Agriculture sector is receiving lower tariffs (as low as Rs 5/unit). Bio-briquette sector can be provided similar tariff. Alternatively, capacity cost part of electricity tariff relief could be provided.

viii. **Investment Subsidy:** The Renewable Energy Subsidy Policy 2016 has provision for a maximum subsidy amount of up to 40% of the total investment cost for energy conversion and processing equipment, hardware part of the enterprise and basic infrastructure required for the enterprise but not exceeding Rs. 100,000 for micro enterprises based on renewable energy. Likewise, maximum subsidy amount of up to

30% of the total investment cost for energy conversion and processing equipment, hardware part of the enterprise and basic infrastructure required for the enterprise but not exceeding Rs. 200,000 will be provided for small and medium enterprises based on renewable energy. Smoother co-ordination mechanisms between the respective institutions to make delivery smoother and bio-briquette more exclusive in these provisions should be done.

ix. **Accelerated depreciation:** Provision for accelerated depreciation on the total value of briquetting plant and machine for the first few years should be made. According to the Income Tax Act, accelerated depreciation of 1/3 of the value of the fixed assets investment is present for special industries and co- operatives registered under Co-operative Act 2048. Bio-briquette sector should be recognized as eligible for this accelerated depreciation.

x. **Concession loans:** The Renewable Energy Subsidy policy 2016 has provisions for soft loans and Interest subsidy for renewable energy. For Solar systems, the interest rate on credit will be maximum 5% if Government of Nepal (GoN) provides the fund for the loan and the interest rate on credit will be maximum 9% if banks use their own fund for loan. A 50% subsidy is also provided on bank interest for commercial solar installations. These concessions schemes should be expanded to encompass bio briquette sector as well.

xi. **Financing:** Bio briquetting sector has a high upfront financial investment cost. Financing mechanisms to help investors need to be explored. Easy financing via Central Renewable Energy Fund (CREF) can be an option. The immediate objective of the Central Renewable Energy Fund (CREF) Component is to institute the CREF as the core financial institution responsible for the effective delivery of subsidies and credit support to the renewable energy sector. This could also include seed funding for revolving investment funds, special credit facilities, and supporting lending institutions through both capacity building and underwriting. Apart from this, climate finance mechanisms such as Green Climate Fund (GCF) can also be mobilized. Bio-briquette sector can also be supported a Carbon-offset Project using carbon markets.

xii. **Certification and Standardization:** Industry standards, codes of practice and regulations are required for successful implementation. For this purpose representative groups from industry and both central and local government agencies should be charged with the task of developing standards and regulations compatible with good international and local practice. The Renewable Energy Testing Station (RETS) is well equipped to carry out testing of both the fuels as well as the stoves. Benchmarks are already available for improved cookstoves. Similar benchmarks can be developed for biomass briquettes. Likewise, a certification system can also be developed to certify those enterprises that meet with the quality standards. A technical committee can be constituted to propose standards and certification system to be developed together with AEPC, RETS and Nepalese Bureau of Standards and Metrology (NBSM).

xiii. **Capacity building:** The Energy Sector Plan (1999) has provision for technical Support for biomass energy, solar energy and mini-grid electrification to provide technical support for the development and implementation of renewable energy solutions. Policies for capacity building and community mobilization could help in sustainability of bio briquettes.

xiv. **Program Management and Monitoring:** There is a need to track the progress of the implementation of the renewable energy and energy efficiency program because, as experience builds in the early stages of implementation, it may be necessary to make modifications both at macro and micro levels. There should be provision for continuous monitoring and evaluation of the program to assess whether or not targets are met, and if any changes are required. A strong co-ordination mechanism for strategic and operational support is required.

xv. **Research and Development:** R&D needs to be undertaken in the field of boilers and cookstoves to make them more suitable for the use of briquettes. It has been found that some conventional systems do not work efficiently when using briquettes. Moreover, R&D dedicated towards dryer technology (used in removing moisture from raw materials) is required to improve efficiency and reduce costs. Research also should extend to assessment of quantification of potential raw materials and their quality assessment for briquetting. An information clearing house, such as Bio-Briquette Technology Support Facility as a Special Cell in AEPC, in cooperation with private sector for the entire biomass sector could be formed that identifies the technology needs for the entire sector. Likewise, Masters and PhD projects can also be undertaken with collaborative efforts of government, private sector and educational/ research institutions.

It is important that the government decreases incentives for specific technologies over time, in order to move them towards market competitiveness. On the other hand, it is also very important to provide a stable, predictable and transparent regulatory framework with a clear timeframe for the reduction and phase-out of support schemes so as to continue to attract investments in producing new technologies.

4.5 Implementation/institutional strategy

The institutional strategy must include working in close collaboration with all the relevant stakeholders. The role of AEPC as a facilitator is crucial to the success of implementing this policy framework. An integrated approach that includes BEST Central Co-ordination Committee, AEPC, private enterprises, research institutions, development partners as well as end- users is required to successfully implement the policy framework.

More details on the policy framework for promotion of sustainable use of biomass briquettes is given in Annex 3 of this report.

5. Gender Equality and Social Inclusion

5.1 Women and Energy

The type, quantity and price of energy available have different effects on men and on women because they do different things with it. Men and women have different levels of access to different fuels, and energy shortage affects women more severely than it does men, especially in the context of rural households.

Women are the primary energy producers in rural households, spending a lot of time gathering locally sourced biomass to fulfil their daily energy needs. This results in severe opportunity costs that prevent rural women from participating in other tasks, such as education. Studies show that when women are overburdened with lack of access to energy, they have increased tendencies to keep their daughters at home to assist with household chores. This further limit opportunity for girls to move forward through education, and increasing the likelihood that their families will remain in poverty. Rural households are thus stuck in a vicious cycle of lack of energy security and poverty.

5.2 Gender Mainstreaming in Renewable Energy

Gender mainstreaming is defined as "including gender as one of basic underlying factors that is taken into account in planning processes, i.e. recognizing gender differences in energy needs, use and priorities; developing programs responding specially to these needs; and incorporating meaningful roles for women in planning and implementing programs".

Some projects ensure women participation in projects by doing positive discrimination in favor of women enabling them to take up management and decision- making positions. Energy related projects including improved cookstoves, solar cookers, solar housing systems as well as biogas are often considered to be positively biased towards women. Alternatively, encouraging women entrepreneurship in rural renewable energy is another means of gender mainstreaming in these projects.

Gender mainstreaming has been prioritized in several renewable projects across the world, including Bangladesh, India, Pakistan, Malawi, Ethiopia, Zimbabwe, Nepal, among others.

5.3 Gender and Biomass Briquettes

Studies have shown that biomass briquetting can indirectly help for woman empowerment and ensure their strong participation in the development of national economy by reduction of 70% to 80% fuel collection time. In Nepal's case, bio-briquetting has contributed to women's income. Hundreds of women have been trained on bio-briquette entrepreneurship, and several women's groups are working in making bio-briquettes in multiple districts across Nepal. This has resulted in providing direct employment to about 400 people, of which 25% are women. Gender sensitive collaborative approaches by private enterprises working with community based groups have been widely successful, and are being replicated by many other enterprises as well.

Government policies that are focused on rural energy in Nepal are much more gender sensitive, and recognize the need for bridging gender disparities and greater social inclusion. Many of the recent rural energy programs are guided by AEPC's Gender Equality and Social Inclusion (GESI) Mainstreaming plan, which paves way for supporting and benefitting women in rural communities.

More details about the gender mainstreaming in biomass briquettes policy in Nepal is given Annex 4 of this report.

6. Stakeholder Consultation and Dissemination Workshop Reports

Two stakeholder workshops were organized by the Asian Institute of Technology (AIT) as a part of the CTCN project. The first one was a two day stakeholder consultation workshop in January 2018. The overall objective of the consultation workshop was to gain an overview of the key issues and challenges in bio briquette sector, and how to address them.

The first day of the workshop focused on technology framework and business model for briquette industries. Key issues in Nepal faced by bio-briquette enterprises include inadequate knowledge of value of biomass, lack of value addition to biomass, inability to make efficient use of biomass and lack of adequate facts on accessibility and characteristics of biomass in

Nepal. Affordability of technologies, product diversification, drying of products and end user technologies were also identified as prominent issues. The business model session focused on possible business models for Nepal, including cash at gate policy, product diversification, 3rd party financing and build- operate- transfer models. Some of the chief barriers in operationalizing these models were identified as lack of investment support, market segmentation and consumer identification, marketing mechanisms and networking, demand creation and stove designs. SWOT analysis of the proposed business models were also carried out.

The second day agenda was policy framework, where pertinent gaps in Nepalese policy scenario were identified and measures to bridge these gaps discussed. Some of the gaps include: Revenue rates for briquettes not fixed, lack of consumer awareness, high upfront costs, market barriers, technology support, tax and tariff reform and institutional development, quality control and standards, low- interest loans, grants and other financing mechanisms for briquette industries, investment support via low- interest loans, grants or subsidies for combustion (e.g. pellet industries). Measures to bridge these gaps include creation of an enabling environment, special protection for industry, fiscal incentives for market barriers, institutional development and risk management.

The AIT team also went for site visit to Centre for Energy and Environment- Nepal (CEE-N), Organic World Pvt. Ltd. And Himalayan Naturals Pvt. Ltd. to understand the issues faced in manufacturing process.

This stakeholder consultation workshop gave way to important aspects to be included for the policy framework and constructed the way forward for training program that would be held later in June 2018.

The second workshop was a two and half day stakeholder dissemination workshop and training, held in June 2018. The overall objective of this dissemination workshop cum training was to disseminate the key findings on business model and policy framework in bio briquette sector to the relevant stakeholders, including decision makers, and to train the stakeholders on how to address the key technological issues prevalent in the sector in Nepal.

The first day of the workshop focused on business model and policy framework for briquette industries. The business model session focused on appropriate business models for Nepal. Uncarbonized briquette enterprises should emphasize on product diversification, and cash-at-gate policy to ensure raw material supply security. For carbonized briquette enterprises, third party financing was proposed. Way forward session shed light on how the government could intervene in the business model and facilitate demand creation and supply security. The policy framework session focused on several policy recommendations that could be operationalized in Nepal including financing, tax exemptions, accelerated depreciation, prioritizing bio briquette sector, focusing on research and development, creating consumer awareness and setting national standards and certification schemes. The second day was a training on how to address technology issues faced in Nepal, including selection of raw materials, binder choice, use of technology, etc.

The third day agenda was high level stakeholder dissemination, where the business model and policy framework were disseminated to the high level stakeholders. Measures on how the government could facilitate the operationalization of business model were decided. This requires a holistic approach that encompasses the entire supply chain, from assessment of biomass potential raw material to demand creation. On the policy front, there was general agreement that bio briquette sector should be a national priority sector and receive its full benefits. Policies need to be revised to recognize 'briquette' and 'pellets' explicitly. It was also decided that accelerated depreciation and decreased electricity tariffs for bio briquettes would be immediately looked into.

The stakeholder dissemination workshop and training gave way to important aspects to be included for the policy framework and how it could help in operationalization of business model.

Detailed reports about the stakeholder consultation and dissemination and training are provided in Annex 5 and 6, respectively.

<u>ANNEX 1</u>

Review of Biomass Briquetting and Status of Biomass Briquetting Industry in Nepal

A Report Submitted to

Climate Technology Centre and Network (CTCN)

An Output of the Project

Promotion of Sustainable Use of Biomass Briquettes in Nepal

Prepared by

Department of Energy, Environment and Climate Change
Asian Institute of Technology (AIT)
Pathumthani 12120, Thailand.
September 2018

Executive Summary

This report is an output of the project "Promotion of Sustainable Use of Biomass Briquettes in Nepal". The project is funded by the Climate Technology Centre and Network (CTCN), supported by Ministry of Forests and Environment (MoFE)/Ministry of Energy, Water Resources and Irrigation (MoEWRI), Nepal, and Alternative Energy Promotion Centre (AEPC), Nepal, and carried out by Asian Institute of Technology (AIT), Thailand.

Biomass briquetting technology enables efficient utilization of agricultural, wood and forest residues for heat and electricity generation. Low loose bulk density, high moisture content, irregular shape and size, low heating value and high ash content are major drawbacks that results difficulties in biomass residues collection, storage, and utilization which can be improved by briquetting technology. Initially, the primary expectation is to expend less energy for producing biomass briquettes of higher energy yield and less carbon footprint. The utmost objective is to develop proper management strategy including innovative policies and financial mechanisms for enhancing the adoption, encouraging local entrepreneurs/investors, and bring socio-economic and environmental benefits.

This report has presented a comprehensive review on biomass briquetting that includes globally available biomass briquetting technologies, basics of biomass briquettes formation, and influencing technical parameters such as particle size, moisture content, temperature, compaction pressure and binding materials. Also reviewed the present status of biomass briquetting technology and briquetting industry, and types of biomass resources available in Nepal.

Biomass resources are the primary source of energy supply in Nepal about 81.5%, and 77.6% of primary consumption is met by traditional biomass fuels. Also 74.1% households directly depend on traditional biomass for cooking. Nepal Government has emphasized to promote bio-briquette production and utilization, and dissemination of improved cookstoves (ICSs) in the National Energy Strategy 2013, Biomass Energy Strategy 2017 and 14^{th} Three-Year Plan 2016-2019. Since 1982, biomass briquetting in Nepal has been developed significantly and drawn the attention of entrepreneurs and investors that resulted in the growth of 26 bio-briquette industries.

Promotion of biomass briquetting in Nepal has the potential to enhance energy security, reduce wood fuel consumption, create job opportunities, tackle indoor air pollution and health hazards, prevent forest fires, improve agricultural waste management, and empowers women. Nepal has an abundant resource of biomass residues for bio-briquette production which can be classified into five different groups such as agricultural residues, forest residues, wastes from wood-based industries, herb processing industries, and municipal solid wastes. It was identified that there are several issues that could be addressed for future development and enhancement of the briquetting industry in Nepal which are subdivided into three categories such as feedstock related issues, technical issues, and social, economic and other issues.

It was found that biomass briquetting industry currently focused on briquette production using charred biomass from only a few types of biomass residues. Lack of information on biomass resources availability, and data on cost and energy related to the collection and transportation of residues to the processing plant are the major drawbacks identified. The commencement of region-specific biomass resource availability assessment program could be

a potential solution which will identify, estimate and assess the potential of available biomass resources for briquetting in each specific region. Involving communities in biomass residue collection, briquette production and supplying briquettes to the market could be the best possible solution for socio-economic development of different regions. The adoption of small-scale portable biomass briquetting systems would be a possible solution for installing community-based decentralized bio-briquette production facilities.

The adoption of retort kiln or torrefaction pretreatment for charred biomass production, hydraulic or piston-press system for briquette production, and waste heat utilization, integrating biomass gasification system with briquetting system and hybrid solar-biomass dryer for drying biomass residues could be the prospective solutions to resolve major technical issues. Biomass co-denisification could be an effective way for optimizing biomass resources utilization and eliminating the dependency on inorganic and imported binding materials. This requires the identification of optimal conditions for briquette production such as particle size, mixing ratio, compaction pressure and temperature using different biomass types. A holistic approach could be adopted for designing and developing of user-friendly ICSs for efficient utilization of bio-briquettes.

Biomass pellets production could act as an accelerator for developing a sustainable competitive market of densified biomass solid fuels in Nepal. Biomass pellet markets in Asia besides Europe are rapidly picking up for heat and electricity generation. Hybrid densification system which can produce both briquettes and pellets just by changing extrusion mold or small-scale mobile pelleting-press systems could be adopted for promoting pellet production besides bio-briquette production.

The government could take initiatives for creating public awareness and increasing acceptability, knowledge and technology transfer, and expertise enhancement by organizing workshops, capacity building, and hands-on training programs. Mass media could play a vital role in disseminating economic and environmental benefits of using bio-briquettes for heat and electricity generation, and also for cooking and space heating. Research and development studies could identify and estimate energy demands and prospective technological solutions in which bio-briquettes could be used efficiently to meet the demand.

The Government also could introduce innovative policies and financial mechanisms such as imposing energy tax, renewable obligation scheme, feed-in-tariff, renewable heat incentives, and tax exemption could be the effective measures for accelerating the growth of biomass briquetting industry in Nepal. The development of biomass value chain integrating and creating an interlinkages between research and development institutes, farmers and agro-forest industries, enterprises, distributors, households, and institutions and energy-intensive industries could be helpful for the policy makers for developing sustainable biomass management strategy. Compulsory obligations to adopt preventive measures for ensuring safety from self-heating, off-gassing, dust, fire, and explosions during biomass collection, processing and storage could create a favorable environment for the personnel involved in biomass briquetting industry in Nepal.

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1. Introduction

1.1 Background

Life is a process of continual exchange and transformation of energy. The milestones of human civilization have been largely driven through the use of ever-advancing energy systems that have ameliorated human abilities and ingeniousness. Thus, energy access is essential for the sustenance of human life and for the overall development within the spheres of society, economics and environment.

However, global warming, rising energy demand and depletion of fossil fuels have led to the worldwide research and development of alternative energy such as solar energy, wind energy, biomass, geothermal energy and so on. Countries around the world, both developed and developing, are aiming to mitigate carbon emissions as well as their dependence on fossil fuels in the fight against climate change and for improving energy security. One interesting renewable and carbon-neutral energy source is biomass, which are the organic matter derived from plant material and animal waste.

In addition to the aforementioned global issues, Nepal faces some unique energy challenges. Nepal, a central Himalayan country in South Asia, has a population of around 28.9 million with around 81% living in rural regions. The GDP and GDP per capita of US$ 21.1 million and US$ 729 respectively (World Bank, 2017). The country has no known fossil fuel reserves and being landlocked between China and India, depends on these countries for the transport of coal and oil imports. This makes fossil fuels more expensive on top of the already rising prices. Along with this, frequent strikes and geopolitical tensions further drive up prices and cut down the reliability of fossil fuel supply. In 2006, 53 % of Nepal's foreign currency was spent on for petroleum imports- double of that in 2001. Along with this, Nepal imported about 293,000 tons of coal in 2008-2009. Moreover, Nepal faces immense increases in electricity demand every year while the production and transmission capacities are limited. This has forced the Government of Nepal to import significant amounts of electricity from India.

The landscape of Nepal can be broad subdivided into Mountain region in the north, Hill region covering the central landmass and Terai (planes) in the south. The land-use map is shown in Fig. 1. As of 2011-2012, around 20% of the total land area was covered in cultivated land, grassland occupied about 12% and others (ice/snow, waterbodies, rocky slopes etc.) covered around 21%. About 39.6% of the total land area in Nepal was covered by forests and shrubs (ERMC, 2013). Hence, the country heavily depends on fuelwood/firewood for supplying majority of their energy needs. Moreover, this has resulted in adverse effects on the following- (i) Heath: Diseases and deaths related to indoor air pollution and increased workload for collection of fuelwood; (ii) Environment: Increased rates of deforestation which results in soil erosion, landslides and higher net CO2 emissions and (iii) Economy: Increasing price of fuelwood. Moreover, with about 1 TOE for every $1,000 of GDP, Nepal has the lowest energy intensity among the South Asian countries (IEA, 2012). Thus, there is a huge potential for improvement in the areas of energy efficiency, energy security and sustainability in Nepal.

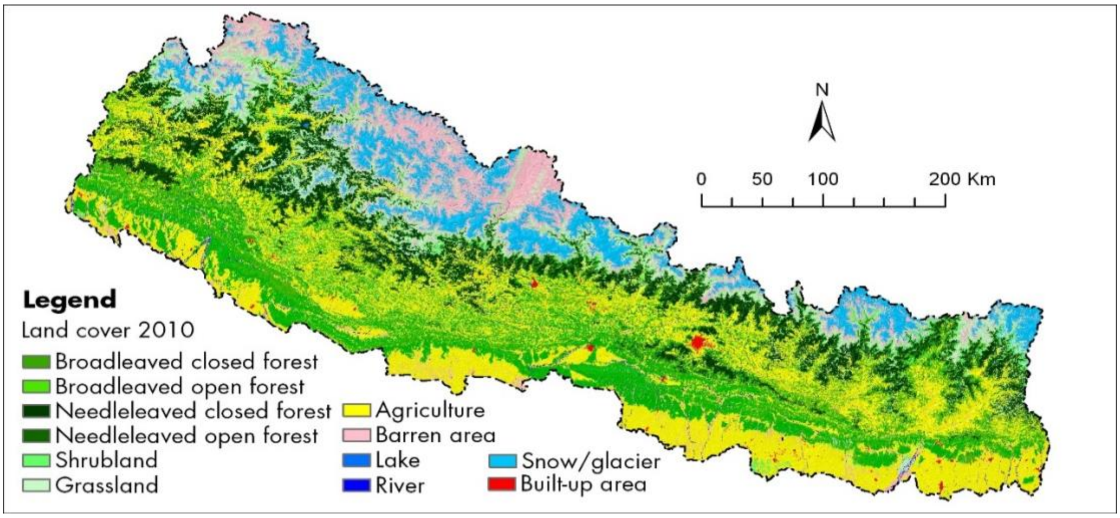

Fig. 1. Land-use map of Nepal (Uddin et al, 2015)

1.2 Energy Scenario in Nepal

According to IEA (2016), Nepal had a total primary energy supply (TPES) of 11.69 Mtoe in 2015. Most of the primary energy in Nepal is derived from biofuels (fuelwood, agricultural residue and animal waste), followed by oil products and coal as shown in Fig. 2(a). Around 30% of the electricity is imported, while the rest is almost completely generated using hydropower. Majority of the energy is consumed in the residential sector (for heating, cooking etc.), followed by the transport, industrial and commercial sectors as shown in Fig. 2(b). The energy consumption in the industrial sector is highest in manufacturing (89.6%), followed by agro-based industries (6.6%), while the rest is used in construction, mineral-based and power-based industries. In this sector, most of the energy is used in process heating (64%), power motives (22%) and boilers (9%); while lighting, process cooling, and others make up the remainder. The energy is consumed primarily during brick, lime and cement production as well as in steel processing. As for the commercial segment, hotels and restaurants consume a significant share of the energy, at around 55.6%, followed by barracks/canteens (17.2%) and service sector (5.2%). The rest of the commercial activities make up around 21.9% of the consumption.

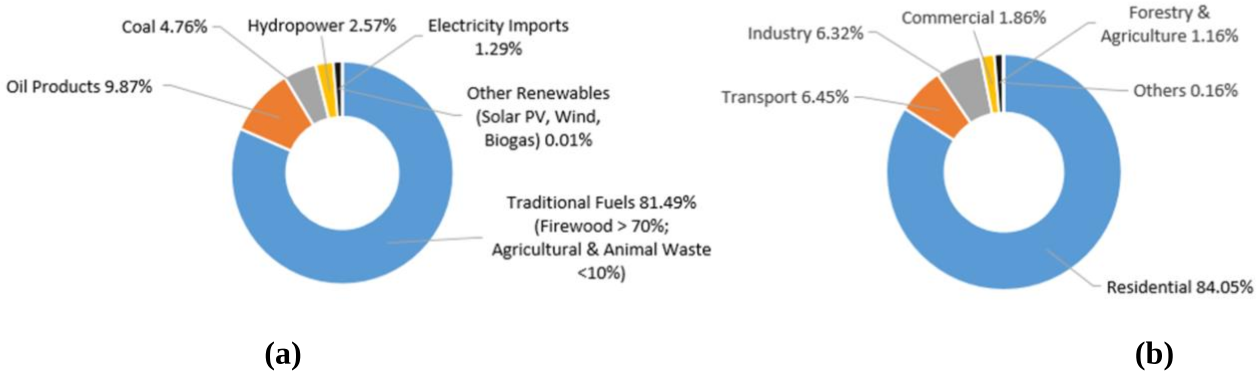

Fig. 2. (a) Nepal's total primary energy supply by fuel type 2015; (b) Nepal's total final energy consumption by sector 2015 (IEA, 2016)

According to WECS (2014), the majority of Nepal's energy demand in 2011 was covered by fuelwood, which is used primarily in the residential sector (94.7%) and partly in the commercial (2.7%) and industrial (2.6%) sectors. The other biofuels used to an extent (exclusively in the residential sector) are animal waste (dry dung) and agricultural residue.

Oil products make up the second largest energy source, which is used mostly in the transport sector (57.9%), followed by the residential (15.3%), industrial (10.5%), agricultural (9%) and commercial (7.2%) sectors. The other imported fossil fuel, coal, is used mainly in the industial sector (92.8%), while the rest is used in the commercial sector. Grid electricity is used in almost all the sectors, with the highest consumption in residential (45.7%), industrial (38.3%) and commercial (12.2%) sectors.

The energy demand for the year 2011 and the estimated energy demands for 2016 and 2021 are tabulted in Table 1. The total energy demand is expected to rise by around 8.57% within 2011-2016, with an annual increase of 1.77%. In this period, the demand on almost all the types of fuels are estimated to increase by around 8-9%, with the exception of grid electricity (6.6%). Whereas, between 2016 and 2021, the energy demand is predicted to increase by 9.81%, at 1.96% per year. Similarly, the demand on most types of the fuel is expected to grow by about 9-10% within this period.

Table 1. Estimated Future Energy Demand of Nepal (ERMC, 2013)

Fuel Type	**Energy Demand by Year (in Million GJ)**		
	2011	**2016***	**2021***
Fuelwood/Firewood	267.4	291.6	319.8
Animal Waste	19.1	20.8	22.9
Agricultural Residue	13.2	14.4	15.8
Oil Products	46.2	50	55.2
Coal	14.8	16.2	17.7
Grid Electricity	10.6	11.3	12.5
Modern Biomass	4.6	5	5.5
Others	0.4	0.4	0.5
Total	376.3	409.7	449.9

*Future Estimates

1.3 Renewable Energy in Nepal- Status and Potential

In addition to hydropower, renewable energy in Nepal is a sector that is rapidly developing in Nepal. While Nepal mainly relies on hydroelectricity for its energy needs, solar, wind and biomass power is being seen as an important supplement to solve its energy crisis, detailed as follows:

(i) Solar Energy: Nepal has high potential for at least four types of solar energy technology- grid-connected PV, solar water heaters, solar lanterns and solar home systems. Nepal experiences solar insolation between 3.6 to 6.2 kWh/m^2/day with around 300 days of sun a year, making it ideal for solar energy systems. The country has a solar PV generation potential of 2,100 MW. (AEPC, 2008)

As of August 2016, the total installed capacity of solar was around 18.4 MW, including 606,730 solar home systems (14.6 MW), 1592 institutional solar photovoltaic systems (2.4 MW) and 52,733 small solar home systems (537 kW) with an additional 148,800 systems are in the final stage of installation. It is worthy of note that 225,000 solar home systems are used across 2600 Nepalese villages with an output of 5.36 MW, and 943 medium-size solar PV units provide 1.2 MW of electricity for the communications sector. 155,000 units of solar lanterns (popularly known as *solar tuki*) were in use as of 2010 comprising 737 kWp of capacity. Other installations include photovoltaic pumping systems, solar street lights etc. Nepal Electricity Authority (NEA) installed a 100kW solar plant as a pilot project; the World Bank is supporting 25MW solar on grid development; while ADB is also supporting utility scale solar PV development for grid connection. There are solar mini grids being installed with initiative from the private sector using a special purpose vehicle (SPV) model in Khotang and Okhaldunga, eastern Nepal (Rai, 2016; Singh, 2016).

(ii) Wind Energy: According to the Renewable Energy and Energy Efficiency Partnership (2012), Nepal has a considerable potential for wind energy with at least 200 to 300 MW of possible capacity. The best sites were reported to be in the Mustang district (though many of these sites are remote from the nearest roads and transmission networks). A second, more thorough assessment looked at wind resources in the Annapurna Conservation Area and reported at least 716 MW of capacity within 10 kilometres of the NEA grid. A third study done jointly by the Department of Geology at Tribhuvan University and the Ministry of Physical Planning and Works found at least, 3,000 MW of technical wind potential even if 10% of total potential area of wind power is considered. From which, 448 MW of potential that could be quickly and commercially exploited. (AEPC, 2008)

The government is supporting promotion of wind and wind-solar hybrid mini-grid to support un-electrified isolated rural communities. The cumulative installed capacity of wind turbines in Nepal is 113.6 kW as of August 2016.This includes 65kW installed by AEPC and supported by private companies, 45.1kW by private companies, and 3.5kW by Practical Action and installed by local company. (Rai, 2016)

(iii) Biomass: Biomass is the most significant primary energy source in Nepal till date. Usage of biomass for energy comprises of traditional sources especially wood, and to some extent agricultural residues and animal dung. Despite the share of traditional biomass in the total primary energy mix reducing from 90.2% in 1995-96 to 80% in 2013-14, it still remains very high (WECS, 2014). The field of modern biomass includes improved cookstoves, biogas plants, and briquettes and pellets.

Fuelwood is derived from community forests, outer forest lands, shrub lands, fruit trees etc. As of 2013, the gross annual supply of fuelwood is around 33.1 million tons, of which around 56% is obtained in a sustainable basis. The gross annual supply of sustainable fuelwood is estimated to be around 18.6 million tons, out of which around 70% is derived from reachable lands. Within the reachable supply, 6.5 million tons is from community forests and a similar amount is obtained from the reachable areas of outer forest lands. Similarly the annual gross supply of unsustainable fuelwood from outer forests is around 14.5 million tons, wherein 70% is obtained from reachable areas (ERMC, 2013).

The total sustainable fuelwood production from fruit trees is around 184,000 tons (energy equivalent of 3.08 million GJ). Mango contributes the highest fuelwood at around 61.7% of the total, followed by citrus fruits (17.2%), winter fruits (10.3%), litchi (3.7%), jackfruit (3.6%) and guava (3.5%) (ERMC, 2013).

In areas where wood supply is limited, the field and processing residues of crops (in dry solid form) are utilized. Within 2011-2012, the production potential of agricultural residues is around 23 million tons. The production potential of agricultural residues is highest in the Terai region at about 60% of the total. This is followed by Hills (34.9%) and Mountain region (5.1%). Rice paddy is the highest contributor with around 10 million tons (around 44.8% of the total). This is followed by maize (25%) and the rest consists of wheat, sugarcane, grain, oil and millets (30.2%).

Livestock form a very essential part of the Nepali farming system, with at least 1.2 million households owning cattle and buffalo. The annual animal waste production potential is around 15 million tons, with 50.2% in the Hill region, followed by Terai (39.6%) and Mountain (10.2%). The technical biogas potential is at least one million household-size plants, with 57% located in the Terai plains, 37% in the hills and 6% in remote hills (ERMC, 2013; Multiscope Consultancy, 2015).

As of 2017, modern biomass installations include 1.3 million improved cooking stoves; 380,000 biogas plants; and 7,000 metric tonnes of briquettes and pellet per year (MoPE, 2017). The targets specified by MoPE (2017) includes 3 million improved cookstoves for household cooking, 600,000 domestic biogas plants using cattle dung and to reach annual production of 20,000 metric tonnes of pellets and briquettes by enhancing the production capacity.

1.4 Energy Strategies and Policy Framework

In response to the energy dilemma, the Nepalese government has put forward several strategies and policies. Some of the major initiatives aiming for energy efficiency, energy security and sustainability in Nepal are listed as follows:

(I) Biomass Energy Strategy (2017)

In order to address the practical utilization of the biomass resources in Nepal, the Ministry of Population and Environment (MoPE, 2017) developed the Biomass Energy Strategy. The aim of this initiative is to promote the biomass energy (e.g. biogas, ICS, gasifier, briquettes/pellets, cogeneration, waste to energy, etc.) in a reliable and affordable way. This is to address the increasing energy demand of Nepal and contribute to environment conservation by transforming traditional biomass energy use into modern, sustainable and clean energy by target year 2030.

The main objectives of this plan are as follows:

i. To contribute to energy supply and energy security by generating energy through management of agriculture forest residues and organic wastes from municipal urban and industrial areas.
ii. To support the employment and income generation through the entrepreneurship development in biomass energy; and to reduce the existing dependency on imported energy through effective, efficient production and utilization of biomass energy

In order to achieve the aforementioned objectives, the following strategies are to be adopted:

i. Increase production of sustainable biomass energy by utilizing agriculture, forest residues and organic wastes.
ii. Contribute to increased access to clean cooking technologies to all Nepalese households through the means of modern biomass energy by.
iii. Increase effectiveness and efficiency in the utilization and production of biomass energy.
iv. Partially substitute the utilization of diesel and petrol by bio-diesel and bio-ethanol.

(II) 14th Three-Year Plan (Fiscal Year 2016/17-2018/19)

The National Planning Commission of Nepal laid down several targets with regards to energy and environment on their 14th Three-Year Plan. The vision and aim within this plan are sustainable economic development through use of renewable energy and to reduce dependency on conventional and petroleum energy.

The action plan includes the following:

1. To promote and expand the use of biogas, improved cook-stoves, gasifier, bio-briquette and other cost-effective biomass energy technologies to reduce the use of wood.
2. To create an investment environment for banks and cooperatives to invest in RE.
3. To use Solar Energy in residential areas and public buildings in cities to minimize the energy crisis.
4. To formulate a policy to produce bio-fuel inside the country as a partial alternative to petroleum products.
5. To develop and expand the use of wind and solar energy for electricity generation and also use wind and solar pumps for irrigation in the Terai.
6. To promote, develop and expand the use of renewable energy technologies such as micro and small hydropower, solar energy, bio mass and wind energy.
7. To promote and expand necessary technologies and processes to produce energy from waste.

(III) Paris Climate Agreement (2015)

Nepal ratified the Paris Climate Agreement in 2015 and submitted its Nationally Determined Contribution (NDC) in October 2016.

Some of the main targets mentioned in the NDC are as follows:

1. To achieve an 80% share of electricity from renewable sources in the energy mix by 2050
2. To reduce dependency on fossil fuels by 50%
3. To increase the share of electric vehicles to 20% by 2020
4. To maintain 40% of the total area of the country under forest cover
5. To reduce about 14 million tonnes of CO2e by 2020 with a sub-national project on REDD+
6. To deploy renewable systems under the National Rural Renewable Energy Program (NRREP)
7. To build an electrical (hydro-powered) rail network by 2040.

(IV) National Energy Strategy (2013)

The Water and Energy Commission Secretariat (WECS) of Nepal formulated the National Energy Strategy in 2013.

The major strategic objectives of this initiative are as follows:

1. Ensuring sustainability in the consumption of biomass energy resources
2. Development of hydropower resources as the lead energy resources
3. Reduction in dependency on imported fossil fuels
4. Providing an adequate supply of energy at reasonable and affordable price
5. Promoting renewable energy technologies and energy efficiency
6. Minimize detrimental environmental effects resulting from energy supply and use

(V) Nepal Energy Efficiency Programme (NEEP, 2009)

NEEP was agreed upon in 2009 between the governments of Nepal and Germany. The aim of this programme was to improve framework conditions for the planning and implementation of energy efficiency measures in Nepal.

The three main components of this initiative are as follows:

i. Energy efficiency in markets (industries and public infrastructure),
ii. Clean cooking (with a focus on improved cooking stoves)
iii. Policy advice on energy efficiency

1.5 Biomass Briquetting- A Solution to Nepal's Energy Woes

As mentioned earlier, heavy dependence on traditional sources of energy such as fuelwood, leads to soil erosion, landslides, loss of flora and fauna, climate change and global warming, while traditional briquettes are polluting and inefficient. Instead, the abundantly available biomass residues and wastes can be effectively utilized by adopting efficient processes such as briquetting. With this technology almost all kinds of biomass residue can be upgraded by densifying loose biomass materials to produce a compact product of different sizes with the application of temperature and pressure. The process of briquetting is applied basically to improve fuel characteristics, handling and transportation, storage as well as combustion properties.

In light of these issues, biomass briquetting has been included in various energy policies and strategies, described as follows:

Biomass Energy Strategy (2017):

- To encourage private sector for production and marketing of improved and modern biomass energy technologies such as briquettes/pellets, improved cookstoves (ICS), biogas, gasifier, cogeneration, waste to energy, etc.
- To provide technical and financial assistance for research and study on modern efficient, and affordable biomass energy technologies (briquettes, pellets, industrial boiler, biogas, ICS, gasifier, cogeneration, waste to energy etc.) for determining their feasibility, goals, quality control, emission standards, technology development and improvements.
- Provide financial assistance to briquette, pellet, biogas, metallic stoves, cogeneration etc. up to 2030.
- To reach the annual production of 20,000 metric tonnes of briquette and pellets by enhancing the production capacity in order to contribute towards making indoor air pollution free Nepal by 2022 and ensuring availability of modern clean energy in all the households 2030.

14th Three Year Plan (2016-2019):

- To promote and expand the use of biogas, improved cook-stoves, gasifier, bio-briquette and other cost-effective biomass energy technologies to reduce the use of wood.
- To extensively promote and expand biomass briquette, biogas and improved cook stoves
- To formulate and implement policies regarding biomass briquette production and distribution and biomass energy generation.

Forest Policy (2015):

Financial and technical support to the users of alternative energy including biogas, biomass briquettes, improved cooking stoves, biofuel etc.

National Energy Strategy (2013):

- Promote emerging biomass energy technologies such as briquettes, gasifiers, cogeneration and liquid biofuels.
- Developing fuel efficient stoves and briquettes by 2015.
- Replace 50% of the traditional cooking stoves by ICS and continuously study, develop and disseminate emerging biomass energy technologies such as briquettes, gasifiers, co-generation and liquid bio-fuels within 2015-2030.
- Give legal recognition of energy source to the residues and by-products generated in forest, agriculture and livestock sectors, promote the use of residues and by-products at local level through improved/modern biomass energy technology such as briquette, charcoal, biogas, etc.

Rural Energy Policy (2006):

- Technology for production of briquette, bio-fuel, biomass gasification, etc., based on the availability of fuel-wood, paddy husk, sawdust and other agricultural residues will be developed and disseminated by identify in suitable location.
- Emphasis shall be given on research activity to identify raw material for the production of the briquette and reduce the cost of its production.
- Activities related to awareness creation in the use of briquette; bio-fuel, biomass gasification, etc. will be conducted by encouraging the use of local skill and resource.
- Activities related to awareness creation in the use of briquette; bio-fuel, biomass gasification, etc. will be conducted by encouraging the use of local skill and resource.
- Subsidies for the development and promotion of briquette, bio-fuel, biomass gasification etc. will be encouraged.

In search for alternatives to traditional fuels, the private sector introduced charred rice briquettes in 1982 and screw extruder rice husk in 1987, but these industries did not survive long due to various techno-economic issue as well as lack of supporting policies and initiatives. However, after about three decades, Nepal is experiencing a significant reform in the briquetting scenario following the establishment of research and promotional institutions, introduction of favourable policies and programs (CEEN, 2012; Singh et al, 2010a). Since 2010, the briquetting industries are slowly on the rise again. In the year 2013 alone, three piston press briquetting industries approached Centre for Energy and Environment Nepal (CEEN) to have their products analysed.

2. Biomass Briquetting Processes and Technologies

2.1 Overview

Biomass, in its loose original form, is difficult to successfully use as a fuel in large-scale applications because it is bulky, wet, and dispersed, translating to low density, low calorific value per unit volume and high moisture content (Kaur et al, 2017). Biomass densification represents technologies for converting loose plant residues, crop residues, sawdust, wood shavings etc. into compact fuel (around 7–10 times its original bulk density) (UNEP, 2013). The compaction is achieved through the application of pressure on the loose biomass material which gives rise to the following: (i) attraction forces between solid particles (such as van der Waal's and electrostatic forces); (ii) interfacial forces and capillary pressure in movable liquid surfaces; (iii) adhesion and cohesion forces at not freely movable binder bridges; (iv) solid bridges; and (v) mechanical interlocking or form-closed bonds between the particles in contact (Moral and Khan, 2004; Moral and Rahman, 2001; Rahman et al., 2003). This process improves the fuel characteristics such as energy density and combustion properties as well handling characteristics of the materials (such as shape and size) for transport, storage etc. During densification, about 40% of the energy is required for compressing the material and the remaining for overcoming friction during compression.

Conventional processes for biomass densification can be classified into baling, pelletization, and briquetting, which are carried out using a bailer, pelletizer, screw press, piston or a roller press. Bales are a traditional method of densification commonly used to harvest crops. A bale is formed using farm machinery (called a baler) that compresses the chop. The shape of the bales can be square, rectangular or round, depending on the type of baler used. Pelletization and briquetting are the most common processes used for biomass densification for solid fuel applications. Biomass briquetting (or bio briquetting) produces briquettes which are cylindrical or rectangular and with/without an inner hole. Whereas, pelletization produces pellets which are cylindrical and are smaller in diameter than briquettes.

A biomass briquette (or bio-briquette) is a compressed block of combustible and locally available biomass material such as agricultural residues (e.g. sugarcane bagasse, rice husk, coffee husk etc.), animal waste, forest residues (tree leaves, lumber waste etc.), charcoal, sawdust, wood chips, plastic or paper etc. (Grover and Mishra, 1996; Koopmans and Koppejan, 1997; Rousseta et al., 2011; Tyagi, 1990; Yaman et al, 2000). For making briquettes, Thailand utilizes maize cobs (Wilaipon, 2007), agricultural waste like rice straw and rice bran in China (Chou et al., 2009), whereas in Brazil coffee husk is preferred (Felfli et al., 2010). They can be utilized in various sectors including generating heat within the residential sector, small-scale commercial or industrial use to even generating power for larger industries (Kaliyan and Morey, 2008). Biomass briquettes have been found to have superior fuel characteristics and combustion in loose biomass, and can be a sustainable and viable replacement for fuels such as coal, furnace oil, diesel, kerosene, lignite and fuelwood (Sharma et al, 2015). Briquetting technology based on the use of waste biomass has been practiced successfully in many developing countries in Asia and Africa including Japan, India, Cambodia, Uganda, Tanzania, Zambia and Kenya as well as developed countries such as U.S.A. Some sample of biomass briquettes are presented in Fig. 3.

Biomass briquettes could be used in various applications, including the following:

- Cooking, space heating and water heating in households and commercial institutions
- Process heat for industries including tobacco, tea, poultry etc.
- Firing ceramics and clay wares such as improved cookstoves, pottery, bricks etc.
- Fuel for gasifiers for electricity generation
- Powering boilers for steam generation
- Pellets made from suitable agricultural waste can be used as animal feed

Moreover, biomass briquettes could also be co-fired with coal. Co-firing involves combustion of two different types of materials, typically a carbon emissions-intensive substance such as coal and a material with lesser CO_2 emissions such as biomass. This process is carried out mainly to reduce total CO_2 emissions while meeting the heat requirements of the boiler. It has been found to be a very cost-effective means of using biomass for energy. For proper co-firing to take place a few modifications to the current characteristics of power plants would be required, thus a moderate investment is needed. (Basu et al, 2011).

Fig. 3. Samples of biomass briquettes from around the world (*Energypedia, 2017*)

The comparison of characteristics of biomass briquettes and conventional fuels are presented in Table 2. There are several benefits of using biomass briquettes, which includes (but is not limited to) the following:

1. Reduction in the health risks such as respiratory and eye diseases associated with indoor air pollution.
2. Usually cheaper than coal, diesel, kerosene and wood etc. Biomass briquettes provide higher calorific value per unit cost than coal when used for firing industrial boilers.
3. Raw materials for briquetting are readily available and briquetting machinery are of relatively low cost
4. This process help creates a variety of jobs including collection of raw materials, plant staff, and distribution and so on. Income generation through raw material collection can be greatly beneficial for the unemployed and low-income section.
5. Briquetting can help prevent forest fires (which are not uncommon during the dry season) through the utilization of flammable forest residue such as pine needles.
6. The process reduces/eliminates the possibility of spontaneous combustion in storage that has been observed with coal.

7. This process can help promote a cleaner environment by solving the issue of disposing organic residue and waste materials. It can thus prevent the decomposition of residues in the surroundings.
8. Biomass Briquettes can be used in furnaces where other solid fuels such as wood pellets are used.
9. This technique can reduce deforestation as it is a substitute to fuelwood. Deforestation is linked to a number of problems including soil erosion, landslides, loss of biodiversity and habitat, loss of carbon sink and so on.
10. Can help eliminate the long hours required for collection of fuelwood.
11. Biomass briquettes are a renewable energy fuel as opposed to coal and oil products
12. Very low sulphur content, thus lower emissions of toxic oxides of sulphur
13. Lower ash content compared to coal and wood/loose biomass (as seen in Table 2.1) resulting in easier maintenance
14. Since the biomass briquette lifecycle includes carbon fixation along with combustion, the net carbon dioxide emissions is much lower than that of fossil fuels
15. Typically, biomass briquettes have a consistent quality, have high burning efficiency and are ideally sized for complete combustion.
16. Combustion of biomass briquettes is usually more uniform in comparison to coal and wood, especially due to lower moisture content.
17. Boiler response to changes in steam requirements is faster due to higher quantity of volatile matter in briquettes.
18. Biomass briquettes can be produced near the consumption centres and supplies do not depend on erratic transport over long distances
19. Easy transportation and feeding as biomass briquettes are dense and compact

However, there are some limitations of biomass briquetting, given as follows:

- Collection and pre-treatment processes for feedstock are energy intensive
- Needs to be kept away from water and high humid weather due to the hygroscopic behaviour of the biomass materials that increase moisture content and loosen the bonds between particles
- Undesirable combustion characteristics of briquettes maybe observed e.g. poor ignitability, smoking, etc.
- Some of the types of briquetting technology require high investment.
- Ventilation is usually recommended while using briquettes, as inadequate oxygen in the space may lead to the release of the toxic carbon monoxide gas.

Table 2. Comparison of Fuel Characteristics of Various Fuels (*AgroFuelIndia, 2017*)

Particulars	**Biomass Briquettes**	**Wood/Loose Biomass**	**Coal**	**Furnace Oil /Light Diesel Oil**	**CNG**
Calorific Value (kcal/kg)	3,500 – 3,700	2,500-3,000	4,200 – 7,000	9,550 - 10,550	8,000 - 10,500
Ash Content (%)	1 - 15	20 - 25	20 - 40	~0.02	Negligible
Moisture Content (%)	6 - 10	20 - 35	20 - 50	Negligible	Negligible

2.2 Biomass Briquetting Process

The briquetting process (Fig. 4) primarily involves drying, grinding, sieving, compacting and cooling operations. Any moisture in the raw material is first removed in a dryer, and the dried material is ground in a hammer-mill grinder. The ground material is then passed through a screen for sieving and then stored in a bin placed over the briquetting press to ensure a regular flow of materials into the briquetting press. The briquetting press/machine continuously packs the material through a die and thus, the briquettes are produced. Grover and Mishra (1996) stated that during briquetting, the high pressure converts the moisture in the material to steam, which hydrolyzes the hemicellulose and lignin into lower molecular carbohydrates, lignin products, sugar polymers, and other derivatives. Under high temperature and pressure, these products work as adhesives and combine the particles together. Further heating facilitates the loosening of biomass fbers and sofens the structure.

The components of a typical briquetting unit can be divided into three groups: (a) pre-processing equipment; (b) material-handling equipment; and (c) briquetting press.

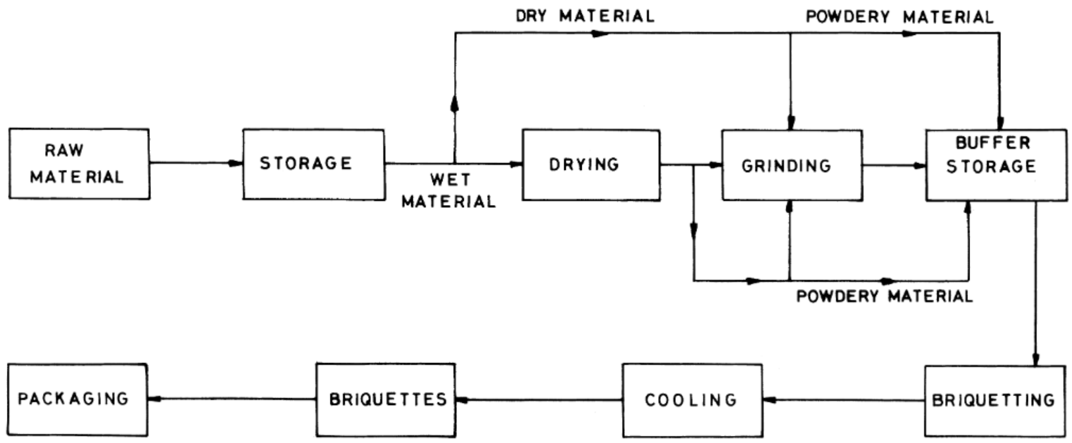

Fig. 4. Flow diagram of the biomass briquette production process (Tripathi et al, 1998)

The basic concept of biomass briquetting involves the compaction of loose biomass material using pressure or force in a die or mould to get a compact solid as per the shape of the die after removal of the force or pressure (illustrated in Fig. 5). The variables affecting the briquetting process include (i) raw material characteristics (size, ash content and moisture content etc), (ii) use of additives/binders, (iii) temperature, (iv) pressure, (v) residence and relaxation time, (vi) mould/die geometry and (vii) preheating of the raw material(s). The process variables are detailed in Section 2.2, while the feedstock characteristics are elaborated in Section 3.2.

2.2.1 Process Routes for Biomass Briquetting

The production of biomass briquettes or pellets can be achieved through a number of pathways or routes, which is chosen depending on criteria including type and nature of raw material, required production capacity, type of end product requirement and so on. Various combinations of operating conditions and modes of operation are possible in practice.

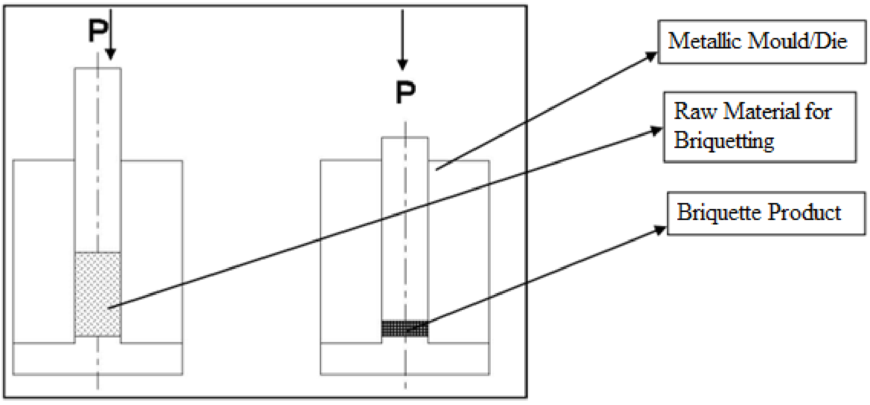

Fig. 5. Basic Concept of Biomass Briquetting (Singh, 2013)

Accordingly, the routes of biomass densification (briquette/pellet production) may be classified based on process type/variables, as follows:

- Based on applied pressure (UNEP, 2013; Wilaipon, 2009):
  - Low pressure up to 5 MPa
  - Intermediate pressure 5-100 MPa
  - High pressure above 100 MPa

Usually high-pressure processes will release sufficient lignin to agglomerate the briquette. Medium pressure machines are usually assisted by heating equipment, and may or may not require binders, depending upon the raw material. Whereas low-pressure machines invariably require binders (with the exception of wet densification). Such external binders might be: starch, clay, molasses or wood tar etc. All briquettes using inherent binders (lignin) or external hydrophilic binders (starch, molasses, gum, clay) are not waterproof and will disintegrate when they come into contact with water or stored under humid conditions.

- Based on solid fuel dimension (Clarke et al, 2011):
  - Pellets: Cylindrical, with diameter of about 6-7 mm and length below 25 mm. A few examples of pellets are illustrated in Fig. 6.
  - Briquettes: Cylindrical or rectangular with or without an inner hole, with diameter over 25 mm. Some examples of briquettes are shown in Fig. 7.

Fig. 6. Various Types of Biomass Pellets (Gemco Energy, 2018)

Fig. 7. Various Types of Biomass Pellets (MAE Development, 2017)

- Based on operating conditions (Bhattacharya et al, 1989; Bhattacharya and Salam, 2006; UNEP, 2013):

- **Hot and high-pressure densification**: This is the most widely used process and is often synonymous with the term "densification" itself. Usually taking place at around 150-300°C and elevated pressures (around 150-250 MPa). However, the temperature should not be increased beyond 300°C as it may lead to the disintegration of the biomass. The heating of the biomass is generated through friction during compaction and may be aided with external heat supply. The application of heat and pressure improves the density as well as the combustibility of the fuel. A binder is typically not required for this type of densification as lignin (present in most biomass) acts as a natural binding agent. The choices of technology include piston press, screw press and pelletizing press.

- **Cold and low-pressure densification**: This process involves the compaction of biomass materials at ambient temperature without external heat supply. The pressure applied is usually between low (0.2-5 MPa) and intermediate (5-100 MPa) levels. Biomass materials with high moisture content (12-20%) can be compressed into briquettes through this technique (Kaliyan and Morey, 2009). A binder may or may not be employed. However, binder-less briquetting at low temperature and pressure is typically possible only with decayed fermented biomass; briquetting of wood residues in suspension in water has also been reported recently (detailed below). In the case of densification using binder, a binding agent is added to glue together the biomass particles. Since there is no need to soften lignin, the temperature and pressure required are low. Hydraulic piston-presses and screw-presses are usually employed used for this process. Cold densification is a suitable and cost-effective method for small scale solid fuel production and can also be carried out at home.

- **Wet densification**: This is a special type of cold and low-pressure densification, wherein binderless densification can take place using decomposed biomass. In this process chopped biomass materials are submerged in water and kept for several days for decomposition to take place. Decomposition helps in softening as well as loosening the fibres of the biomass materials, making them easier to work with (Musa, 2007). Wet briquetting of composted material essentially consists of the two steps- (a) Extrusion of the partially decayed material to obtain soft briquettes of high moisture content and (b) Drying of the soft briquettes. However, there are drawbacks to this process, including- (i) it is a time-consuming process, (ii) high moisture content in the final product which needs to dried before usage, (iii) loss of heating value during decomposition, (iv) densified products show high relaxation behaviour, low bulk density and low water resistance. Pineda (1982) described a process in which fermented biomass is decanted and dried first. The dried residues of medium-size were then densified. The resultant fuel was found to be satisfactory based on binder application and binder type (organic and inorganic).

A binder is a chemical that helps the biomass particles to stick to each other and form compact briquettes. Examples of binders include molasses, coal tar, bitumen, starch, resin, clay, cement, lime, sulphite liquor etc. The types, function and other details of binders are provided in Section. There are various types of binders that can be used depending on the biomass material, briquetting method and other factors. They can be broadly divided into organic binders, inorganic binders and compound binders. They can also be classified as film type, matrix type and chemical type. Typically, production of biomass briquettes without binders require high temperature and pressure, e.g. using piston press and the screw press. The application of high pressure and temperature can instigate attractive forces between particles, as well as act upon the cellular structure to release lignin (present in most biomass materials) which behaves as a natural binder. Densification using binders can thereby be carried out without the requirement of high pressure and temperature since there is no need for lignin softening (Bhattacharya and Salam, 2006). Along with biomass mixing, an appropriate binder is added and needs to be mixed with the biomass thoroughly, especially if a low-pressure technique is to be employed.

- Based on operating conditions:
- Batch densification: Densification of biomass in a batch-wise manner can be achieved through piston press technology.
- Continuous densification: Densification technology that operate continuously include screw extruder, roller press and pelletization.

2.3 Biomass Briquetting Technology

The various biomass briquetting and pelletizing technology options that are currently in use are detailed as follows (Bhattacharya and Salam, 2006; Grover and Mishra, 1996; Kaur et al, 2017; Tumuluru et al, 2011; 2010; UNEP, 2013):

1. Piston Press/Ram Press

Presses of this type are used to create solid briquettes for a wide array of purposes. This technology can be used for biomass and charred material, and makes use of mechanical or hydraulic force to drive the piston or ram back and forward and gives high compaction strength (illustrated in Fig. 8). Material is fed into a cylinder and compressed by a piston through a slightly tapering die. The material is heated by frictional forces as it is pushed through the die. Cooling is usually necessary to condense steam formed and contained inside the briquettes; otherwise the pressure of the steam would result in surface cracks and fragility of the briquettes. The production rate depends on the channel diameter and the properties of materials pressed.

The two types of piston press are detailed as follows-

(a) Mechanical Piston Press develops a compression force of around 2000 kg/cm^2 (around 196 MPa) to obtain high quality briquettes with high unit densities (>1000 kg/m3) without the addition of binders. The material is heated to 150-300°C. Briquettes produced are usually cylindrical with a diameter of 50 to 100 mm (UNEP, 2013). Energy loss in the machine is limited, and the output in relation to power consumption is optimal. Mechanical piston presses are typically used for large-scale production, ranging from 200–2500 kg/hr (Tumuluru et al, 2011) as well as smaller-scale 40-1500 kg/hr (UNEP, 2013). Problems experienced include piston blockage, wear and tear.

(b) Hydraulic Piston Presses are commonly used as briquetting machines and makes use of the hydraulic mechanism. The piston receives energy from an electric motor driven high pressure hydraulic oil system. The pressure is applied not only longitudinally but also in the radial direction. A regulator is used to adjust the pressure and thereby maintain consistency. However, due to slower reciprocation of the cylinder, the output is lower than mechanical presses. The briquettes produced using this technique have uniform shape and size, around 40 × 40 mm cylinders, and unit densities in the range of 800–1000 kg/m^3 (Song et al, 2010). However, these briquettes usually have a unit density lower than 1000 kg/m^3 because of limited pressure. The piston speed of about 7cpm which leads to reduced wear rate of the parts. The production capacity of this type ranges from 50 – 400 kg/hr.

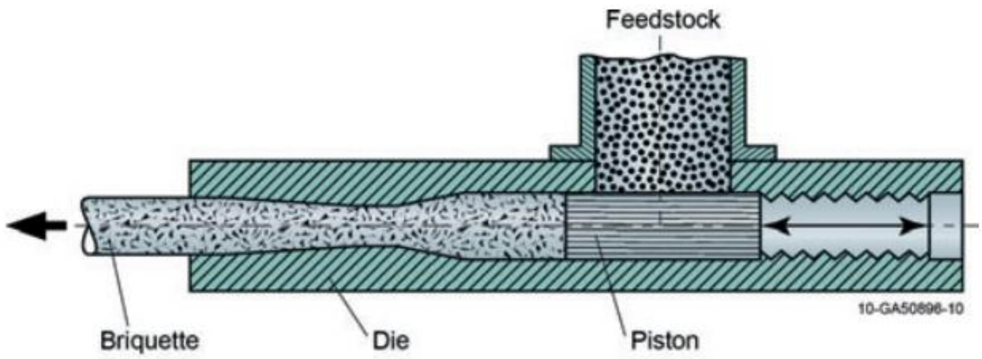

Fig. 8. Piston Press (Mechanical/Hydraulic) (Hassan, 2011).

2. Screw Extruder/Screw Press/Screw Extrusion Technology

This type of technology is used to compact biomass into homogeneous briquettes that could be substituted for coal. This technology creates a toroidal, or doughnut-like briquette. During extrusion, biomass moves from the feed port, with a rotating screw, through the barrel and against a die, resulting in a significant pressure gradient and friction due to shearing of the biomass (Grover and Mishra, 1996) (Fig. 9 and Fig. 10). The hole in the centre of the briquette allows for a larger surface area and air circulation, creating a higher combustion rate. The speed and energy consumption of this process as well as the quality of the briquettes rely on a number of factors including flowability, particle size and distribution, forces between particles within the material. (Kaur et al, 2017). Smaller particle sizes (2–4 mm, according to the die diameter) are more favourable as they result in enhanced material binding (Grover and Mishra, 1996; Olsen, 2006). The temperature of the feed is increased through the overall effect of wall friction in the barrel, internal friction of the material and the high screw rotational speed (around 600 rpm). The heated material is then pushed through the extrusion die to form briquettes or pellets. External heating devices (such as band or tape heaters) are employed if the heat generation is insufficient to make the biomass attain a pseudo-plastic state required for smooth extrusion. The high temperatures attained lead to charring of the material and make it more eligible for burning or co-firing applications.

During screw extrusion, biomass is processed through the following stages:

- Conveyance of solids- The ground biomass is partly compressed, and maximum energy is needed to deal with particle friction.
- Initial compression- The feed particles soften and become inelastic because of the high temperature (200–250°C), leading to the formation of local bridges and interlocking particles. The material is also heated and gets uniformly mixed due to the friction it experiences.
- Final compression- The material moves into the tapered die, where further moisture is removed (at temperatures around 280°C), leading to increased compression of the material.
- Discharge- The pressure through the mass is normalized into a uniform extruded product.

Screw extrusion briquetting technology was invented and developed in Japan in 1945, and by April 1969, around 638 plants had been constructed (Grover and Mishra, 1996). The technology has been adopted by European countries thereafter.

There are two types screw press technology-

i. Conical Screw Press: In this type of press, a conical screw compresses the raw material. The screw forces the material into the compression chamber. A rotating die head extrudes the material through a perforated matrix to produce briquettes of diameter about 2.5 cm. A knife cuts the densified product to a specified length. This type of with press can also be used to produce briquettes diameters of about 10 cm by using a single-die matrix.
ii. Heated Die: In this type of press, the material is forced by a screw having no or small taper through a slightly tapered die, which is heated from outside normally by electric heaters. The die temperature is normally maintained at about 300°C. The raw materials get heated up to about 200°C during the process, most of the heating is caused by friction. The biomass materials often get partially pyrolyzed at the surface causing significant amount of smoke generation during the process. The die cross-section can be circular or square with rounded corners. The briquettes are 5-10 cm in diameter. The design of the screw results in the formation of a central circular hole in the briquette, which acts as an escape route for steam formed during briquetting. Capacity of this type of presses ranges from 50 to 800 kg/hr. The major maintenance problems of these briquetting machines are due to the wear of the screw and the die.

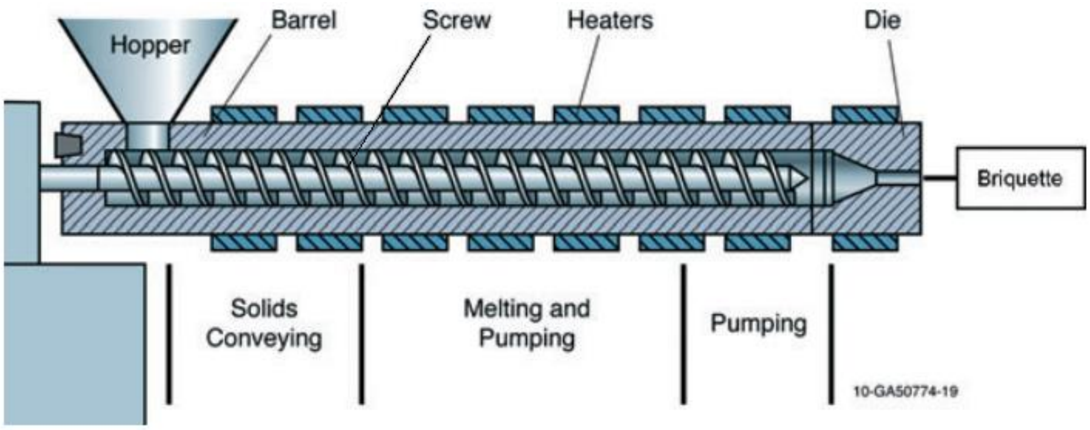

Fig. 9. Screw Extruder System (Brewer, 2011)

Fig. 10. Screw Pressed Sawdust Briquettes (Tokewoods, 2018)

3. Roller Press

These machines consist of two rollers of the same diameter, rotating horizontally in opposite directions on parallel axes (Fig. 11). Ground biomass, when forced through the gap between the two rollers, is pressed into small pockets, forming the densified product. Since the rotation of the rollers is in opposite directions, the biomass is drawn in one side and the densified product is discharged from the opposite side. The distance between the two rollers, which is normally referred to as "the gap," depends on many factors such as the type of biomass, the particle size, the moisture content, and the addition of binders. Shape of the densified biomass depends upon the type of die used (Yehia 2007). Typical bulk densities range from 450 to 550kg/m^3 (Kaliyan and Morey, 2009; Mitchell et al, 2011). The feeding can be carried out with the help of gravity or using forced screw feeding.

Roller press technologies can vary from low pressure to high pressure depending upon the briquetting raw material and additives. The automatic recycling of the loose/disintegrated particles is the main advantage. Moreover, roller presses can handle biomass with higher moisture content (up to 20%) (Kaliyan and Morey, 2009). Design parameters such as the roller diameter, gap width, roller force, and die shape have an impact on the quality of the densified product (Yehia 2007).

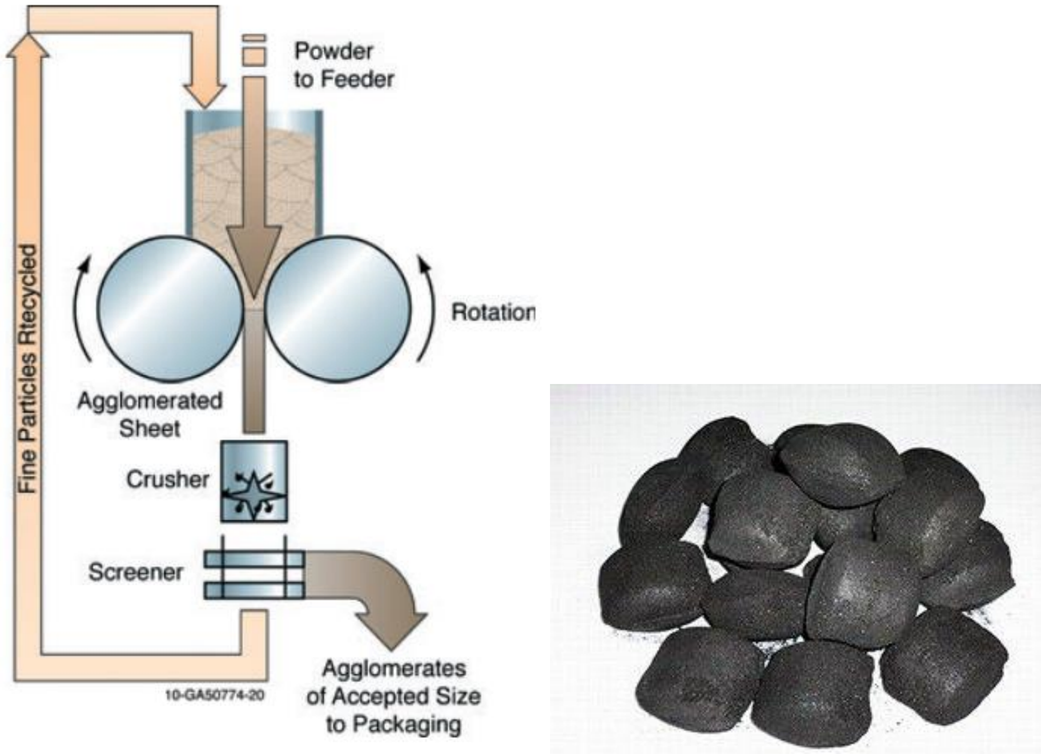

Fig. 11. Roller Press Technology and sample briquettes (Yehia, 2007)

4. Pelletizer/Pelletization Technology/Pellet Mills/Pelleter

This technology is similar to briquetting, except that it uses smaller dies (around 30mm) to produce smaller densified products called pellets (Fig. 12) and each machine has a number of dies arranged as holes bored in a thick steel disk or ring. The main application of pellet machines is to produce animal feed from various types of agricultural wastes, while a number of plants have been set up to produce fuel pellets (Gilbert et al., 2009).

Fig. 12. Wood Sawdust Pellets (Pellet Energy Systems, 2018)

The various types of pelletizers are detailed as follows.

Ring Die/Ring Matrix and Flat Die/Disk Matrix Pellet Presses

In both the ring- and flat-die machines, the die remains static while the rollers rotate (Fig. 13). The die keeps rotating while being in contact with the roller. The raw material is heated (due to friction) and pushed through the holes in the die. The densified material emerges from the die as strands of uniform section and cut with knives into the desired length. Some rotating die pellet mills are available in which the rollers remain stationary during the production process. This technology is used mainly for biomass with low ash content. Notably, moisture contents above 16% may choke the pellet mill. However, a die with larger diameter (e.g. 7-8 mm) can be used for high moisture feeds (>10%) (Kaliyan and Morey, 2009).

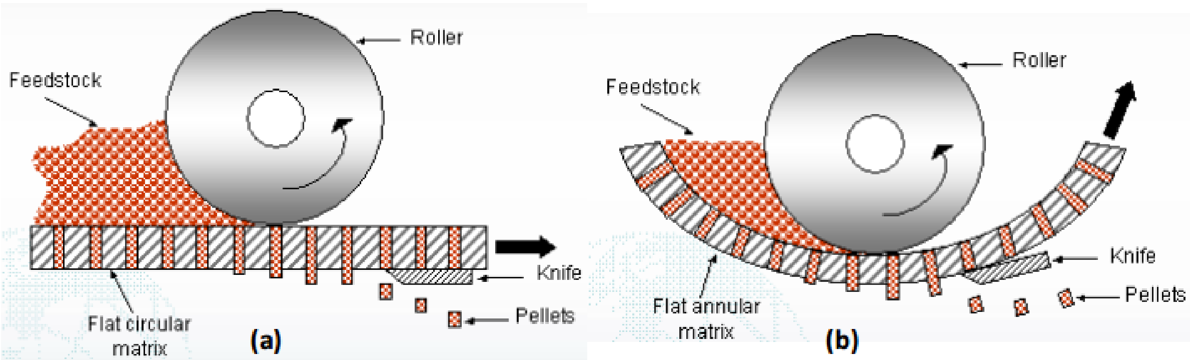

Fig. 13. Pelletizing Presses – (a) Disk Matrix; (b) Ring Matrix (Bhattacharya and Salam, 2006)

Punch Press Pelletizing Press

Another verity of pelletizing press is the punch press, as shown in Fig. 14. In this type of press, a punch forces the raw material through holes in the die. Punch press can be used to produce both pellets and briquettes by changing the die. The punching speed of eccentric wheel in punch press pelletization is high (about 280 beats/min.) which increases the raw materials temperature up to 150°C. Thus, a wide range of biomass materials is applicable for this type.

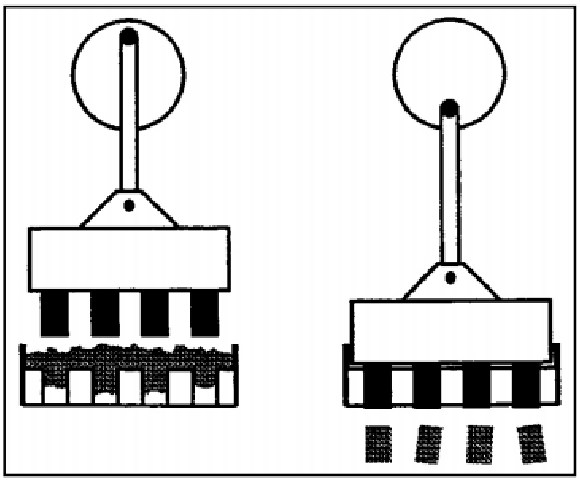

Fig. 14. Schematic diagram of punch presses (Bhattacharya and Salam, 2006)

Cog-Wheel Pelletization

A relatively recent development in the field of pelletization technology is the "cog-wheel" pelleting principle (Hartmann, 1997) (Fig. 15). This process is carried out by forcing the raw material through radial passages in two externally corrugated matching wheels (as illustrated in). The end product is normally in the form of pellets. The pellets are normally 5 -15 mm in diameter and the length is below 30 mm. The capacity of the machines is in the range 3– 8 ton/hr. Manufacturers claims that the pelleting machine can densify all cereals, hay, straw, grass etc. The machine can be stationary or mounted on a mobile system which carries out harvesting, pre-treatment operations (e.g. size reduction and drying) as well as densification in the field. Pellets of bulk density 400-600 kg/m3 can be produced with a specific energy consumption of 20- 60kWh/ton. (El Saeidy, 2004)

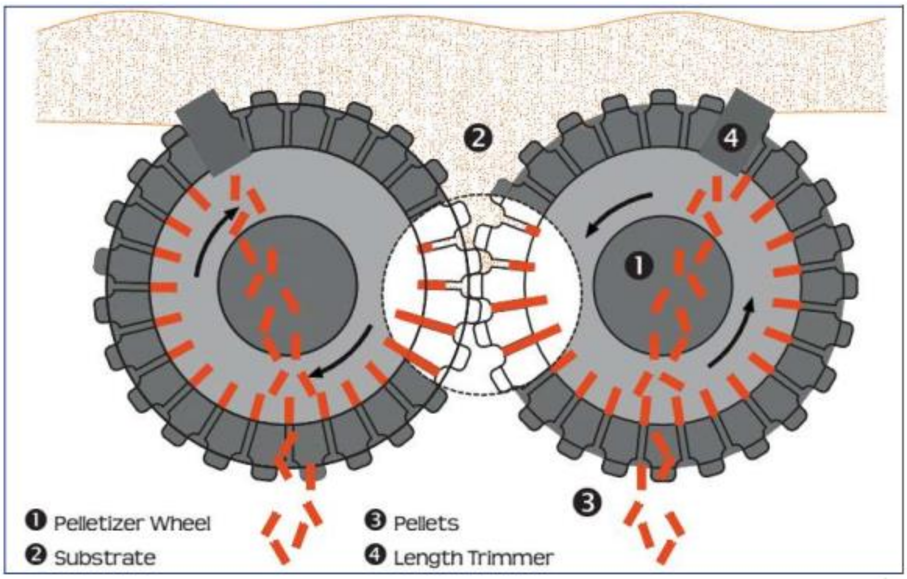

Fig. 15. Cog-Wheel Pelletization Principle (Bhattacharya and Salam, 2006)

Mobile Pelletizers

There are also mobile pelletizers available which allows the user to set up the machine at any location reducing problems incurred in transportation and handling (Fig. 16). These systems do not occupy permanent space which is a major advantage over fixed densification plants. Mobile densification systems usually perform the tasks of chopping, particle separation, compression, screening, cooling and packaging (Bumgarner and Kempf, 2015). The production capacity ranges from 200 – 450 kg/hour (Kingman, 2017).

1. Compaction/Compression

This method of briquetting makes use of manual compaction force for producing beehive briquettes (Fig. 17), cylindrical charcoal briquettes, briquettes from paper and biomass waste etc. It is used in small scale production and is mainly adopted in developing countries.

Small quantities of briquettes can also be made by hand moulds. Here sun drying or a gentle heat treatment in a curing furnace is required to form strong briquettes due to the property of binders in building up hydrogen bonds among themselves and the biomass (Vest, 2003). In China, ground coal is mixed with water and approximately 20% of clay binder to form honeycomb/beehive briquettes by a mechanized briquetting press followed by sun drying. In Kenya and Benin, biomass of fine particle size (saw dust, rice husks, wood shavings, charcoal dust, etc.) is mixed with approximately 20% of (waste) paper pulp to form briquettes in a manually operated piston press. However, plastic and municipal waste cannot be converted into the briquette in the same way as it does not contain a great amount of biological materials such as lignin to act as a natural binder. Thus, a higher pressing temperature and compacting pressure should be applied (Husain et al., 2002; Kaur et al, 2017; Ndiema et al., 2002).

Model: GC-HBP125 Hydraulic Briquette Machine	
Manufacturer	GEMCO
Plant capacity	125 kg/h (maximum)
Space requirement	3.15×1.27×1.79 m^3
Briquette dia.	70 mm
Power	9.0 kW

- **Hammer Mill**
  - Model: CF420 with Cyclone
  - Capacity: 350 - 450kgs / hr
  - Power: 11kw
  - Price: USD 1,250
  - Spare parts: Hammer and Screen (Price: USD 115)

- **Pellet Mill**
  - Model: CF420 with Cyclone
  - Capacity: 90-120kg/hr
  - Power: 4kw
  - Moisture: 10-15%
  - Pellet size: diameter 4-10mm
  - Price: USD 548
  - Spare parts: Flat die(USD 49)& Roller (USD 43)

Fig. 16. Mobile Pelletizers: Electric Motor Driven (left) and Diesel Driven (Right) (Gemco Energy, 2018)

Fig. 17. (left) Beehive Briquetting and(right) Manual Briquetting Press (Singh, 2013)

Manual compression technology is also available wherein the pre-treated biomass is compressed in a die using a lever to apply force manually, during which excessive water is expelled and the remaining materials is obtained in the form of a cylindrical mass with a hole in the centre. Paper, saw dust, leaves, grass, etc are used to obtain briquettes through this technology.

2. Tabletizer/Tabletization Technology

A tabletizer makes uses of a hydraulic motor and ram to press the biomass into a cylindrical mould of around 4 to 6-inch diameter, compacting the feed from around 10 to 2 inches (Fig. 18 and Fig. 19). The products of this process- tablets, are smaller compared to most biomass briquettes. Typically, a pressure of around 20,000 psi (around 137.9 MPa) is adequate for ramming the particles to stick together without the need of binders. Coarse-cut and long raw materials are preferred for this method as they adhere together easily. The average density of tablets is around 880 kg/m^3 compared to 160 kg/m^3 of bales and 720 kg/m^3 of pellets. However, tabletizing consumes more energy when compared to pelletization. Furthermore, tablets have not been extensively studied for energy density and for different biomass feedstock, and also need to be evaluated for power generation and gasification. The energy requirements and scale-up methods of tabletizers are currently under research. Along with this, research is ongoing for product application in gasification and co-firing (Gibson, 2010).

3. Cuber/Cubing Mill

These types of mills consist of a die ring/disk and a press roller wheel/compression roller that bear similarities with the die ring of a pelletizer. The chopped biomass material is moved uniformly along a screw conveyor/auger conveyor and is then forced by a heavy press wheel through the openings of the die ring (Fig. 20 and Fig. 21). Pressure ranging from 24 – 34 MPa is attained in this type of densification. The cubes get bonded by virtue of the natural binders present in the chopped biomass, heat generation as the biomass is forced through the dies, and the high pressure of the press wheel. Outside the die ring, the cubes get broken by an adjustable deflector within 50 to 75 mm in length. A binder is usually required in order to improve the cube durability. Types of binders used include starch, bentonite, agro colloids, hydrated lime, lingo-sulfonates (pulp and paper operation by-product) and other commercial binders. (Sokhansanj and Turhollow, 2004; 2002).

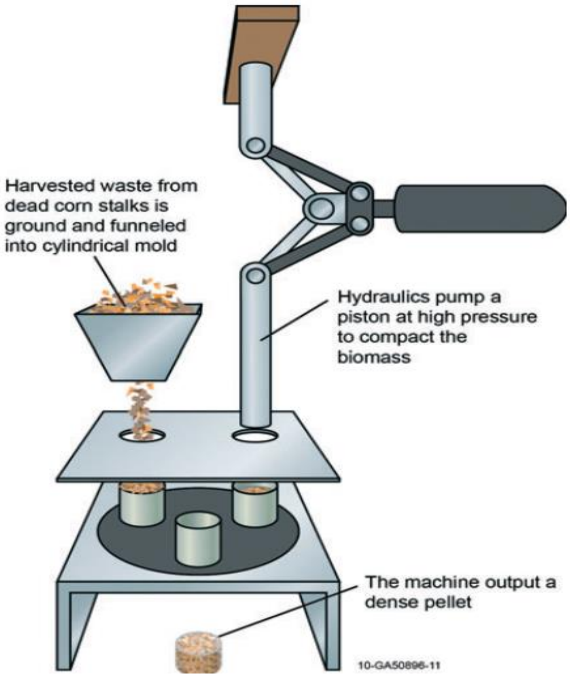

Fig. 18. Working of a Tabletizer Machine (Vanengelenhoven, 2011)

Fig. 19. Biomass Tablets made from Grass

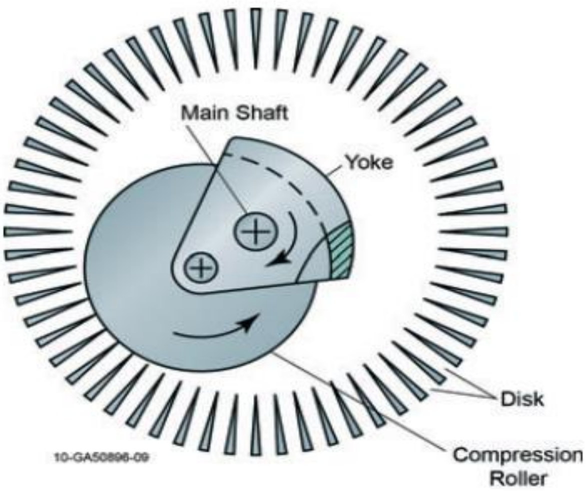

Fig. 20. Mechanical arrangement of a Cuber (Sokhansanj and Turhollow, 2004)

Fig. 21. Biomass cubes made from wood waste and grass

4. Agglomeration

This is a method of increasing particle size by gluing powder particles together. This technology is used for a variety of powders, such as hydrated lime, pulverized coal, iron ores, fly ash, cement, and many others. The application of agglomeration for biomass is limited (Beaudequin et al, 1985; Reynieix, 1987).

The most widely used agglomeration technique is tumbling agglomeration, wherein differently sized balls are housed in a rotating chamber. Usually powder with a binder is fed into the agglomerator. As the agglomerator rotates, forces that arise (i.e. centrifugal, frictional, gravitational and inertial) force the smooth rolling balls on to the power. This results in the powder particles to bind together and grow in sizes. The larger balls move onto the surface and gets pushed out while the smaller ones stay at the bottom (Siemons et al. 1989). The various types of agglomerator are conical, drum, pan and plate shaped.

An agglomerator that makes use of granulation operates by the following steps: (i) fine raw material is fed to the pan and wetted using a liquid binder; (ii) the rotation of the disc causes the wetted fines to become small, seed-type particles (nucleation); and (iii) the seed particles become larger by coalescing (similar to the snowball effect) until they are ejected from the pan.

Agglomeration is a function of material properties and process parameters. These parameters are interrelated, and process settings depend very much on the powder characteristics (Mort 2009; Siemons et al. 1989). The chief process parameters are the ball residence time (which relies on powder feed rate, acting volume, and pan-tilt angle) and proper rolling action (which depends on scraper position, binder premixing, and pan-tilt angle). Mort (2009) also stated that binders play a considerable role in the quality of the agglomerates. Fig. 22 shows the process of agglomeration as a function of various material properties and process parameters. Agglomerated materials are typically spherical with diameters around 4-6 mm, depending on the residence time of the feed in the agglomerator.

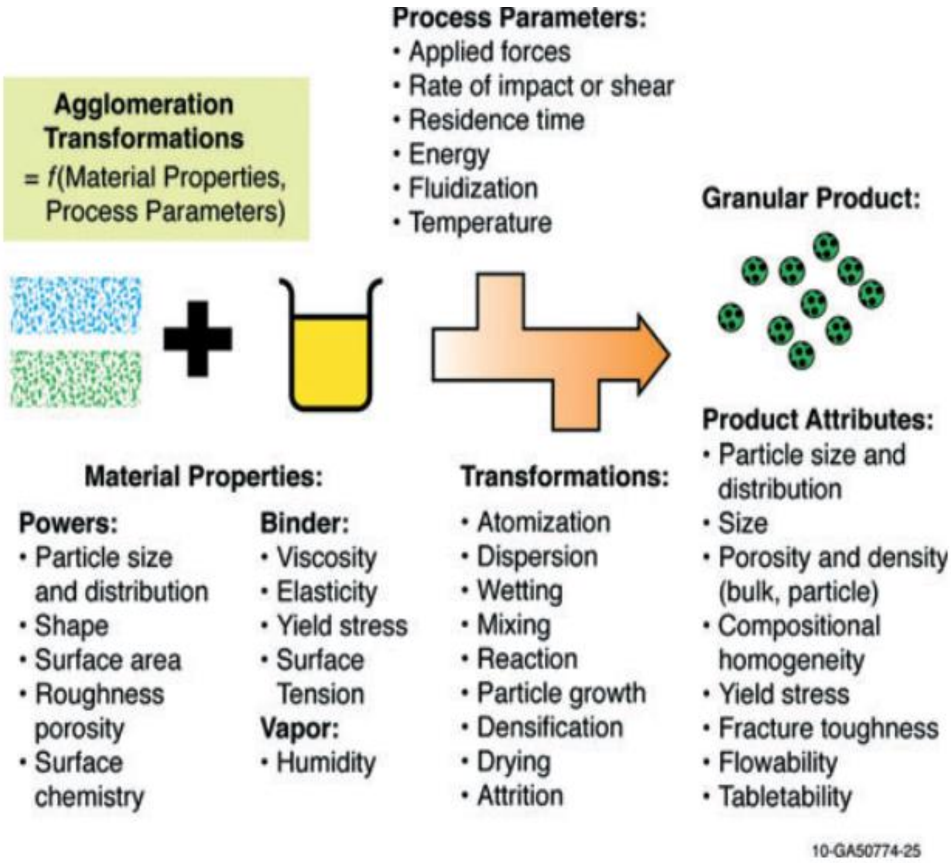

Fig. 22. Relations between material properties, process parameters, transformations and product attributes in a binder agglomeration process (Mort, 2009)

2.3.1 Comparison of Briquetting Technology

A comparative study of various biomass briquetting technology in terms of feedstock material properties, specific energy consumption, and suitability of the densified material for different end-use applications is tabulated in Table 3.

It can be deduced from Table 3 that screw pressed material is more suitable for co-firing and combustion because the biomass is carbonized during densification, whereas the pellet, roller, and piston-pressed materials are more suitable for biochemical and thermochemical conversion processes. It is worthy of note that both non-charred biomass and charred biomass can be used as raw material in all of the listed types of technology, with the exception of agglomeration wherein non-charred biomass is not applicable. (*Charring is a chemical process of incomplete combustion of certain solids when subjected to high heat. By the action of heat, charring removes hydrogen and oxygen from the solid, so that the remaining char is composed primarily of carbon*.)

- The two biomass densification techniques (i.e. briquetting and pelletization) can be compared as follows (Austin 2010):
- Briquetting machines, unlike pellet mills, can handle larger-sized particles and higher moisture contents without the addition of binders.
- Briquette processing is more efficient than pelleting because the biomass materials do not necessarily have to be pre-processed or uniformly ground up, which results in lesser preparation time and energy use.

- Briquetting can be set onsite. Briquetting waste by-products and reusing them onsite for energy rather than transporting them to another location or to a landfill can save on disposal costs.
- From the investment point of view, the purchase capital and maintenance costs for briquetting are less than for pelletization.
- Pellets have been considered more of a residential fuel even though they are used in some larger, commercial applications.
- If transportation is one of the main criteria, pellets are more advantageous because there are more pounds per foot than briquettes. This is especially true if the briquettes are larger because it allows for more air between them when they are stacked

▪ The two types of pellet mill technology can be compared as follows (AMISY, 2012):

- Ring die pellet mills have a wide range of application in commercial use with relatively large production capacity, 300-3,500 kg/hr. While flat die pellet mill is popular with home use, capacity from 30-2000kg/hr.
- Material feed rate is easy to control in ring die pellet mill since it has forced feeding system that ensures continuous and even feeding. While in flat die, materials dropped off into the pelletizing chamber depends on unit mass of the particles.
- Rollers diameter of flat die pellet mill is independent from the thickness and diameter of the die, while for a ring die pellet mill rollers diameter is limited/dependent on die's diameter.
- Hence, the roller pressure on feedstock can be controlled for flat die pellet mills by enlarging the inside bearing space, adopting a big bearing which also expands the working life. This is the advantage over rind die pellet mill.
- Pellet breakage is high due to the high die rotational speed in ring die pellet mill.

▪ In the case of piston press technology, the two types (i.e. mechanical and hydraulic) can be compared as follows:

- Generally, a mechanical press gives a better return on investment than a hydraulic press. (LogistEC; 2012)
- Hydraulic press machines can tolerate higher moisture contents than the usually accepted 15% for mechanical piston presses (Grover et al., 1994). However, even if the moisture tolerance differs between the raw materials, it seems doubtful that it is possible to successfully produce durable briquettes with raw-material moisture much higher than 20%. It is also likely that even if higher moisture contents can tee tolerated in the press, organic material would have to be dried after briquetting if long storage times are planned. (Eriksson and Prior, 1990)
- The operating life of a mechanical press is considerably longer than for a hydraulic press. (CFNeilsen, 2018).
- The briquettes made on a mechanical press can be used both for consumer briquettes and industrial briquettes. The density can be regulated, so that it is high for consumer logs and lower for industrial briquettes. Whereas, the briquettes made on a hydraulic press are usually used as consumer briquettes. The density is lower than a mechanical press and due to this, do not burn as long (CFNeilsen, 2018).
- Historically, biomass briquetting technology has been developed in two distinct directions. Europe and the United States has pursued and perfected the reciprocating ram/piston press while Japan has independently invented and developed the screw press technology. Among the available briquetting technology, piston press and screw extrusion technology are most widely used, they can be compared as follows (Kaur et al, 2017; Sharma et al, 2015; Tumuluru et al, 2011; UNEP, 2013).

Table 3. Comparison of Various Biomass Densification Technology (Gibson, 2010; Grover and Mishra; 1996; Hancock et al, 2003; Kaliyan and Morey, 2009; Kaliyan et al, 2009; Lei et al, 2018; Olsen, 2006; Mani et al, 2002; Sokhansanj and Fenton, 2006; Sokhansanj and Turhollow, 2002; Tumuluru et al, 2010)

Particular	**Pellet Mill**	**Piston Press**	**Roller Press**	**Cuber**	**Tabletizer**	**Screw Press**	**Agglomerator**	**Manual**
Production Capacity (kg/hr)	200 - 8000	200 - 2500	900 - 1500	-	-	100 - 200	-	~6
Optimum moisture content of the feedstock (%)	10–15	10–15	10–15	15–25	10–15	4–8	No information	Up to 80%
Particle size requirements (mm)	<3	6–12	<4	12–16	<20	2–6	0.05–0.25	Small Fibre
Addition of binder	Not required	Not required	Required	Required	Not required	Not required	Required	Required typically
Shape	Cylindrical	Cylindrical	Generally Elliptical (depends on the shape of the die)	Cylindrical	Cylindrical	Cylindrical	Spherical	Various
Dimensions (mm)	4.8–19.1 (dia); 11–19 (length) 12.7 to 25.4 (length)	32 (dia) x 25 (thick)	Almond shaped; 31.75 (length) × 20.32 (width) × 11.16 (depth)	33 x 33 cross section and 25.4 to 101 (length)	100–150 (dia) 50 (length)	Length: 1940 Width: 750 Height: 1310	2–6 (diameter)	Various
Wear of contact parts	High	Low	High	Low	Low	High	Low	Low
Output from machine	Continuous	In strokes	Continuous	Continuous	In strokes	Continuous	Continuous	In strokes

Particular	Pellet Mill	Piston Press	Roller Press	Cuber	Tabletizer	Screw Press	Agglomerator	Manual
Specific energy consumption (kWh/ton)	16.4–74.5	37.4–77	29.91–83.1	28–75	High energy requirements (Still under research)	36.8–150	-	No electricity requirements
Through puts (kg/hr)	500	2500	500–1000	500	500–1000	500–1000	-	-
Unit density (kg/m^3)	1100–1200	100	-	8 00	1200	1000–1400	-	-
Bulk density (kg/m^3)	650–750	400–500	480–530	450–550	600–700	500–600	400–500	-
Maintenance	Low	High	Low	Low	Low	Low	Low	Low
Combustion performance of briquettes	Very good	Moderate	Moderate	-	-	Very good	-	Moderate
Carbonization of charcoal	Not possible	Not possible	Not possible	Not possible	Not possible	Makes good charcoal	Not possible	Possible
Suitability in gasifiers	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	-
Suitability for co-firing	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Suitability for biochemical conversion	Suitable	Suitable	Suitable	Suitable	Suitable	Not suitable	-	-
Homogeneity of densified biomass	Homoge-neous	Not homogenous	Not homogeneous	Not homoge-neous	Not homogeneous	Homogenous	Homogenous	Homoge-nous

- The screw extruder briquettes are more superior and homogenous than piston pressed briquettes due to their storability and combustibility This is because in the case of screw press briquettes the outer surface gets partially carbonized, facilitating easy ignition, combustion and protection from ambient moisture. These briquettes are also suitable for use in gasifiers. While, for piston press briquettes are somewhat brittle as the carbonization of the outer layer does not take place; and are non-homogenous as well. However, significant amounts of smoke may be emitted by screw presses during the partial pyrolysis of the raw material surface.

- While the briquettes produced by a piston press are completely solid, screw press briquettes on the other hand have a concentric hole which gives better combustion characteristics due to a larger specific area. The screw press briquettes are also homogeneous and do not disintegrate easily. Having a high combustion rate, these can substitute for coal in most applications and in boilers.

- Solid briquettes from piston presses are considered unsuitable for cook stoves and give excessive smoke unless broken into small pieces of l-2 cm in thickness. On the other hand, screw pressed briquettes are easy to burn and give better combustion than wood. Moreover, SPB should be placed in a vertical position as far as possible so that the air can easily pass through the central holes. These can be broken into suitable sizes so as to fit well in the combustion chamber.

- The screw extruder machine is usually comparatively lighter in weight as there are no reciprocating parts and flywheel unlike the piston press machines.

- Similarly, the continuous operation of screw presses ensures smooth running of the machine and briquettes of uniform size, whereas shock loads may be experienced in piston presses.

- In the case of screw presses high wear of the screw and die may take place. Whereas, in piston presses, the relative motion between the ram and the biomass is lesser leading to reduced wear of the ram.

- In the case of screw presses, the machine parts and the oil used in the machine are free from dust or raw material contamination.

- Along with this, the power requirement of the screw press machine (average 60 kWh/ton) is higher compared to that of piston press (average 50 kWh/ton)

Grover et al. (1994) have reported a number of research studies aimed at the betterment of the screw press technology, namely in regard to the screw wear and high-power consumption. The studies indicate that an appropriate hard facing alloy to the screw surface considerably increases the lifetime, which can have significant effects on the costs and seamlessness of production. Moreover, preheating the biomass has also been found to reduce power consumption in the range of 10-40% (Bhattacharya et al, 2002; Grover et al, 1994). Moreover, Bhattacharya et al. (2002) reported that replacing electrical heaters with biomass stoves for die-heating can bring in 35% savings in electrical energy.

The role of roller presses, tabletizers and agglomerators in energy applications is still in the infant stages of research. Further studies and testing regarding energy consumption, process and feedstock variables are required to examine their suitability (Tumuluru et al, 2011). In conclusion, screw press has been found to produce excellent quality briquettes while piston press has been found to be the most cost-effective technology (Grover and Mishra 1996; Kaur et al, 2017). Thus, the choice of technology depends on various factors such as type of biomass, application, required briquette characteristics, investor appetite and so on.

2.4 Briquetting of Charred Biomass

Charring is a chemical process of incomplete combustion of certain solids when subjected to high heat. The resulting residue matter is called char. By the action of heat, charring removes hydrogen and oxygen from the solid, so that the remaining char is composed primarily of carbon. Polymers like thermoset, or most solid organic compounds like wood or biological tissue, exhibit charring behaviour. Charred biomass or charcoal can also be converted into briquettes using the same type of technologies described in Section 2.3. Charcoal briquettes can be converted to briquettes in two ways (Fig. 23)- (i) the biomass raw material is converted to briquettes using a densification technique. These briquettes are then later carbonized to obtain charcoal briquettes; (ii) the biomass is first converted to charcoal through carbonization. The charcoal is then densified to form briquettes.

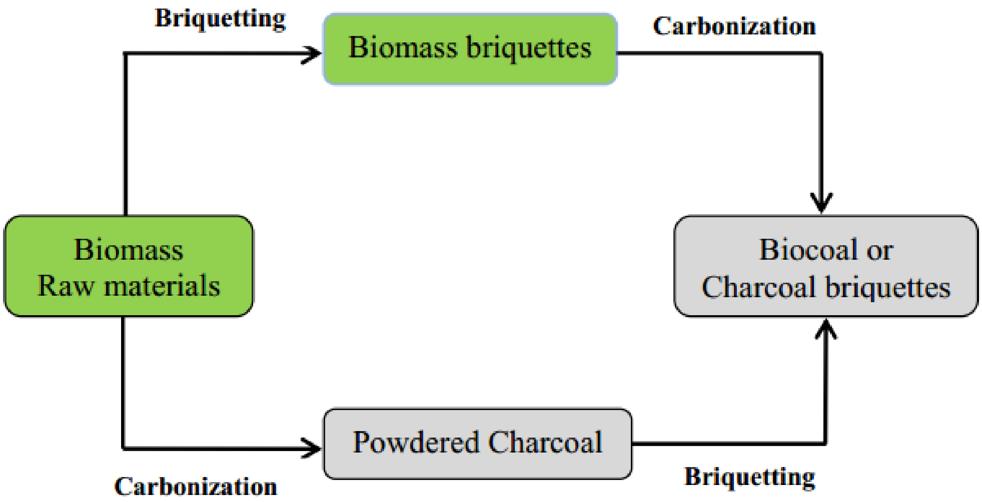

Fig. 23. Methods for obtaining charcoal briquettes (Singh, 2010)

The raw materials for charcoal briquettes are charcoal powder and binder. A third component, which is called filler, serves as a combustion rate controller and to retain the shape of the briquette during combustion. Ground charcoal, mixed with binder and filler, is passed on to the briquetting press. Different types of briquette shapes can be obtained depending upon the equipment or mould used. Charcoal briquetting for specific technologies are described as follows:

(a) Pelletizer/Pellet Press

Usually a foot peddle pelletizer or manual/electric pelletizers are used in the case of charred biomass. These are illustrated in Fig. 24and described as follows:

(i) Foot peddle pelletizer: A foot peddle pelletizer uses the openings at the top over a feeder to feed the briquetting material, which is compressed using a foot peddle, which drives a piston upwards when the holes are closed by a lid. Next the lid is removed, and the pellets are ejected upwards.

(ii) Manual/Electric Pelletizers: These types of pelletizers are based on the meat mincing machine (manual or electric) which is converted to a pelletizer by putting a two or three hole die in the front. The operating principle is similar to that of a screw extruder.

Fig. 24. **(left)** Peddle Press Pelletizer **(centre)** Manual Pelletizer **(right)** Electric Pelletizer

(b) Piston Press: The Piston press technology for briquetting of charcoal is the same as that for the biomass. The only difference is that binders and fillers have to be used while using charcoal for briquetting. Also, the tapering in the piston press needs to be lesser in the case of charred material.

(c) Roller Press: Roller press technology is more often used for briquetting of charcoal and coal briquettes (Fig. 25). The charcoal or coal is first treated with a binder and then the mixture is fed into the roller press. In the case of briquetting of coal, since there is always some sulphur in the coal some desulfuring agents such as lime or lime based products are added to the mixture before briquetting to absorb the sulphur which is released during combustion. As coal and coal products are difficult to ignite to decrease the ignition temperature of the briquettes, some biomass, which is mostly volatile matter, is also added. This makes it easier to ignite the briquettes.

Fig. 25. **(left)** Coal Briquettes **(right)** Charcoal Briquettes (both from roller presses)

(d) Screw Extruder/Screw Press: The machinery and operating principle for briquetting of charcoal by using the screw extruder is the same as in the case of biomass briquetting (Fig. 26). Since charcoal is the briquetting material used, some binders and fillers are required to obtain strong briquettes.

(e) Compression Technology: This is the simplest form of briquetting using manual or mechanical force to obtain briquettes from charcoal. Charcoal/coal is mixed with some binder and compressed to obtain briquettes. Many different types of mold maybe used as per the situation and availability. Various types of compression technology for charred biomass is shown as follows:

(i) The simplest technique is to compress the mixture of charcoal and binder by hand to obtain oval shaped briquettes in the absence of any kind of mould. This is shown in Fig. 27 .

 

Fig. 26. **(left)** Screw Extruder Machine **(right)** Screw extruded charcoal Briquettes (Singh, 2010)

 

Fig. 27. **(left)** Manual Pelleting **(right)** Hand-made pellets

(ii) A simple mould and hammer can be used to compress the charred material with a binder. This briquetting technique is common in African countries (Fig. 28).

 

Fig. 28. **(left)** Simple Mould and Hammer **(right)** Briquetting using mould and hammer

(ii) Beehive briquetting: Beehive or honeycomb briquetting consist of compressing the briquetting mixture consisting of charcoal/coal with binder into a cylindrical mould with cylindrical pins (usually 13- 19) to obtain circular briquettes normally of 13cm height and 5 inches diameter. The finished product looks very similar to a honeycomb or a beehive. Many different types of metallic mould have been developed to improve the quality and strength of the briquettes as well as to increase the production capacity for beehive briquetting. They can be classified as simple manual moulds and mechanical moulds.

- **Manual moulds** can be of different sizes and have around 13 to 19 holes (Fig. 29). Since the pressure of briquetting depends upon the person using the mold, the briquettes may not be strong enough. Thus, other moulds such as foot peddle press mould, improved hand mold, Chinese mould, mechanical moulds the briquetting pressure is greater and the briquettes are stronger (Fig. 30).

Fig. 29. Various types of manual beehive briquetting moulds

Fig. 30. **(left)** Improved hand mould **(centre)** Foot peddle press mould **(right)** Chinese manual mould

- **Mechanical moulds** make use of simple mechanical arrangement to produce stronger briquettes with ease (as compared to manual moulds). They can be used to make single briquette, two or more briquettes at a time (Fig. 31). Since the pressure of briquetting is more the briquettes are more compact and stronger.

Fig. 31. Various types of mechanical mould

(f) Agglomeration: Agglomeration equipment consisting of a rotating cylinder is used to make briquettes in this method. A mixture of charcoal powder and binder (with water if necessary) is agitated by the motion of the cylinder (Fig. 32). Charcoal particles cluster together under the influence of the binder. As the cylinder rotates, the particles are drawn to the top; when they come down again rolling; other particles stick to the agglomerate, which turns into charcoal ball by the "snow ball effect". The briquettes reach a steady size when the tendency to grow as above is balanced by the tendency to diminish in size due to attrition. (Bhattacharya and Shrestha, 1991).

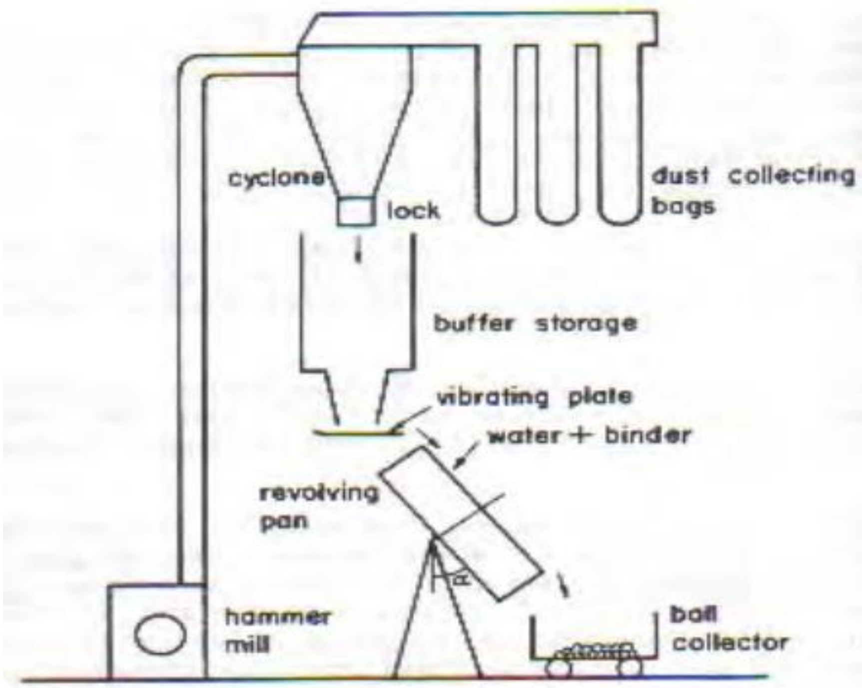

Fig. 32. Agglomeration of charred biomass

2.5 Process Variables

A number of variables influence the densification process, which in turn affect the properties of the densified product. These include temperature, pressure, residence time, and die geometry and speed. They play an important role in reaching the desired product quality of densified biomass in terms of durability, density and calorific value. Variables pertaining to raw materials (e.g. particle size, moisture content etc.) are described in Section. The process variables of densification are elaborated as follows:

(i) Pressure

Densification is carried out by subjecting the feed stock to pressure. Lower pressure causes reduced density while higher pressure may cause fracture of the briquettes (Tabil and Sokhansanj, 1996). The density of the final product increases with increase in applied pressure (Bhattacharya and Yeasmin, 1984; Reed et al., 1980). However, Yaman et al. (2000) in their study of fuel briquettes from olive refuse and paper mill waste suggested that there is an optimum briquetting pressure above which may result in fractures due to sudden dilation. They concluded that optimum briquetting pressure influences the mechanical strength by increasing plastic deformation. For a given die size and storage condition, there is a maximum die pressure beyond which no significant gain in cohesion (bonding) of the briquette can be achieved (Ndiema et al. 2002).

High pressures and temperatures during densification may develop solid bridges by a diffusion of molecules from one particle to another at the points of contact, which increases density. Li and Liu (2000) observed that compression of oak sawdust at pressure application rates varying from 0.24to 5.0 MPa/s has a significant effect on the dry density of the compacts at moisture content of 10.3%. They also observed that when the compaction speed was lower than 3 MPa/s, the density of the logs decreased, whereas the effect was negligible with the increase in compaction speeds to >3 MPa/s. Demirbas et al. (2004), in their article on compaction of biomass waste materials like waste paper, observed that increasing the pressure from 300 to 800 MPa, with about 7% moisture (w.b.), increases the density sharply from 0.182 to 0.325 g/Ml, and then the densities slightly rise to 0.405 g/mL. They also observe that for a sample with 18% moisture content at the same pressures, the briquettes' densities increase sharply to 0.278 and 0.836 g/mL, respectively.

Pressure also plays an important role in the quality of pellets made from agricultural biomass. During continuous pelletization of agricultural biomass, a backup pressure is needed to initiate the process of pelletization. The backup pressure is created by the buildup of material in the press channel, which sets the requirement for a pressure (prestressing pressure) to overcome the friction within the channels. The initial pelletization pressure depends on die dimensions such as die hole, die length, friction coefficient, and prestressing pressure (Holm et al. 2006). Butler and McColly (1959) observe that the density of chopped alfalfa-hay pellets is proportional to the natural logarithm of the applied pressure and that an increase in pressure significantly increases density.

(ii) Temperature

Temperature is one of the most important parameters affecting the process of densification and properties of the densified product. Quality attributes of briquettes such as density and durability are significantly influenced by temperature of the barrel as well as the biomass feed. With increasing temperature, pressure required for briquetting goes down (Kaliyan and Morey, 2006). Similarly, the maximum permissible moisture content can be increased with higher temperature (Yaman et al, 2000).

Hall and Hall (1968) found that for a given moisture content, the pressure required to obtain a certain wafer density of Bermuda grass and alfalfa was reduced by the addition of heat in the die. In addition, the upper limits of moisture content at which a certain pressure was able to produce a specific wafer density was increased by the addition of heat. Smith et al. (1977) in their study of briquetting wheat straw, found that the degree of compaction and dimensional stability went up as the temperature was increased from 60 to 140°C. They also found that briquette expansion decreased when the die temperature was between 90 and 140°C. They further observed that briquettes were surface-charred and slightly discolored at temperatures above 110°C due to chemical degradation. Moreover, Bhattacharya and Yeasmin (1984) found that the compression strength of densified biomass depended on the temperature at which densification was carried out. Maximum strength was achieved at a temperature around 220°C. It was suggested that the decrease in compressive strength beyond this temperature was probably due to thermal degradation of one or more constituents of the biomass. Also, it was found that at a given applied pressure, higher density of the product was obtained at higher temperature.

By varying the temperature of biomass, the briquette density, briquette crushing strength and moisture stability can be varied (Joseph and Histop, 1999). In a screw extruder, the temperature does not remain constant in the axial direction of the press, but gradually increases. Internal and external friction cause local heating and the material develops self-bonding properties at elevated temperature. It can also be assumed that the moisture present in the material forms steam under high-pressure conditions, which then hydrolyses the hemicelluloses and lignin portions of biomass into lower molecular carbohydrates, lignin products, sugar polymers and other derivates. The addition of heat also relaxes the inherent fibres in biomass and apparently softens its structure, thereby reducing their resistance to briquetting which in turn results in decreased specific power consumption and a corresponding increase in production rate and reduction in wear of the contact parts (Grover and Mishra, 1996). However, the temperature should not be increased beyond the decomposition temperature of biomass, which is around 300°C. The distinctive feature of a screw type briquetting machine is that heat is applied to the die 'bush' section of the cylinder. This brings about two important operational advantages (Joseph and Histop, 1999). The machine can be operated with less power and the life of the die is prolonged. It has been shown that by heating the material for a determined temperature interval, a more stable product with a lower recovery of original dimensions could be obtained than was possible with unheated materials **(**El-Saeidy, 2004**)**. It has been also concluded that bioresidue having relatively high moisture content could be stably compacted at an elevated temperature, whereas this was not possible at ambient conditions. The temperature of the die should be kept at about 280-290°C. If the die temperature is more than the required one, the friction between the raw material and the die wall decreases such that compaction occurs at lower pressure, which results in poor densification and inferior strength. Conversely, low temperature will result in higher pressure and power consumption and lower production rate (Grover and Mishra, 1996).

Similarly, Motolcsy and For (1986) reported that for pellets produced in a laboratory scale device in the temperature range 130ºC to 170ºC, both strength and moisture stability increased with increasing press temperature. Hill and Pulkinen (1988) found that high-temperature conditioning of the raw materials will increase pellet durability. They reported that pellet durability of alfalfa increases by about 30–35% when pelleting temperature increases from 60 to 104°C. Tabil (1996) found that pelleting temperatures >90°C signifcantly improved durability values of alfalfa pellets. They concluded that it is necessary to precondition the grinds to above 90°C to promote better bonding of particles and to produce good durable pellets. Mani et al. (2003) and Sokhansanj et al. (2005) observed a similar effect in terms of temperature, where higher temperatures resulted in reduced resistance of the material against an applied load for densification and resulted in better quality of pellets. Kaliyan and Morey (2006) used the glass transition temperature behaviour of the biomass to understand the densification behaviour. Glass transition temperature was found to be inversely related to moisture content. Their studies included three different temperatures: two within the glass transition temperature (75 and 100°C) and one outside (150°C). The durability values of the densified biomass outside the glass transition temperature were lower compared to ones within the range.

(iii) Retention/Hold/Residence Time and Relaxation Time

The quality of the briquettes is significantly influenced by the retention or hold times of the materials in the die (Tabil and Sokhansanj 1996). The effect of hold time is more pronounced in the case of low pressure application in comparison to higher pressure cases (Carre et al, 1987). Al-Widyan et al. (2002) found that retention times between 5 and 20 seconds did not have a significant effect on olive cake briquette durability and stability. Li and Liu (2000) found that the hold time for oak sawdust had more effect at lower pressures than at higher pressures. At the highest pressure (138 MPa), the effect of hold time became negligible. They also observed that the holding time had little effect on the expansion rate, and that holding time had more effect at lower pressure than at high pressure. It appeared that hold times greater than 40 seconds had a negligible effect on density. A 10-second hold time could result in a 5% increase in log density whereas at holding times longer than 20 seconds, the effect diminished significantly.

In general, relaxation time impacts the density of materials as well. Final relaxed density of briquetted fuel and the relaxation behaviour following removal from the die depend on many factors related to die geometry, the magnitude and mode of compression, the type and properties of the biomass material, and storage conditions (Shaw, 2008). Many studies on high-pressure compaction of biomass materials have indicated that, on removal of densified material from the die, the density of the compacted material decreases with time to a final relaxed density. For most feed materials, the rate of expansion is highest just after the removal of pressure and decreases with time until the particle attains constant volume (Carre et al. 1987; Miles 1980; Shaw, 2008). The relaxation characteristics, which are mainly measured by the percentage elongation and increase in voidance, depend on many factors related to feed material and storage conditions, such as relative humidity (Wamukonya and Jenkins 1995). Shrivastava and Shrivastava (1990) used statistical analysis of rice husks to establish a multiple correlation and found that the volume expansion of the densified product depended on the die temperature and pressure amongst other factors.

(iv) Die/Mould Geometry and Speed

Die geometry refers to the size and shape of the die. These dimensions affect the durability and density of briquettes. The amount of material that can be pelleted and the energy required for compression are affected as well. Die geometry also influences product properties like moisture content, bulk density, and durability. The L/D (length to diameter) ratio of the pellet die can be a good metric for the degree of compression during pelletization. An increase in the length of the pellet die increases the pelleting pressure, whereas an increase in the diameter of the pellet die decreases the pelleting pressure. Hence, the dimensions of the die and the press channels in the matrix have a strong influence on determining the pressure needed to press pellets through the matrix. (Holm et al, 2006).

Butler and McColly (1959) found that for a constant mass of material, pellet density is greater for smaller diameter chambers at a given pressure, and longer pellets were produced in smaller chambers, which resulted in a lesser expansion. Tabil and Sokhansanj (1996) studied the effect of process parameters like steam conditioning, die geometry, L/D ratio, die speed, and particle sizes of the biomass and found that at a higher conditioning temperature of >95°C, the durability of the pellets increases. They also concluded that durability of the pellets significantly improves when a smaller die with higher L/D ratios is used. Also, they found that the hammer mill screen size does not have much effect on pellet durability, but the speed of rotation of the die (at about 250 rpm) significantly increases durability. Shankar and Bandyopadhyay (2005) found that die barrel temperature and screw speed significantly affect quality attributes like bulk density and hardness of the biomass feed mix during extrusion processing. Shankar et al. (2008a), in their studies on volumetric flow rate through a single screw extruder, found that L/D ratio and screw speed significantly affect the flow rate of the biomass feed mix in a single screw extruder, and this flow behaviour affects the final quality of the pelleted biomass.

Hill and Pulkinen (1988) report that pellet durability of alfalfa increases by about 30–35% when pelleting temperature increases from 60 to 104C. They also indicate that an L/D ratio between 8 and 10 is ideal for making high quality pellets. Heffiner and Pfost (1973) evaluated the effect of three die sizes (4.8 × 44.5; 6.4 × 57.2; and 9.5 × 76.2 mm) on durability, finding that the pellets produced on the smallest die have the best durability values. Tumuluru et al. (2010a), in their article on pelleting of distiller's dried grains with solubles (DDGS), report that larger die diameters of 7.2 mm produce less-durable DDGS pellets as compared to a smaller one (of 6.4 mm), both with and without steam addition.

3. Raw Materials for Biomass Briquettes

3.1 Raw Materials/Feedstock for Biomass Briquetting

The raw material or feedstock is an integral aspect for successful biomass briquetting, which must be suitable in terms of abundant availability, low cost as well as physical and chemical characteristics such as moisture content, ash content, and biomass composition and so on. A variety of organic materials could be used as feedstock for biomass briquettes including agricultural residues, forest residues, municipal and industrial solid waste etc. Oladeji (2015), in his review paper, stated various types of raw materials that have been studied and tested for briquetting including wood residue, tree leaves, straw, grass, wheat straw, cotton residue, rice straw and husk, banana peel and leaves, ground nut shells, maize husks as well as processed material waste such as sawdust, paper, charcoal fines and so on. A list of briquetting raw materials used around the world is tabulated in Table 4.

Table 4. List of Feedstock for Biomass Briquetting by Country

Raw Materials	Country	Reference
Agro-residues	China	Chen et al. 2009
Banana rachis	Colombia	Granados et al. 2014
Carton and textiles	Estonia	Kers et al. 2010
Charcoal dust/fines	Kenya, Uganda	Njenga et al. 2013a, 2013b
Coffee husk/wood residues	Brazil, Colombia	Granados et al. 2014; Felfli et al. 2011
Corn cob	U.S.A.	Kaliyan and Morey 2010
Lignite	Turkey	Beker and Kii 1996
Oil palm	Malaysia	Granados et al. 2014; Shuit et al. 2009
Palm kernel shells	Indonesia	Bazargan et al. 2014
Plastics	U.S.A.	Gug et al. 2015
Rice husk	Colombia, India	Granados et al. 2014; Gadde et al. 2009
Rice straw	India, Southern Taiwan, Thailand	Silalertruksa and Gheewala 2013; Gadde et al. 2009; Tsai et al. 2006
Sawdust/waste papers	Colombia, Kenya, Peru	Granados et al. 2014; Ngusale et al. 2014; Sánchez et al. 2014; Njenga et al. 2013a
Sorghum stalk/corn stover/wheat straw	U.S.A.	Theerarattananoon et al. 2011
Sugarcane bagasse/coconut shells	Colombia, Taiwan	Granados et al. 2014; Tsai et al. 2006
Switch and hay grass	Canada	Roy and Corscadden (2012)
Vegetable waste	India	Srivastava et al. 2014

As shown in Table 3.1, various types of biomass resources can be utilized as feedstock for briquetting. Some studies carried out on briquetting feedstock are detailed as follows:

(i) Rice Husk

Recognizing the potential of rice husk as fuel in Thailand, investigations were carried out to determine techno-economic feasibility of rice husk briquette production (Pitakarnop, 1983).

The study showed that good quality briquettes could be made from rice husk of moisture content 8-12% with heated-die screw press briquetting machines with die temperature in the range 260-280°C. Bhattacharya et al. (1984) densified rice husk in a heated-die screw press. Rice husk was also mixed with water hyacinth at different ratios. Quality tests carried out for the products showed that ricehusk alone formed better briquettes than the mixture.

Brandt (1987) carried out combustion tests for rice husk briquettes. The test results showed that rice husk briquettes produced less CO than wood. Schaap (1985) studied rice husk briquetting with the objective of designing an improved briquetting machine. Combustion and mechanical quality of the briquette in relation to production parameters were analyzed for this purpose. The die was redesigned with a steam outlet to avoid explosion resulting from higher moisture content and heating rate. Bhattacharya et al. (1985) analyzed the potential of the use of densified rice husk and sawdust in Thailand from an energy viewpoint. A survey of rice husk and sawdust briquette manufacturers and market was also conducted.

(ii) Straw/Stover/Stalk/Sticks

Experiments on straw pelletization were carried out in a portable pelletizing unit by Wilen et al. (1985). The mechanical properties of straw pellets produced were found to be comparable to those of peat pellets.

In Germany, a joint enterprise was formed by nine agricultural and one nonagricultural partners for operation of a briquetting plant (Brenndorfer, 1985). The technical function of the plant was satisfactory. Combustion of the briquettes resulted in very low emissions. Koullas and Koukios (1987) densified wheat straw at 100-150°C. The effects of temperature, moisture content, particle size, pressure and the time of treatment on a series of process and product characteristics were analyzed. The gross calorific value of the densified fuel and overall efficiency of processing appeared to pass through an optimum mostly influenced by particle size and pressure.

Krist-Spit and Wentink (1985) reported work carried out in Ethiopia on briquetting of five residues: corn stover, cotton stalks, wheat straw, white coffee parchment and black coffee husks. Two different species of black coffee husks could be distinguished; these are the so called agglomerated and non-agglomerated species. Attempts were made to compress all residues by a conical screw extruder but tests on wheat straw and black coffee husk were unsuccessful. Later a hydraulic piston press was used to compress these materials. Extensive quality tests were carried out for the briquettes. It was concluded that the "screw made" briquettes from cotton stalks, corn stover and white coffee parchment are most likely to be suitable for domestic use. Resistance to humid atmosphere and resistance to mechanical shocks from transport of these were satisfactory. Wheat straw briquettes rendered good combustion results but did not show enough resistance to shock. Agglomerated black coffee husk briquettes were of very poor quality in every respect even though the lignin content of the material was not in any way lower than the other materials.

(iii) Leaves, Grasses and Weeds

The briquette forming ability of water hyacinth was investigated by Koser et al., (1982). Pressure, water content and temperature were found to strongly influence the briquetting process. Riley and Moini (1981) studied harvesting, processing and densification of chaparral with respect to technical feasibility, economics and energy balance. It was concluded that although the concept was feasible from the engineering point of view, the economics was less attractive. Rajvanshi (1985) reviewed and generated data on availability of residues for densification in India. The most suitable biomass materials for briquetting were identified and various suitable binders were explored. Simple economic analysis for producing briquettes from sugarcane leaves showed it to be an unattractive proposition.

Martin (1985) studied the feasibility of harvesting, drying and briquetting papyrus for fuelwood or charcoal substitution in Rwanda. The study concluded that the production of papyrus briquettes would have an economic advantage over wood charcoal.

(iv) Wood Waste

Verma et al. (1979) densified sawdust with the help of low-grade natural gum. Maximum strength was achieved by briquetting a mixture of sawdust, charcoal and gum from *Sterculia villosa* (Gum Chary). According to Gopalachari (1985), research work carried out in Central Fuel Research Institute (India) showed that sawdust briquettes were preferable to rice husk briquettes in tobacco curing, because rice husk briquettes required a special furnace.

Bradfield and Levi (1984) studied the effect of species and wood to bark ratio on pelletization. Pelletization of pure hardwood alone was not successful. Higher percentage of bark in furnish gave higher amount of lignin and extractives. As lignin and extractive content increased above a threshold level of about 34 percent, the durability of pellets decreased. A possible explanation given for this result was that the auto-adhesive action of the thermally softened, non-crystalline wood polymers are like that of mastic with little internal strength of its own. Above the threshold value of non-crystalline wood polymers, "excessive mastic" between crystallites reduces the strength and durability of the pellets. Species with almost the same lignin and extractive content did not show similar ability to be pelletized. This could be due to difference in hemicellulose fraction, percentage of extractive and chemical composition of lignins and extractives.

Young (1987) reported about some combustion tests carried out to compare charcoal with partially pyrolysed briquettes, unpyrolysed briquettes and wood. Different combinations of fuels and stoves were used to study the percentage heat utilized, burning rate, emissions and flame patterns. The study concluded that sawdust briquettes had similar combustion characteristics to wood and would never be a substitute for charcoal in existing stove designs; there was no appreciable difference between unpyrolysed and partially pyrolysed briquettes with densities ranging from 750 kg/m3 to 1,200 kg/m3 with heat treatment up to 150°C.

(v) Other Biomass

Hislop (1986) reported a case of residue briquetting in Gambia. In 1980, a groundnut shell briquetting plant was installed near the capital of Banjul. Briquettes were manufactured successfully but the existing charcoal stove did not burn the briquettes efficiently and produced an acrid smoke. Production was ceased after a year due to breakdown of a machinery component.

Grover (1996) found that ground groundnut shells could be satisfactorily briquetted by means of a heated-die screw press; the briquette production was found to increase by 20% on the rated capacity of the machine. He also pointed out that groundnut could also be briquetted without grinding; however, the briquette quality would not be very good and the screw wear would be more. Eriksson and Prior (1990) presented an interesting account of briquetting residues, including groundnut shell, in Africa.

Mannaperuma (1982) reported about a coir dust compaction unit that consisted of a mechanical dewatering equipment, a solar dryer and a densifier. Initially several types of densifiers were tried; among those, a heated-die screw-press was found to be the most suitable.

3.2 Feedstock Characteristics

Aside from availability and costs, there are a number of characteristics of the raw material that play key roles in determining their suitability for briquetting and as a fuel. The analysis of feedstock suitability is done using three methods: (i) Proximate analysis- which evaluates the fixed carbon, volatile matter, moisture and ash content; (ii) Ultimate analysis- which determines the component elements and their percentage composition; (iii) Analysis of physical and chemical characteristics- this includes calorific value, particle size, shape and distribution, bulk density and biomass composition. Analytical results of various biomass materials are presented in Table 7.

The pertinent characteristics for biomass briquetting feedstock are detailed as follows:

(i) Moisture content

Moisture content refers to the amount of liquid, especially water, which is inherently present in almost all biomass materials. This moisture can act both as a binding agent as well as a lubricant. An optimum moisture content is necessary for the density, stability, and durability of the briquette or pellet. Higher moisture content could drive up the costs as more energy is consumed during drying and densification (for the removal of excess moisture). Whereas, lower moisture content could lead to flakiness within the material (Asamoah et al, 2016). It has been studied that moisture aides in densification as it can increase the attraction and contact area of particles via the van der Waal's forces (Mani et al, 2003). Moisture in biomass material assists in the processes involving breakdown of complex constituents- starch gelatinization, protein denaturation, and fibre solubilisation. Steam treatment can further promote these reactions, resulting in considerable improvement in the binding ability of the particles (Thomas et al. 1997). It was reported moisture content between 8-12% is optimum for briquetting (Kaliyan and Morey, 2009; UNEP, 2013). Kaliyan and Morey (2009) also reported that 12-20% moisture content may aide cold densification (at room temperature). However, densifying materials with moisture content over 20% may be impossible.

Tumuluru et al (2011) stated in their review that the optimum moisture content depends on the type of feedstock and the operating conditions. In the case of corn stover, lower moisture content (5-10%) resulted in briquettes with greater density, durability and stability compared to biomass with 15% moisture (Mani et al, 2006). Li and Liu (2000) studied the densification in a punch and die assembly of grass, wood shavings, tree bark, sawmill waste, fresh alfalfa and alfalfa hay, and reported that the optimum moisture content of 8% for dense briquettes. While, moisture content below 4% causes briquettes and pellets to become fragile within a few days. Moreover, they remarked that 5-12% moisture content can produce logs of suitable density and long-term storability from bark, hardwood and softwood in the form of chips, sawdust and mulches (Li and Liu, 2000). Felfi et al (2011) concluded that the sugar cane bagasse has high moisture content (about 50%) and much energy is necessary for its drying before its briquetting. These factors suggest that the sugarcane bagasse is less appropriate for briquetting than other residues such as rice husk, coffee husk and sawdust, which have homogeneous particle size, very good flowability and moisture content below 15%.

Briquetting at optimum moisture content and temperature could facilitate the melting of lignin which can in turn enhance the binding properties. Kaliyan and Morey (2009) stated that the level of moisture can have an effect on the glass transition temperature (also known as the glass-liquid transition temperature, i.e. the point at which an amorphous material changes (reversibly) from a hard and relatively brittle "glassy" state into a viscous or rubbery state). They reported that corn stover with 10-15% moisture levels showed a reduction in glass transition temperatures of around 70–90°C. It found that rise in moisture levels led to considerable reduction in glass transition temperature of lignin, gluten and starch (Chirife and Del Pilar, 1994).

Thus, moisture content broadly affects biomass densification in three ways:

(i) Reduction in glass transition temperature;
(ii) Enhances solid bridge formation;
(iii) Increases the contact area of particles by van der Waal's forces.

(ii) Ash Content

Ash is the residue that remains after combustion, which consists mainly of non-combustible inorganic materials such as minerals and metals as well as combustible organic matter (in case of incomplete combustion). Typically, biomass materials have lower ash content compared to coal. However, ash from biomass usually contain higher amounts of alkaline minerals (mainly potash), which tend to devolatalise[1] during combustion and condense on tubes (especially on those in the superheaters). These substances also reduce the ash sintering[2] temperature, resulting in deposition of ash on the exposed surfaces of the boiler, which can lead to reductions in efficiency. On the other hand, rice husk has a relatively high ash content of 20% but the ash contains fewer alkaline minerals, thereby it has a high ash sintering temperature.

Increased slagging[3] behaviour is also associated with high ash content. Slagging behaviour is determined by the temperature of operation and the mineral composition of ash. Minerals such as K_2O, Na_2O and SiO_2 are problematic in this regard. Researchers have not yet been successful in evaluating the slagging temperature of ash, due to several complexities involved. Slagging usually occurs when biomass with greater than 4% ash content is used (Grover and Mishra, 1996).

(iii) Volatile Matter

These comprise of the components of carbon, hydrogen and oxygen present in biomass that are released as vapour (typically as short and long chain hydrocarbons) upon application of heat. The presence of volatile matter can influence the combustion rate and to an extent the heating value. Most biomass materials have higher volatile matter (70-86%) compared to coal (around 35%) (Loo and Koppejan, 2008). Thus, biomass have more fractional heat contribution from volatiles, more reactivity and faster combustion rate during devolatalization phase as compared to coal (Chaney, 2010). Fuels with lower volatile matter require processing into powdered form and longer time for combustion (Veeresh et al, 2012).

(iv) Fixed Carbon

The combustible solid residue (char) - remaining after volatile matter is released upon heating a fuel- is mainly comprised of fixed carbon and some remaining amounts of hydrogen, oxygen, sulphur and nitrogen. It is essentially the percentage of carbon available for char combustion. The amount of fixed carbon gives a rough estimate of heating/energy value of the material. This is not equal to the total amount of carbon in the fuel because a considerable amount is released as hydrocarbons in the volatiles.

(v) Particle Size, Shape and Distribution

Particle size and shape are integral factor for the densification process. The The compaction process becomes easier with smaller particle size. Finer particles also posses a larger surface area for accepting moisture andbonding, resulting in a more dense and durable densified product. In general, the particle size should be below 25% of the densified product (UNEP, 2013). Residues of small particle size such as sawdust, coffee husk, rice husk can be used directly as feed materials for briquetting. However, bigger biomass materials such as groundnut shell, cotton stalk etc. need to be reduced in size to be suitable for densification. A hammer mill may be used to reduce the biomass particle size. Materials such as wood and straw may require chopping before hammer mill. It is useful to crush larger particles to get a random distribution of particle size, which results in sufficient amount of small particles is present for interlocking into the larger particles. The presence of different size particles improves the packing dynamics and also contributes to high static strength (Ludwig, 1994). However, granular and uniform particles ensure better flowability in bunkers and storage silos (Grover and Mishra, 1996). Thus, both these factors need to be considered before deciding the particle size and distribuition.

In the case of pelletization, Payne (1978) and MacBain (1966) concluded that fine and medium-ground particles are preferred as they provide a greater surface area for moisture addition during steam conditioning which improves binding. They also stated that certain amounts of fines to medium particle sizes increase the pelleting efficiency and reduces costs. However, very small particle sizes can result in jamming of the pellet mill and reduction in productivity. On the other hand, large particles are fissure points that cause cracks and fractures in pellets Table 5shows the ideal particle size distribution for producing quality pellets (MacBain; 1966).

Table 5. Ideal particle size distribution for producing quality pellets (Payne, 1997)

Sieve size (mm)	3.0	2.0	1.0	0.5	0.25	<0.25
Material retained on sieve (%)	≤1	≤5	≈20	≈30	≈24	≥20

Particle sizes above 6 mm are preferred in the case of briquetting as it results in better interlocking of the particles and increased durability (Tumuluru et al, 2011). Grover and Mishra (1996) suggest biomass material of 6-8 mm size with 10-20% powdery component (< 4 mesh) produce best results for briquetting. They also stated that even though high pressure screw extruders (100 - 150 MPa) are capable of briquetting material of oversized particles, the briquetting will not be smooth and clogging might take place at the entrance of the die resulting in jamming of the machine. In addition, larger particles which are not conveyed through the screw start accumulating at the entry point and the steam produced due to high temperature inside the barrel of the machine starts condensing on fresh feed resulting in lump formation and subsequent jamming. However, fine and powdered particles of size less than 1 mm are not suitable for a screw extruder because they are more cohesive and non-free flowing entities. Moreover, for some biomass residues, such as hard shells, the act of breaking them down into smaller irregular shapes can help fibres and particles to pack more closely, therefore aiding agglomeration (Engelleitner, 2001)

On the other hand, Song et al. (2010) reported that particle sizes between 19.05–31.15 mm resulted in good quality briquettes using a hydraulic piston press with wheat, oats, barley, and canola. They also concluded that larger particle sizes during briquetting help in interlocking particles and produce a more durable briquette. Furthermore, Faborode and O'Callaghan (1987) analysed the effects of mechanical pre-processing (chopping and grinding) on the production of straw briquettes in closed dies, between pressures of 8 MPa to 50 MPa. Although greater difficulty and longer hold time is required to achieve binding unchopped straw when compared with chopped straw, their results indicate that when binding does take place, the briquettes showed more stability. In other words, for high pressure compaction, briquettes formed from unchopped straw were more stable, although more energy was required for their formation to overcome frictional forces. (Faborode and

O'Callaghan, 1987). Thus, particle size and distribution need to be considered according to the biomass/residue and densification technology.

(vi) Bulk Density

This parameter is defined as the mass per unit volume of a material, expressed in kilograms per cubic metre (kg/m3) or pounds per cubic foot (lb/ft3). Higher bulk density results in higher energy/volume ratio, easier handling and storage as well as a more durable product. Bulk density can be improved by reducing the particle size (Trezek et al, 1981). The bulk densities of some loose biomass material are shown in Fig. 33.

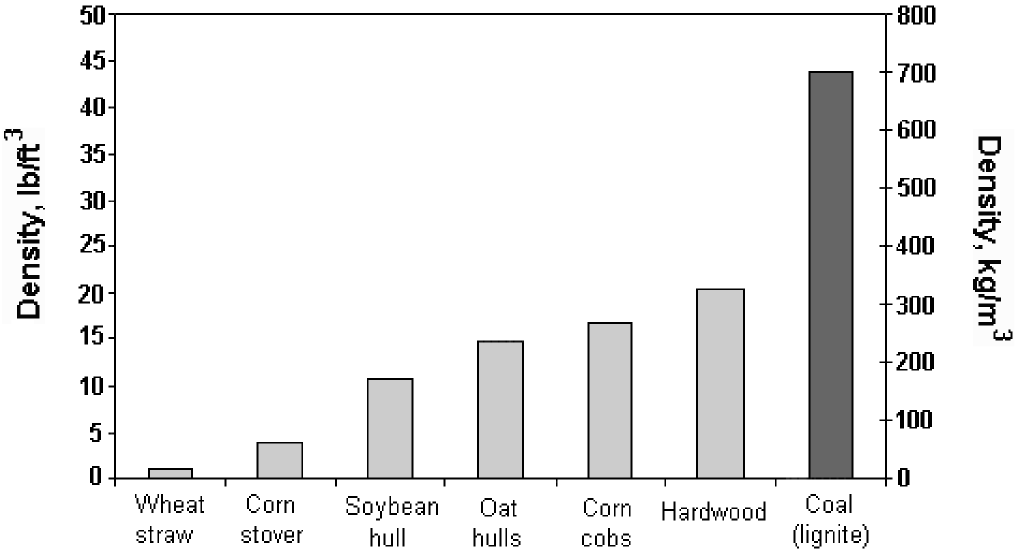

Fig. 33. Typical bulk densities of biomass materials and coal (Clarke, 2011)

(vii) Calorific Value

The calorific value (typically expressed in MJ/kg) is an important parameter as it is a measure the energy content of the material. This energy can eventually be turned into heat energy through combustion. Thus, biomass with higher calorific value is preferred as feedstock for fuel briquettes. The calorific value depends largely on the content of carbon and hydrogen, and vary according to the type of material. The calorific value is limited by fuel moisture content as heat is used to vaporise the water, lowering the heat released. Furthermore, it is also limited by the ash concentration in a fuel; approximately every 1% addition of ash translates to a 0.2 MJkg-1 decrease in the heating value (Chaney, 2010).

(viii) Elemental Composition

The elements that constitute biomass materials are darbon, hydrogen, oxygen, nitrogen and sulphur. The main components of solid fuels are carbon, hydrogen and oxygen. Ultimate analysis of biomass using this method reveals the principal constituent as carbon, which comprises between 30 to 60 % of the dry matter. After that, typically 30 to 40 % is oxygen. Hydrogen is the third main constituent making up between about 5-6%. Typically nitrogen and sulphur (and chlorine) normally make up less than 1% of dry biomass. Higher the ratio of the sum of carbon and hydrogen to oxygen [(C+H)/O]- higher the calorific value (Vargas-Moreno et al, 2012). Usually biomass with lower sulphur and nitrogen content are preferred as they may give rise to harmful emissions of sulphur oxides and nitrogen oxides respectively.

(ix) Biomass Composition

Biomass energy is essentially the stored solar energy in the form of chemical energy of its constituents, as a result of photosynthetic reaction. The components of biomass include cellulose, hemicelluloses, lignin, lipids, proteins, simple sugars, starches, water, hydrocarbons (HCs), ash, and other compounds. The concentrations of each class of compound vary depending on species, type of plant tissue, stage of growth, and growing conditions. In general, most land biomass is composed primarily of lignocellulose (i.e. cellulose, hemicelluloses and lignin). Plant biomass has both low molecular weight and macromolecular compositions. Low-molecular-weight substances include organic matter and inorganic matter, while macromolecular substances include cellulose, hemicellulose, and lignin (Mohan et al. 2006). This proportion of combustible organic components are also known as extractives.

The compositional changes that occur during biomass processing and densification can have an impact on the standard of compaction. The effects of densification process variables (as described in Section) on some common chemical constituents like starch, cellulose, hemicellulose, fat, and lipid can indicate briquette quality parameters such as moisture content, bulk density and durability of the densified biomass. Shankar and Bandyopadhyay (2004 and 2005) and Shankar et al. (2008) reported that the protein and fat in the feed material significantly affect the quality of the extruded feed and also inflence flow behavior. Along with this, starch behaves as a natural binder as well (Karunanithy et al, 2012). Moreover, Thomas *et al* (1998) identifed some of the important ingredients that influence pellet quality, including starch, protein, nonstarch polysaccharides (NSP), sugar, fat, fber, inorganic matter, and water. Lignocellulose refers to plant dry matter (also known as lignocellulosic biomass), which is composed of carbohydrate polymers (cellulose, hemicellulose), and an aromatic polymer (lignin). Cellulose and hemicelluloses (holocellulose) have a gross energy value of 18.60 MJ/kg, whereas that of lignin varies from 23.26 to 26.58 MJ/kg (Demirbas, 2009).

Fig. 34 shows the arrangement of cellulose, hemicellulose, and lignin in a biomass matrix. The biochemical compostion of some agricultural straws and woody biomass are listed in Table 6.

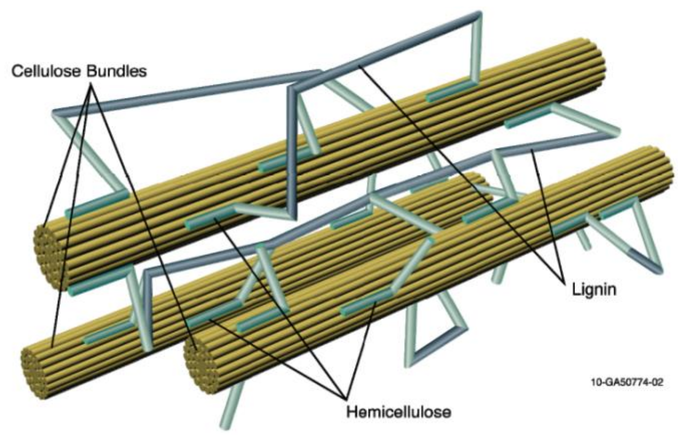

Fig. 34. Arrangement of cellulose, hemicellulose, and lignin in biomass matrix (Murphy and McCarthy 2005; Shaw 2008)

(a) Starch: Starch is an available component in plant matter, which acts as a binder (Thomas et al, 1998; Wood, 1987). It occurs as semi-crystalline granules in the chloroplasts of green leaves and in the amyloplasts of storage organs such as seeds and tubers. Starch is a D-glucose polymer with branched (amylopectin) or unbranched (amylose) chains (Collado and

Corke 2003). Its behavior is mainly controlled by the gelatinization it undergoes at high processing temperatures in the presence of moisture. It is further improved by mechanical shearing during the densification process. Starch granules at high temperatures and moistures influence the binding properties of the feed. Collado and Corke (2003) state that starch undergoes mainly the reactions of gelatinization, pasting, and retrogradation, and, among all these reactions, gelatinization plays a major role in the pelletization process. Gelatinization of starch is an irreversible process and is mainly influenced by densification process variables like heat, water, shear, and residence time (Thomas et al. 1999). Binding/adhesion characteristics of starch are mainly based on the amylase-to-amylopectin ratio. During gelatinization of the starch granule, amylase immediately forms double helices that may aggregate (hydrogen bonds) to each other, creating semi-crystalline regions and helping in binding (Tumuluru et al, 2011). In the pelleting process, starch not only acts as a binder but also as a lubricating agent, helping to ease the flow of materials through the die. The greater the percentage of starch gelatinization, the higher the pellet durability (Heffner and Pfost, 1973). Wood (1987) studied the effects of adding raw starch or pregelatinized starch on the pellet hardness and durability. He found that pregelatinized starch resulted in higher pellet hardness and durability values than those for raw starch.

Table 6. Biochemical Composition of Selected Agricultural Straws And Woody Biomass (Adapa et al, 2009; Demirbas, 2009; Mohan et al, 2006; Pratima, 2016; Sjostrom, 1993)

Compostion (% d.w.)	Wheat Straw	Barley Straw	Rice Straw	Hardwoods	Softwoods	Corn cobs	Grasses	Switch-grass
Protein	2.33	3.62	-	-	-	-	-	-
Fat	1.59	1.91	-	-	-	-	-	-
Starch	2.58	0.11	-	-	-	-	-	-
Lignin	13.88	17.13	14.2	16–25	25–35	15	10–30	12
Cellulose	34.2	33.25	34	40–55	40–50	45	25–40	45
Hemicellulose	23.68	20.36	27.2	24–40	25–35	35	35–50	12

The main components in biomass, i.e. starch, proteins, fats and lignocellulesic materials (cellulose, hemicellulose and lignin) are detailed as follows:

(b) Protein: Protein will plasticize under heat and act as a binder, which helps increase the strength of the densified products (Briggs et al., 1999; Winowiski, 1988). During feed pelleting, the combined effects of heat, moisture, and shear result in protein denaturation, which induces the binding functionality of protein (Thomas et al, 1998; Wood, 1987). Protein that is heated during the densification process undergoes denaturization leading to the formation of new bonds and structures with other proteins, lipids and starch available in the biomass and improves the binding capacity (Nyanzi and Maga, 1992; Thomas et al., 1998).

According to Briggs et al. (1999) and Wood (1987), increasing the protein content increases pelleted feed durability. Raw protein improves the physical quality of the pellets better than denatured proteins. Feed pellets formed using extrusion of protein result in the modification of the protein structures where non-covalent and covalent bonds stabilizing secondary structures are destroyed, resulting in new intermolecular bonds (Lampart-Szczapa et al. 2006). Extrusion processing of proteins results in texturization mainly because of aggregation, fragmentation, and covalent cross-linking between protein and starch (Schaich and Rebello 1999; Shankar and Bandyopadhyay 2006). Wood (1987), in his article on the functional properties of protein and starch fractions, concludes that protein plays a great part in feed quality attributes like hardness and durability, which shows that pellet durability is protein-dependent and emphasizes that protein in raw form and starch in a gelatinized state, when added, generate more durable pellets (Table 8).

Shankar and Bandyopadhyay (2004; 2005) at higher processing temperatures of 100–200°C proteins crosslink with starches and lipids, which results in more durable and stable pellets. They also found that feed moisture content plays a key role in these processes. Sokhansanj et al. (2005) found that feed material with larger fractions of starch and protein composition produces denser and more stable pellets than biomass with a larger composition of cellulose. Also it was found that 8–12% moisture level is the ptimum condition for pelleting cellulosic materials.

(c) Fat/Lipid: In general, the fat added to the biomass acts as a lubricant during pelletization, increasing throughput and reducing pelleting pressure (Thomas et al. 1998). But an increase of fat decreases the binding capacity of the biomass and may require additional binders to improve its durability and hardness. This is because fat acts as a lubricant between the feed particles, and between the feed and the pellet-mill die-wall. In the case of of animal feed pellets with higher fat content, pressure in the die is decreased due to low friction which would result in with lower durability (Angulo et al, 1996; Briggs et al 1999; Cavalcanti, 2004; Richardson and Day, 1976; Stark, 1994). Rout (1997) in his article on extrusion of aquafeed with high lipids of about 8–10%, found that a commercial binder is required to improve density and water-stability values. Briggs et al. (1999) found that increased oil content produces lower quality pellets since fat is hydrophobic and tends to interfere with particle binding during pelletization and inhibits the binding properties of the water-soluble components in the feed such as starch, protein, and fiber (Thomas et al, 1998). Moreover, high levels of fat (>6.5%) affected the binding functionality of starch and protein, and the fat content was the dominant factor determining the pellet durability.

(d) Cellulose: Cellulose is an integral structural component of the primary cell wall in plants, various types of algae and other other organsims. It is an organic, polysaccharide compound ($C_6H_{10}O_5$) consisting of a linear chain of several hundred to over ten thousand $\beta(1\rightarrow4)$ linked D-glucose units (Crawford, 1981; Updegraff, 1969). Cellulose forms crystalline microfibrils that are surrounded by amorphous cellulose inside plant cells (Chen et al, 2004). The structural integrity of cellulose is due to hydrogen bonding that occurs between glucose monomers (Goldstein 1981). According to Nelson and Cox (2005), cellulose is considered to be an abundant source of carbon in biomass. Semi-crystalline structure and highly hydrogen bonded cellulose itself is not a suitable adhesive, but this limitation can be overcome by heat treatment in the drying range, making the cellulose molecule more flexible. For hot pressing of wood material, Zandersons et al. (2004) conclude that the strength of binding in wood-based products mainly depends on converting cellulose to an amorphous state.

(e) Hemicellulose: Hemicellulose is any of several heteropolymers (matrix polysaccharides), such as arabinoxylans, present along with cellulose in almost all plant cell walls. Hemicellulose found in the cell wall is more of a heteropolysaccharide, which is a combination of many sugars other than simple glucose. While cellulose is crystalline, strong, and resistant to hydrolysis, hemicellulose has a random, amorphous structure with little strength. It is easily hydrolyzed using a dilute acid or base as well as many hemicellulase enzymes (Tumuluru et al, 2011). The amorphous structure of hemicelluloses – which is easily hydrolyzed or dissolved in alkali solution – results from branching. Some researchers believe that natural bonding may occur due to the adhesive products produced by degradation of hemicellulose (Grover and Mishra, 1996).

Table 7. Properties of some Raw Materials for Densification (Asamoah et al, 2015)

Raw Material	Proximate Analysis						Ultimate Analysis					
	Moisture Content (%)	Ash Content (%)	Volatile Matter (%)	Fixed Carbon (%)	Calorific Value (MJ/kg)	Bulk Density (kg/m^3)	Carbon (%)	Hydrogen (%)	Oxygen (%)	Nitrogen (%)	Sulphur (%)	Chloride (%)
Coconut husk/shells	7.5-18.1	0.5-5.9	76.0-81.4	17-20.7	15.5-23	-	47.0-63.5	5.8-6.7	28.3-45.2	0.3-0.8	0.1-0.3	0.1-1.0
Corn cob/husk/straw/ stover	7.0-9.3	4.6-11.8	72.2-84.3	6.7-16.8	-	1,017	45.4-51.2	5.0-6.2	33.0-46.4	0-0.9	0-0.2	0.2
Rice husk/straw	5.1-15.5	7.9-23.5	56.1-68.3	14.2-17.5	14.2-20.5	327	32.6-55.0	4.1-8.1	32.8-42.1	0.2-2.7	0.1-0.4	0.1-0.7
Groundnut shell	1.6	1.5-1.9	77.5-81.5	17.1-19.6	19	-	-	-	-	-	-	-
Tamarind shell	2.8-3.2	3.1-3.4	74.0-78.3	19.3-21.8	15.1	-	-	-	-	-	-	-
Palm fiber/shell/oil	4.2-36	7 4-7.3	78.3-78.9	9.9-10.5	18.4-35.5	-	42.5-42.9	6.4-6.7	42.6-43.3	1.0-1.1	0.1	0.1
Paper waste	7.4-12.6	1.2-15.5	65.5	-	13	-	35.2-48.0	4.9-6.6	51.3-36.8	0.1-0.2	0.1	-
Refuse derived fuel (RDF)	5.1-16.3	1.2-28.0	58.4-83.0	8.3-12.1	13.5-22.0	-	32.5-46.0	4.6-6.6	36.0-49.3	0.3-2.7	0.7	0.3
Grass	3.5-5.0	6.7-22.5	63.3-76.7	9.2-14.3	12.6-17.4	650	42.7-46.7	5.6-6.8	37.4-44.6	0.7-4.2	0-1.7	0-0.2
Sawdust	1.8-9.8	0.2-5.6	77.7-88.6	2.2-21.6	17.5-34.3	133-210	48.3-50.8	5.5-7.0	41.2-46.5	0.1-1.5	< 0.01	-
Shrubs	40.7-48.7	0.1-1.2	73.0-81.5	12.6-25.8	-	50-1,010	-	-	-	-	-	-
Wood	5.3-15.5	0.0-7.5	74.7-85.0	14.6-17.4	16.6-19.0	284-1,026	47.6-53.6	5.6-7.7	36.6-46.0	0.1-0.2	< 0.01	0.0-0.1

Table 8. Effect of Forms of Starch and Protein on Pellet Durability (Wood, 1987)

Ration Mixture	Holmen Pellet Durability (%)
40% raw starch & 60% raw protein	85
40% pregelatinized starch & 60% raw protein	96
40% raw starch & 60% denatured protein	19
40% pregelatinized starch & 60% denatured protein	70

(f) Lignin: Lignin is a a non-crystallized aromatic polymer most commonly derived from wood and an integral part of the secondary cell walls of plants and some algae (Lebo et al, 2001; Martone et al, 2009). The lignin molecule in a plant provides many structural purposes, such as acting as glue to the cellulose fibers. Lignin is a random network polymer with a variety of linkages based on phenyl propane units (Zandersons et al, 2004). Lignin plays a crucial part in conducting water in plant stems. The polysaccharide components of plant cell walls are highly hydrophilic and thus permeable to water, whereas lignin is more hydrophobic, which helps improve storage behavior. At around 200–300°C, lignin starts to become soft, melted and liquefied. At high pressure lignin can glue the cellulose together and solidify to form the briquette (Bhattacharya, et al., 2002; Ilavsky and Oravec, 2000; Moral and Rahman, 2001).

Lignin helps in building solid bridges at elevated temperatures and plays a signifcant role in biomass densifcation. The presence of lignin in the plant materials helps to form pellets without binders. It is the component that permits adhesion in the wood structure and acts as a rigidifying and bulking agent (Anglès et al. 2001). It is, in general, believed that highly lignifed wood is more durable and therefore a good raw material for many applications. It is also an excellent fuel, because lignin yields more energy when burned than cellulose Van Dam et al. (2004) report that lignin exhibits thermosetting properties at working temperatures of >140°C and acts as intrinsic resin in binderless board production. Lignin is the component that permits adhesion in the wood structure and acts as a rigidifying and bulking agent (Anglès et al. 2001). Lehtikangas (1999) states thatmoisture of about 8–15% in biomass will reduce the softening temperature of lignin to 100–135°C by plasticizing molecule chains. The adhesive properties of thermally softened lignin are thought to contribute considerably to the strength characteristics of briquettes made of lignocellulosic materials (Granada et al. 2002).

However, Lehtikangas (1999; 2000) reported a loose correlation between lignin content and pellet durability. Similarly, Wilson (2002) concluded that there is no consistent relationship between lignin content and pellet durability for hard and sofwoods, but that a mixture of woody biomass with higher lignin content gave less durable pellets compared to pure samples. Bradfeld and Levi (1984) reported that when lignin plus extractives content increased above a threshold level of 34% in wood samples, the pellet durability decreased.

3.3 Pre-processing and Feeding of Raw Materials

The configuration of various pre-processing equipment and machinery required in a briquetting plant depend largely on the type of raw materials used for briquetting. For example, a dryer will be required for raw materials with high moisture content (e.g. wood, shrubs, bagasse etc.) and for coarse and stalky materials (e.g. groundut shell, cotton stalk etc.) a grinding unit will be necessary. The stalky materials (e.g. wood, straw etc.) also require a cutting/clipping mechanism and so on. Further information regarding particle size is provided in Section 3.2 (v). Based on the three categories of raw materials, i.e. fine granulated, coarse and stalky the equipment matrix for different possible combinations of briquetting machines is presented in Table 9.

Pre-processing or pretreatment of herbaceous and woody biomass improves both its physical and chemical properties, thereby making the material easy to densify and helping minimize the costs of transport, handling, and storage. Pretreatment using high temperatures makes the material more energy dense, opens up the cell-wall structure, and makes the material easy to densify and transport. Pre-processing equipment includes cutter/clipper (e.g. knife cutting mill), drying equipment (e.g. flash dryer, hot-air generator, pneumatic fans, cyclone separator and drying column) and hammer-mill grinder. Feeding of the raw material is usually done using screw feeders. Material handling equipment includes screw conveyors, pneumatic conveying system and holding bin.

Table 9. Pre-processing and Feeding Equipment Requirement for Various Raw Material Types (Tripathi et al, 1998)

Component	Fine Granulated Material		Coarse Granulated Material		Stalky Material	
	Dry	Wet	Dry	Wet	Dry	Wet
Cutter/Clipper	-	-	-	-	-	+
Dryer	-	+	-	+	-	+
Grinder	-	-	+	+	+	+
Material Handling Equipment	-	-	+	+	+	+
Screw Feeder	+	+	+	+	+	+

Note: '+': Used; '-': Not Used

The various methods for pre-processing raw materials are described as follows-

(i) Grinding: Prior to densification, biomass is ground to a certain particle size. This grinding partially breaks down the lignin, increases the specific area of the materials, and contributes to better binding. Mani et al. (2006), Peleg (1977), and Peleg and Mannheim (1973) concluded that particle size has a significant effect on the binding characteristics and the mechanical properties of pellets. Fine powders have advantages in densification because they have a higher number of contact points, more exposed surface area, and greater surface energy per unit of weight regardless of their physical and chemical characteristics.

Hammer mills are usually employed to reduce the particle size of the feed material. Except sawdust, bagasse pith, coir waste and other materials of similar size, all other materials should be crushed to 6-8 mm size with 10-20% fines to achieve optimum briquetting results. While many types of crushing and grinding equipments are available in the market, for biomass materials, hammer mills are considered the most suitable. These are available in various sizes from a few kg/hr to 10-15 TPH. Maintenance is rather routine and heavy in these machines and it is advisable not to operate these machines for more than 20 hours per day. Some hammer mills are symmetrical so the direction of the rotor can be reversed. In this case, more running time is possible without maintenance.

The output size is governed by the clearance between the lower end of the hammers and the housing and openings of cylindrical grating positioned beneath the rotor. It retains material until reduced to a size small enough to pass between the bars of the gratings. The impact parts are built using high chromium alloys to provide requisite wear resistance to abrasion and impact normally encountered on multiple hammers, casing and spherical grating or sieve. The speeds of these mills vary from 600-1500 rpm. For biomass materials, it is essential to avoid gravity discharge from the hammer mills; instead, suction is produced by an induced draft blower to suck and convey the material pneumatically. Basically, hammer mills are bought out items and are supplied complete with a pneumatic conveying discharge cyclone, a blower and dust separators by many vendors. Most of these vendors have pilot plant facilities to test new materials and then recommend an appropriate machine complete with rpm and power ratings of the motor.

(ii) Preheating: Preheating the biomass to 100–130°C before densification results in better binding characteristics and a higher quality product. It has also been found to reduce power consumption in the range of 10-40% (Bhattacharya et al, 2002; Grover et al, 1994). Most commercial pellet or briquette producers use preheating to form more stable and dense pellets or briquettes (Bhattacharya et al. 1989; Bhattacharya 1993). Aqa and Bhattacharya (1992) indicate that preheating biomass could significantly increase the throughput of the pelletizing machine and reduce the energy requirement per kilogram of the biomass pellets formed.

(iii) Drying: Drying is normally not required for materials like coffee husk, groundnut shells and rice husk. However, drying is essential for sawdust, wet coir pith, bagasse and bagasse pith and some other agro-residues like mustard stalk. If feed is wet and drying becomes essential, integrated drying cum disintegration should be carried out by using the hot flue gases from the thermic fluid preheating furnace.

The types of drier employed for biomass materials are paddle indirect drier, flash, direct type, pneumatic or flash, and direct or indirect type rotary driers. Direct driers are those in which hot air or flue gases are intimately mixed with material and indirect ones are when heat is transferred to materials through a metallic surface and material is not mixed with the hot streams. Indirect driers are normally inefficient and require a large heat transfer area making the equipment bulky and expensive. Rotary driers are highly reliable but tend to be an order of magnitude more expensive than a flash drier, especially at a capacity less than 3-4 TPH. On the other hand, flash driers are highly suitable provided care is taken to avoid hot spotting within the system. This can easily be achieved by controlling the temperature and flow rate of hot steam and ensuring that there is no accumulation of solids at any stage of drying. Otherwise, as the material is highly combustible, a spontaneous fire might occur in the drier. For this reason, fluidised bed driers are not recommended. Another main advantage of a flash drier over a rotary drier is that the former can simultaneously dry, disintegrate and convey the material.

(iv) Steam Conditioning and Explosion: Steam explosion is a technique that has been widely used and is found to be an efficient method of pretreatment for both herbaceous and woody biomass, either for densification or ethanol production. In general, compressed hot water or steam is commonly used in this process. During steam explosion, which is a high-temperature, short-time process, the material is introduced into a reactor and heated under pressure at elevated temperatures. This process produces significant physical, chemical, and structural changes in the biomass and makes more lignin sites available for binding during pelletization (Liu and Wyman 2005). Steam explosion breaks down the lignin into low-molecular weight products, which retain the basic lignin structure and are moderately reactive. Mosier et al. (2005) postulate that the compression and compaction characteristics of the biomass can be improved by disrupting lignocellulosic biomass materials via steam explosion pretreatment.

Steam explosion also has benefits in terms of enzymatic hydrolysis, which are: (1) lignin is extensively depolymerized by cleavage of the β-aryl-ether bonds and is soluble in alkaline solutions or certain organic solvents, and (2) hemicelluloses are partially broken down, are predominantly soluble in water, and apparently condense with lignin, thereby increasing the lignin content. The major effect of a steam explosion is the large increase in the accessibility of cellulose to enzymatic hydrolysis. (DeLong 1981; Foody 1980; Marchessault et al. 1981a; 1981b; Marchessault 1961; Nunes and Pourquie, 1996). According to Zandersons et al. (2004), the activation of lignin and changes in the cellulosic structure during steam explosion help in the formation of new bonds, which in turn create more durable pellets. Steam explosion brings about significant changes in the materials as the hemicelluloses become more water soluble, cellulose is slightly depolymerized, and the lignin melts and is depolymerized (Toussaint et al. 1991). Kaar et al. (1998) note that steam explosion requires little or no chemical input and thus is more environmentally friendly than chemical treatment methods.

(v) Torrefaction: Torrefaction is a method of changing the properties of biomass materials by slowly heating it in an inter-environment to a maximum temperature of 300°C (Felfli et al. 1998). The process is also called a mild pyrolysis as most of the smoke-producing compounds and other volatiles are removed resulting in a final product that has approximately 70% of the initial weight and 80–90% of the original energy content (Arcate, 2000; 2002). Thus, treatment yields a solid uniform product with lower moisture content and higher energy content compared to the initial biomass.

During the initial heating process, biomass undergoes drying and heating until most of the water is removed due to chemical reactions through a thermo condensation process. This happens at over 160°C and also results in the formation of CO2 (Zanzi et al. 2002). Between 180 and 270°C, the reaction is more exothermal, and the degradation of hemicellulose continues. At this point, the biomass begins to brown and give off additional moisture, carbon dioxide, and large amounts of acetic acid with some phenols that have low energy values (Zanzi et al. 2002). The major reactions of decomposition affect the hemicelluloses, and to a lesser degree, the lignin and cellulose (Shafizedeh 1985; Williams and Besler 1996). The biomass retains most of its energy and simultaneously loses its hygroscopic properties. At about 280°C, the reaction is entirely exothermic and gas production increases, resulting in the formation of carbon monoxide, hydrocarbons like phenols and cresols, and other, heavier products. Temperatures over 300°C are not recommended as these initiate the pyrolysis process (Bourgeois and Doat 1985). There are many advantages in the pretreatment of biomass using torrefaction before densification. Torrefaction reduces variability in the feedstock caused by differences in types and species of raw materials, climatic and seasonal variations, storage conditions, and time (Lehtikangas 1999). It also helps develop a uniform feedstock. Furthermore, torrefaction affects biomass physical characteristics like grindability, hydrophobicity and pelletability.

Lignin in the biomass is considered to be the basic binding agent, and the pelletability of any biomass is evaluated based on the amount of lignin present. In general, it is believed that the higher the amount of lignin, the better the binding and milder the process conditions. Woody biomass has more lignin than lignocellulosic biomass. The torrefaction process opens up a number of lignin-active sites by breaking down the hemicellulose matrix and forming fatty unsaturated structures that help create better binding. Bulk densities of the torrefied pellets are in the range of 750–50 kg/m3 (Bergman and Kiel 2005). The flow diagram for torrefaction and pelletization (TOP) process proposed by Bergman (2005) is shown in Fig. 35.

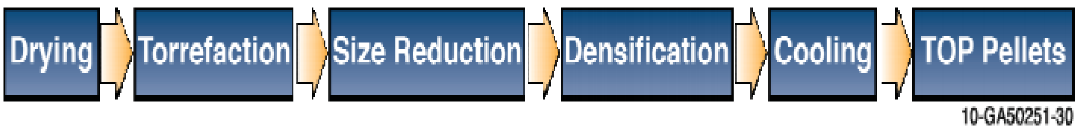

Fig. 35. Flow diagram for torrefied wood pellet production (Bergman, 2005)

Furthermore, torrefaction affects biomass physical characteristics like grindability, hydrophobicity, pelletability, and calorific value. For example, during torrefaction, biomass loses the tenacious nature that is coupled to the breakdown of the hemicellulose matrix and depolymerization of the cellulose, resulting in a decrease in fiber length (Bergman et al. 2005; Bergman and Kiel 2005; Hakkou et al. 2006). Torrefaction also results in the shrinking of the biomass structure, making it light-weight, flaky, and fragile, improving the grinding and pulverizing process (Arias et al. 2008). Studies conducted on grinding-energy requirements of raw and torrefied biomass like willow, woodcuttings, demolition wood, and coal, indicate a significant reduction in power consumed (by about 70–90%) for torrefied biomass (Bergman and Kiel 2005). Also, mill capacities increase from about 7.5 to 15 ton/hr.

Torrefaction causes biomass to become hydrophobic mainly due to the destruction of the hydroxyl group (OH) and does not support the formation of hydrogen bonds (Pastorova et al. 1993). The chemical rearrangement reactions from torrefaction result in the formation of non-polar unsaturated structures that help preserve the biomass by reducing biological degradation, which is similar to coal (Bergman and Kiel 2005; Wooten et al. 2000). Torrefaction also improves binding during pelletization by increasing the number of available lignin sites, breaking down the hemicellulose matrix, and forming fatty unsaturated structures, resulting in bulk densities 750–850 kg/m3 (Bergman and Kiel 2005). The torrefaction process drives off more oxygen and hydrogen compared to carbon, which in turn increases calorific value of the product (Uslu et al. 2008). The net caloric value of torrefied biomass ranges from 18 to 23 MJ/kg (LHV, dry) or 20 to 24 MJ/kg (HHV, dry) (Bergman et al. 2005; Prins 2005).

Torrefaction not only improves the physical properties of biomass, but also significantly changes its proximate and ultimate composition, making it more suitable for fuel applications. In general, an increase in torrefaction temperature results in an increase in carbon content and a decrease in hydrogen and oxygen content due to the formation of water, carbon monoxide, and carbon dioxide. This process also causes the hydrogen to carbon ratio (H/C) and oxygen to carbon ratio (O/C) to decrease with increasing torrefaction temperature and time, which results in less smoke and less water-vapor formation, and reduces energy losses during the combustion and gasification processes. Sadaka and Negi (2009) carried out a wide range of torrefaction studies showing a significant decrease in moisture content (70.5, 49.4, and 48.6%) and corresponding increase in heating value (15.3, 16.9, and 6.3%). Zanzi et al. (2002) made similar observations where increasing the torrefaction temperature from 230 to 280°C and time from 1 to 3 hours increased the carbon content and decreased the hydrogen, nitrogen, and oxygen content due to the formation of water, CO and CO_2.

A study of reed canary grass and wheat straw torrefaction at 230, 250, 270, and 290°C for 30 minute residence times found that the moisture content decreases from an initial value of 4.7 to 0.8% and the carbon content values increase from 48.6 to 54.3%, hydrogen content decreases from 6.8 to 6.1%, and nitrogen content decreases from 0.3 to 0.1%, respectively (Bridgeman et al. 2008). Table 10 and Table 11 present the physical properties and ultimate composition of the torrefied woody and lignocellulosic biomass properties compared to the original.

(vi) Slow Pyrolysis: This process involves heating biomass to 350°C–500ºC in the absence of oxygen and air for extended periods of time (typically 0.5–2 hours). The principal product is a solid (charcoal) that retains 60%–70% of the original energy from the raw biomass. The energy density can be increased, and thus charcoal is a suitable fuel for commercial uses similar to torrifed biomass, residential use, i.e., barbecues, and as a potential soil improvement additive known as bio-char.

Table 10. Properties of wood, torrefied biomass, wood pellets and TOP pellets (Mitchell et al, 2007)

Physical Property	Wood Chips	Wood Pellets	Torrefied Biomass	TOP Pellets
Moisture content (%)	35	7 - 10	3	1 - 5
LHV (MJ/kg)	10.5	15.6 - 16.2	19.9	19.9 - 21.6
Bulk density (kg/m3)	300 - 500	500 - 650	230	750 - 850
Energy density (GJ//m3)	5.8	7.8 - 10.5	4.6	14.9 - 18.4
Hygroscopic nature	Water uptake	Swelling / water uptake	hydrophobic	Poor swelling/hydrophobic
Behavior in storage	Gets mouldy, Dry matter loss	Deteriorates, gets moldy	Stable	Stable

Table 11. Ultimate Analysis, HHV (dry ash free basis), and Moisture Content of untreated and torrefied biomass (Bridgeman et al., 2007).

	Raw	Torrefaction temperature (°K)			
		503	523	543	563
Reed Canary Grass					
C (%)	48.6	49.3	50.3	52.2	54.3
H (%)	6.8	6.5	6.3	6.0	6.1
N (%)	0.3	0.1	0.0	0.1	0.1
O (%)	37.3		37.0	37.3	36.3
Moisture (%)	4.7	2.5	1.9	1.3	1.2
CV (kJ/kg)	19,500		20,000	20,800	21,800
Wheat straw					
C (%)	47.3	48.7	49.6	51.9	56.4
H (%)	6.8	6.3	6.1	5.9	1.0
N (%)	0.8	0.7	0.9	0.8	27.6
O (%)	37.7		35.6	33.2	27.6
Moisture (%)	4.1	1.5	0.9	0.3	0.8
CV (kJ/kg)	18,900	19,400	19,800	20,700	22,600
Willow					
C (%)	49.9	50.7	51.7	53.4	54.7
H (%)	6.5	6.2	6.1	6.1	6.0
N (%)	0.2	0.2	0.2	0.2	0.1
O (%)	39.9	39.5	38.7	37.2	36.4
Moisture (%)	2.8	0.5	0.1	0.1	0.0
CV (kJ/kg)	20,000	20,600	20,600	21,400	21,900

(vii) Fast Pyrolysis: This technique involves processing biomass at temperatures of up to 450°C–500ºC for 1–2 seconds. The process yields up to 75% bio-oil and 10%–15% charcoal. Bio-oil is a higher-energy density fuel, and its handling properties are simplifed, as the fuel is a liquid that is pumped and stored in tanks. Precautions are necessary, as bio-oils are very acidic, have a pungent odour and are prone to separation/settling. Substitute bio-oil for fossil fuel, heavy and middle oils. Research is under way to explore conversion to lighter oils such as diesel and gasoline.

(viii) Ammonia fiber explosion (AFEX) Treatment: AFEX pretreatment method uses aqueous ammonia at elevated temperatures and pressures (Tey-mouri et al, 2005). This process reduces lignin and removes some hemicellulose while decrystallizing cellulose in the biomass. A flow diagram of the AFEX process is shown in Fig. 36. The important process variables in AFEX pretreatment are ammonia loading, water loading, reaction temperature, and residence time. The feedstock variables include moisture content, particle size, and feedstock composition. The typical ranges of the process conditions commonly used in AFEX process are (a) pressure, 20-30 atm; (b) temperature, 70-140°C; (c) residence time, 5 to 10 minutes; (d) ammonia: dry biomass loading, 0.3–2.0 to 1 (w/w); and (e) water: dry biomass content, 0.2 2.5 to 1 (w/w) (Dale, 2009).

Compared to other pretreatment methods, AFEX retains most of the hemicellulose and cellulose sugars in their polymeric forms after pretreatment. The major advantage of this process is little biomass degradation (Dale 2009). Even though AFEX causes physical and chemical changes in the biomass, it does not result in prehydrolysis of hemicellulose to monomeric sugars. Consequently, AFEX-treated biomass may be considered a stable intermediate that can be stored, transported, and integrated with subsequent processing steps. During AFEX pretreatment, 99% of the ammonia is recovered and reused, while the remainder serves as a nitrogen source for downstream fermentation.

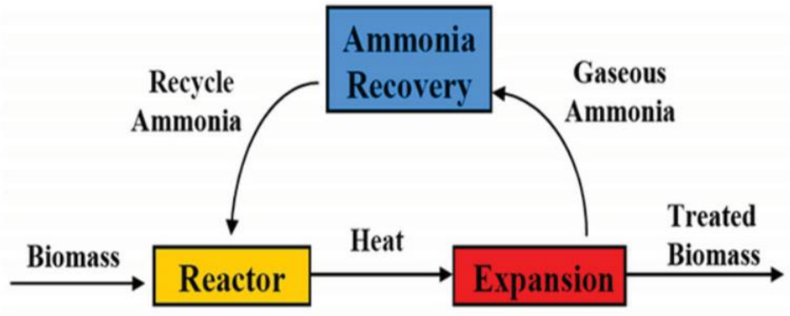

Fig. 36. Ammonia fiber explosion (AFEX) Process (Dale, 2009)

AFEX pretreatment of biomass offers significant advantages for densification, storage, and transportation. Because AFEX-treated biomass is relatively dry and inert, it is more easily stored, transported, and densified to further improve bulk handling properties. These unique features allow biomass to be preprocessed and treated at a site close to the biomass source and then shipped to a centralized biorefinery location. AFEX treatment transfers some lignin and hemicellulose oligomers to the surface of biomass fibers where it can act as a binding agent. Initial trials at MSU have shown that the density and other properties of pellets of AFEX-treated biomass are better than pellets of untreated biomass (Dale, 2009). A collaborative project between North Dakota State University, South Dakota State University, and Michigan State University on densifying and handling of AFEX biomass has indicated that pelleting and briquetting of AFEX-treated corn stover offers higher densities of 3–5 times compared to baled biomass. Also the pellets produced were hard and durable with a specific gravity of up to 1.16 without using any binders, whereas untreated corn stover pellets are much less dense and are not durable at all (Dale, 2009). Moreover, integrating this pretreatment with a densification process can help reduce many logistics problems (Dale, 2009). Eranki et al. (2011), in their study on advanced biomass processing depots, evaluated densifying AFEX products to solve storage and transportation logistics.

3.4 Binders

A binder or binding agent helps to glue together the biomass particles. They improve the binding characteristic of the biomass (usually by forming a gel with water), and produce a more durable product. They also help reduce wear in production equipment and increase abrasion-resistance of the fuel but may result in increased sulphur content in the briquette. A suitable binder should be cheap, non-hygroscopic and non-abrasive. Also, the ash content of the binder should be low, as the calorific value of the product will be reduced in the case of high ash.

The application of binder depends on the technique of briquetting employed. Densification using binder is similar to the process used in coal briquetting, in which a binder is added to glue together the particles. In addition to biomass mixing, an appropriate binder is added and mixed with the biomass thoroughly, especially if a low-pressure technique is to be employed. This enhances the compactness of the biomass materials and prevents them from disintegrating apart. Since there is no need for lignin softening, the pressure and temperature required are low. If fine materials which deform under high pressure, are pressed, no binders are required. The strength of such compacts is caused by van der Waals' forces, valence forces, or interlocking. Natural components of the material may be activated by the prevailing high-pressure forces to become binders. Binder less densified briquetting is possible only at elevated temperatures of 250-300°C under high pressure (Grover and Mishra, 1996). Some of the materials need binders even under high pressure conditions. Typically, in the case of charred material a binder is usually required, while high pressure and heat are not required. The mechanisms of binding between biomass particles are shown in Fig. 37.

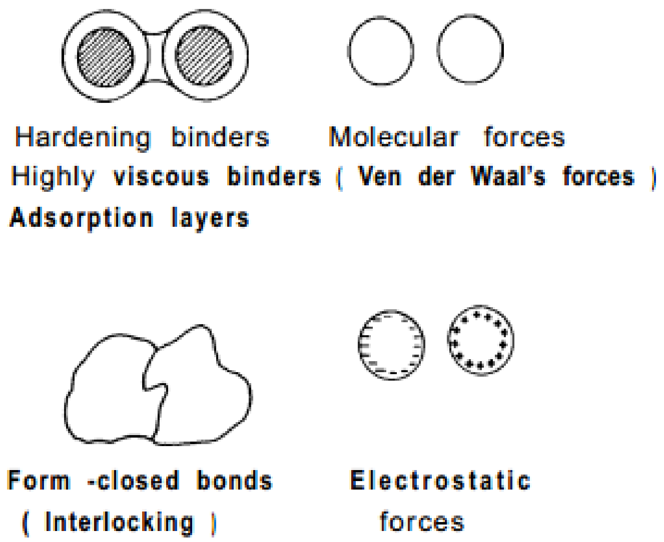

Fig. 37. Types of binding mechanisms (Grover and Mishra, 1998)

However, the addition of some binders can result in an increase in the sulphur content of densified biomass. The most commonly used binder in pellet making is lignosulphonates (Wafolin), or sulfonate salts made from the lignin in pulp mill liquors. The different types of binders used for densification purposes (Tabil et al. 1997) are detailed as follows:

Lignosulfonates, considered the most effective binders, are used in animal feeds (Anonymous, 1983; MacMahon, 1984). The composition includes sulfonate salts made from lignin of sulphite liquors present in pulp industry waste. The general levels of inclusions for effective binding are 1–3%.

Bentonite, also referred to as colloidal clay, is commonly used as a binder in feed pelleting and is made up of aluminum silicate composed of montmorillonite. During processing, binders form a gel with water to improve the binding characteristics. Pfost and Young (1973) report that the addition of bentonite at an inclusion rate of 100 kg/ton of feed mash significantly improves the durability of poultry feed consisting of ground yellow corn, ground sorghum grain, and soymeal ingredients.

Starches are popularly used in the food industry as a thickener or a binder. Wood (1987) reports that precooked starch works as a good binder during pelletization.

Proteins, as mentioned previously, are considered natural binders which are activated through the heat produced in the dies. Protein interacts with the other biomass compositions such as lipids and starches and results in formation of protein starch and lipid complexes which helps in producing more durable pellets. Some agricultural biomass, such as alfalfa, has high protein content and can be used as a binder to improve the durability of pellets made from lower protein biomass.
According to Waters (1969), the choice of binders could be classified as classified as organic, inorganic, and compound binders; detailed as follows:

(i) **Organic binders** (examples tabulated in Table 12) are usually combustible. These are further classified into hydrophobic and hydrophilic binders. The hydrophobic binders include coal tar and pitch, petroleum bitumen or asphalt, wood tar and synthetic and natural resins. These binders produce briquettes, which are resistant to water and weather but smoke when burned. To avoid smoking, the briquettes must be heated at about 300ºC to carbonize the binder; however, the cost of this additional step may not be economically justified. The hydrophilic binders include starch, sulphite liquor, molasses etc. The hydrophilic binders are usually applied in the form of a paste, gel, dispersion or solution in water, and require drying after briquetting. These produce briquettes, which disintegrate if wetted but produce little smoke when burned.

Table 12. List of Organic Binding Agents

Source	Binding Agents
Wood products	Rosin, pitch (tar and rosin), pine and hard wood tar, wood pulp, sulphite liquor (from paper mill)
Sugar-factory residue	Beet pulp, lime cake (carbonation lime-residue), beet-sugar and cane-sugar molasses
Starch	Corn and potato starch
Petroleum products	Crude oil, residuum (asphalts), water-gas tar and pitch, wax tailing, acid sludge, asphalt tar, pintsch gas tar, Pittsburgh flux
Natural asphalts	Impsonite, gilsonite, maltha, refined Trinidad and Bermudez, hard and refined asphalts from impregnated sandstones
Tars and pitches from coal	Blast-furnace tar, producer-gas tar, illuminating-gas tar, by-product coke-oven tar, coal-tar creosote

(ii) Inorganic binders are usually non-combustible. Examples of this type includes clay, lime, sodium silicate (NaO: SiO_2), magnesia, plaster of Paris, natural cement, magnesia cement, slag cement, water glass, Portland cement etc. These are further classified into water-soluble and insoluble binders. The insoluble binders include cement, clay, lime, magnesia, and gypsum and the water-soluble binders include sodium or other alkali silicates. Inorganic binders are normally cheap but result in high ash content of briquettes.

(iii) Compound binders consist of two or more components and have been developed to overcome some of the disadvantages of organic and inorganic binders. Thus, water and weather resistance of briquettes using starch as binder can be improved by paraffin wax or bitumen coating of the briquettes. A compound binder may also consist of some material added to a primary binder for reducing the amount and cost of the primary binder, for example asphalt-clay and coal tar-lime. Binders and fillers used for charcoal briquetting should be cheap. These must not produce objectionable smoke and odour during combustion. Also, these need to be resistant to fermentation and bacterial attack during storage (FAO, 1985). Binders commonly used are starch, clay, tar and molasses; of these, tar and molasses tend to smoke slightly on burning. The binder which most closely meets the requirements, particularly the cost and the odour, is starch (Waters, 1969). Starch can be used in two forms (a) pregelatinized or precooked starch; (b) uncooked starch. Precooked starch may be introduced into the charcoal feed in powdered form and also less water requirement reduces the drying cost. Although uncooked starch is much cheaper, it requires more preparation since the starch made from it has to be cooked at about 190°C before being pumped to the mixer.

Binders could be further categorized as the matrix type and the film type (Komarek, 1967; UNEP, 2013), elaborated as follows-

(i) Matrix type binders are in the form of more or less continuous matrix of the binding material in which the particles to be agglomerated are densely embedded. The amount of binder in the densified product is rather high. Clay, paraffin, pitch, wood tar, coal and sodium silicate etc. belong to this category.

(ii) Film type binders are generally used as solutions or dispersions, water being the most common solvent or dispersing medium. The product acquires its desired strength and stability on curing (e.g. drying, burning, chemical reaction, etc.) after densification. Sodium silicate, bentonite, molasses, starch, gums, glues, tar, petroleum asphalt and Portland cement etc. belong to this category.

(iii) Chemical binders depend for their effectiveness on a chemical reaction between the components of the binder or, alternatively, on a chemical reaction between the binder and the material being agglomerated. A mixture of Ca(OH) and molasses, pitch water, sodium silicate are examples of this type. Lingosulfonates and bentonite falls into both chemical and film type (Lu et al, 2013).

3.5 Additives

The briquetting process does not add to the calorific value of the base biomass. In order to upgrade the specific heating value and combustibility of the briquette, certain additives like charcoal and coal in very fine form can be added. About 10-20% char fines can be employed in briquetting without impairing their quality (Grover and Mishra, 1996).

Further, only screw pressed briquettes can be carbonized. When carbonized with additives in the briquette to make dense char coal, the yield is remarkably increased. However, depending upon the quality of charcoal and coal powder, various formulations can be evolved for optional results. In piston press technology the effect of particle size and moisture content is similar to that of the screw press. But in this case preheating of raw material is not employed and the die is not heated. In fact, the die needs cooling for smooth briquetting

3.6 Quality Parameters for Briquettes and Pellets

Quality parameters of the densified biomass play a major role in the end-user applications. Understanding the quality attributes of the densified biomass in terms of physical, chemical, and biochemical composition will help evaluate the quality changes of the biomass during the densification process. The quality of the densified biomass depends upon the feedstock composition, starch, protein, fibre, fat, lignin, and extractives; feed moisture content; feed particle size and distribution; feed conditioning, temperature/preheating of feed; added binders; and densification equipment variables (e.g., forming pressure, pellet mill, and roll press variables), which significantly affect the strength and durability of the densified products. The quality helps evaluate the energy content, effectiveness of the densification process and determine whether the pellets, cubes, or briquettes can withstand the compressive, impact, and water resistance during storage and transportation.

The quality parameters/attributes typically used to assess biomass briquettes and pellets are as follows:

(i) Moisture Content (%)

The optimum final moisture content of the pellets or briquettes from biomass is greatly dependent on process conditions like initial moisture content, temperature, and pressure. Higher moisture content in the final product results when the initial moisture content is greater than 15%. Mani et al. (2006) observe that initial moisture content of >15% and pressure >15 MPa has a negative effect on the final briquette quality where cracks were observed. Pellets with lower moisture content (<5%) can result in revenue loss for the pellet manufacturer as they tend to break up, creating more fines during storage and transportation. Pellets with high moisture content can be subject to spoilage due to bacterial and fungal decomposition resulting in significant dry matter losses during storage and transportation (Tumuluru et al. 2010b).

(ii) Unit and Bulk Density (kg/m^3)

Several researchers have found that these parameters are greatly influenced by the material's moisture content and particle size, and the process pressure and temperature (Mani et al., 2006; Rhen et al., 2005; Shankar and Bandyopadhyay, 2005). Generally, they found that materials with higher moisture and larger particle sizes reduce the unit and bulk density of the product, while higher process temperatures and pressures increase the unit and bulk density. Rhen et al. (2005) also found a strong correlation between unit density and compression strength (i.e., high dry density corresponds to high compression strength). Tumuluru et al. (2010a), in their article on pelleting DDGS, supported the conclusions that both unit and bulk density greatly depends on feed moisture and die temperature where a maximum density of 1200 kg/m3 is achievable at temperatures of about 100°C and feed moisture content of about 5–7%.

Bulk density is an important parameter for storage and transportation purposes. Pellets or briquettes with higher density are preferred as fuel because of their high energy content per unit volume and slow burning property (Kumar et al. 2009). Bulk density of pellets or briquettes greatly depends upon processing conditions, like temperature, moisture content, particle size, and pressure. High temperatures and lower moisture content favors high density products. Smaller particle size produces denser products. Tumuluru et al. (2010a), in their article on pelleting of Distillers' Dried Grains with Solubles (DDGS), indicate that lower moisture content and higher temperature result in denser DDGS pellets. Shankar and Bandyopadhyay (2004; 2005) observe the same result for the fish feed pellets.

It is generally accepted that raw-material particle size influences the density of the pellets; e.g., small particles give a higher density for single pellets. This is true at least at low and medium densification pressures (Mani et al. 2006). On the other hand, Bergström et al. (2008), in their article on the effect of raw material particle-size distribution on the characteristics of Scots pine sawdust fuel pellets, indicate that the pellets produced show almost equal densities, indicating that the particle-size distribution of raw materials has only a minor influence on bulk density. They also reason that this could be a consequence of raw materials being ground during the pelletizing process, which results in a particle-size distribution different from the raw material. Bergström et al. (2008) also state that high pressure in the dies reduces the influence of the raw material particle-size distribution on the bulk density.

(iii) Durability Index (%)

The durability index is a quality parameter defined as the ability of densified materials to remain intact when handled during storage and transportation. Thus, pellet durability is the pellet's physical strength and resistance to being broken up. This is measured by placing a quantity of pellets in a sealed metal box, which is spun round to abrade the pellets over one another. The amount of dust generated is then measured. Less dust generated means greater durability of the pellets (Kaliyan and Morey 2009). Durability or abrasive-resistance measurements help to simulate either mechanical or pneumatic handling forces, and control the feed quality. Different types of equipment (Holmen tester, tumbling can, Ligno tester, and Dural tester) are used to test durability (Kaliyan and Morey, 2009). Feed moisture content acts a binding agent and as a lubricant, and it develops van der Waals forces by increasing the area of contact between the particles (Tabil and Sokhansanj, 1996).

Moisture in the biomass helps to increase durability when water soluble compounds, such as sugar, starch, soda ash, sodium phosphate, potassium salt, and calcium chloride are present in the feed (Kaliyan and Morey, 2009). High starch content in the feed acts as a binder; however, native starch has less binding capacity than gelatinized starch where the presence of moisture and heat accelerate the process (Israelsen, 1981; Reece 1966; Thomas, 1998; Wood, 1987). Protein present in the biomass feed will plasticize under heat and moisture and act as a binder, increasing the strength of the densified products (Winowiski 1988 and Briggs 1999). In addition, lignin, at elevated temperatures (140°C), acts as a binder as the heat causes it to soften. However, Bradfield and Levi (1984) observe that when the content of lignin and other extractives increases to more than 35%, the durability values decreased. They postulate that the auto-adhesive nature of lignin and other extractives decreases at higher concentrations due to their excessive mastic nature. Furthermore, high fat content in feeds will result in low durability as fat acts a lubricant between the feed particles and feed mill die wall (Angulo et al. 1996; Briggs 1999; Cavalcanti 2004; Richardson 1976; Stark 1994). Particle size is another important parameter that influences durability (Mani et al. 2002; 2003). Finer particles accept more moisture and, therefore, undergo a higher degree of preconditioning (Kaliyan and Morey, 2009). Preheating or steam conditioning of the feed normally increases the activity of inherent binders like starch. Lignin also helps to create plastic deformation at higher temperatures, thus producing more durable pellets. Preheating temperatures are usually restricted to 300°C to limit the decomposition of the biomass (Kaliyan and Morey, 2009). Steam conditioning also helps to release and activate natural binders and lubricants in the feed, increase starch gelatinization and protein denaturation, and produce durable and hard pellets (Kaliyan and Morey, 2009). Pellet mill variables, such as die dimensions and die speeds also influence durability. Smaller die dimensions produce greater gelatinization and higher durability. Die speeds of about 126–268 rpm is optimal for smaller pellets, and lower die speeds of about 6–7 m/s are good for large-size corn-based swine die pellets (Stevens, 1987).

(iv) Percent Fines (%)

The presence of fines in the densified product is not desirable, especially when co-firing with other fossils fuels. Fines are generated during transportation and storage by the breakdown of the densified product. Pellets processed under suboptimal conditions—for example, at lower temperature, lower moisture content, and with less desirable chemical compositions, or with insufficient die size and roller speed—are less durable and can result in more fines in the final product. Percent fines, once they cross the storage threshold value in silos, can aggravate dust explosion and spontaneous combustion problems. Shankar et al. (2008b), in their studies on the effect of storage temperature on the quality of wood pellet properties, found that higher storage temperatures (30–50°C) increase the percent fines by more than 1% during storage of 60 days.

(v) Calorific Value (MJ/kg)

In general, the calorific value of pellets and briquettes depends upon process conditions like temperature, particle size, and in feed pretreatment. Generally, pellets with higher density have higher calorific value. The typical calorific values of wood pellets range from 17 to 18 MJ/kg (Tumuluru et al., 2010b). Pretreatment processes such as torrefaction and steam explosion can have a significant effect on the calorific value of the final product. The typical calorific values of straw-based pellets range from 17– 18 MJ/kg (Satyanarayana et al., 2010). Pretreatment processes such as torrefaction and steam explosion can have a significant effect on the calorific value of the final product and increase them from 20–22 MJ/kg. Tumuluru et al. (2010c & d), in their studies on pretreatment of corn stover and miscanthus biomass using the torrefaction method, found that the calorific value increases by about 20% to its original value when torrefied at temperature ranges of 200–300°C.

3.7 International Standards for Briquettes and Pellets

The standards for densified biomass application as a solid fuel in USA are given by the Pellet Fuel Institute (PFI) and in Europe by the European Common Standard for Solid Fuel (CEN). PFI standards (Table 13) discuss specifications for densified fuel for residential and commercial applications, but do not specify whether it is in a pellet, briquettes, or densified log form.

The combined standards from various European countries such as Austria, Sweden, United Kingdom, France, and Denmark, is known as the European Common Standard for Solid Fuel (CEN). The European Committee for Standardization (CEN/TC 335) prepared technical specifications and testing methods for solid biofuels. CEN/TS 14961 gives the standards for the densified solid fuels like pellets and briquettes. Common European solid biofuels standards were established to avoid ambiguity; previously, many European countries had their own standards. The European Committee for Standardization (CEN/TC 335) prepared technical specifications and testing methods for solid biofuels.

The following are some of the standards developed for classifying properties of solid biofuels based on CEN:

1. Classification of biomass based on origin. Based on CEN/TS 14961, the biomass is classified based on its origin and divided into these subcategories: woody, herbaceous, fruit, and blends and mixtures (Table 14).
2. Major traded forms of solid biofuels (Table 15).

3. Technical specifications for pellets and briquettes according to CEN (Table 16 and Table 17).

Table 13. Pellet Fuel Institute (PFI) Standard Specification for Densified Fuel (PFI, 2017)

Fuel Property	PFI Premium	PFI Standard	PFI Utility
Normative Information (Mandatory)			
Bulk density (lb/ft3)	40.0–48.0	38.0–48.0	38.0–48.0
Diameter (in.)	0.230–0.285	0.230–0.285	0.230–0.285
Diameter (mm)	5.84–7.25	5.84–7.25	5.84–7.25
Pellet Durability Index (PDI)	≥96.5	≥95.0	≥95.0
Percent Fines (at the mill gate)	≤0.50	≤1.0	≤1.0
Inorganic ash (%)	≤1.0	≤2.0	≤6.0
Heating value	NA	NA	NA
Length (% greater than 1.50 in.)	≤1.0	≤1.0	≤1.0
Moisture (%)	≤8.0	≤10.0	≤10.0
Chloride (ppm)	≤300	≤300	≤300
Arsenic (mg/kg; dry)	≤1	≤1	≤1
Cadmium (mg/kg; dry)	≤0.5	≤0.5	≤0.5
Chromium (mg/kg; dry)	≤ 10	≤ 10	≤ 10
Copper (mg/kg; dry)	≤ 10	≤ 10	≤ 10
Lead (mg/kg; dry)	≤ 10	≤ 10	≤ 10
Mercury (mg/kg; dry)	≤ 0.1	≤ 0.1	≤ 0.1
Nickel (mg/kg; dry)	≤ 10	≤ 10	≤ 10
Zinc (mg/kg; dry)	≤ 100	≤ 100	≤ 100
Informative Only (Not Mandatory)			
Ash Fusion	NA	NA	NA

Table 14. Classification of origin and sources of woody biomass according to CEN (Kofman, 2010)

1.1 Forest and Plantation Wood	
1.1.1 Whole trees	1.1.1.1 Deciduous wood 1.1.1.2 Coniferous wood 1.1.1.3 Short rotation coppice 1.1.1.4 Bushes 1.1.1.5 Blends and mixtures
1.1.2 Stem wood	1.1.2.1 Deciduous 1.1.2.2 Coniferous 1.1.2.3 Blends and mixtures
1.1.3 Logging residues	1.1.3.1 Fresh/green (including leaves/needles) 1.1.3.2 Dry 1.1.3.1 Blends and mixtures
1.1.4 Stumps	1.1.4.1 Deciduous wood 1.1.4.2 Coniferous wood 1.1.4.3 Short rotation coppice 1.1.4.4 Bushes 1.1.4.5 Blends and mixtures
1.1.5 Bark (from forestry operations)*	
1.1.6 Landscape management woody biomass	
1.1.7 Wood from garden, park, roadside maintenance, vineyards and fruit orchards	
1.1.8 Blends and Mixtures	

1.2 Wood processing industry, by-products, and residues	
1.2.1 Chemically untreated wood residues	1.2.1.1 Wood without bark 1.2.1.2 Wood with bark* 1.2.1.3 Bark (from industry operations)* 1.2.1.4 Blends and mixtures
1.2.2 Chemically treated wood residues	1.2.2.1 Wood without bark 1.2.2.2 Wood with bark* 1.2.2.3 Bark (from industry operations)* 1.2.2.4 Blends and mixtures
1.2.3 Fibrous waste from the pulp and paper industry	1.2.3.1 Chemically untreated fibrous waste 1.2.3.2 Chemically treated fibrous waste
1.2.4 Blends and mixtures	
1.3 Used wood	
1.3.1 Chemically untreated wood	1.3.1.1 Wood without bark 1.3.1.2 Bark* 1.3.1.3 Blends and mixtures
1.3.2 Chemically treated wood	1.3.2.1 Wood without bark 1.3.2.2 Bark* 1.3.2.3 Blends and mixtures
1.3.3 Blends and mixtures	
1.4 Blends and mixtures	

*Cork waste is included in bark sub-groups

Table 15. Major traded forms of solid biofuels according to European Standard (CEN) (Kofman, 2010)

Fuel	Typical Particle Size	Common Preparation Method
Briquettes	>25 mm	Mechanical compression
Pellets	<25 mm	Mechanical compression
Fuel powder	<1 mm	Milling
Sawdust	1–5 mm	Cutting with sharp tools
Shavings	1–30 mm	Planing with sharp tools
Wood chips	5–100 mm	Cutting with sharp tools
Hog fuel	Varying	Crushing with blunt tools
Logwood/firewood	100–1000 mm	Cutting with sharp tools
Whole tree	≥500 mm	No preparation or de-limbed
Bales Small square bales Big square bales Round bales	 0.1 m^3 3.7 m^3 2.1 m^3	 Compressed and bound to squares Compressed and bound to squares Compressed and bound to cylinders
Bundle	Varying	Lengthways oriented and bound
Bark	Varying	Debarking residue from trees Can be shredded or unshredded
Chopped straw or energy grass	10–200 mm	Chopped during harvesting or before combustion
Grain or seed	Varying	No preparation except for process operations necessary for storage for cereal grain
Fruit stones or kernels	5–15 mm	No preparation or pressing and extraction by chemicals
Fibre cake	Varying	Prepared from fibrous waste by dewatering

Table 16. Technical specifications for pellets according to European Standard (CEN) (Tumuluru et al, 2011)

Origin	Woody biomass (1), herbaceous biomass (2), fruit biomass (3), blends and mixtures (4)
Normative Specifications	
Dimensions (mm) Diameter and length (L)[a]	D06 ≤ 6mm ± 0,5 mm and L ≤ 5 × Diameter D08 ≤ 8 mm ± 0,5 mm and L ≤ 4 × Diameter D10 ≤ 10 mm ± 0,5 mm and L ≤ 4 × Diameter D12 ≤ 12 mm ± 1 mm and L ≤ 4 × Diameter D25 ≤ 25 mm ± 1 mm and L ≤ 4 × Diameter
Moisture (w-% as received)	M10 ≤ 10% M15 ≤ 15% M20 ≤ 20%
Ash (w-% of dry basis)	A0.7 ≤ 0.7% A1.5 ≤ 1.5% A3.0 ≤ 3.0% A6.0 ≤ 6.0% A6.0+ > 6.0% (actual value to be stated)
Sulphur (w-% of dry basis)[b]	S0.05 ≤ 0.05% S0.08 ≤ 0.08% S0.10 ≤ 0.10% S0.20+ > 0.20% (actual value to be stated)
Mechanical durability (w-% of pellets after testing)	DU97.5 ≥ 97.5 DU95.0 ≥ 95.0 DU90.0 ≥ 90.0
Amount of fines (w-% <3.15 mm)[c]	F1.0 ≤ 1.0% F2.0 ≤ 2.0% F2.0+ > 2.0% (actual value to be stated)
Additives (w-% of pressing mass)	Type and content of pressing aids, slagging inhibitors or any other additives have to be stated
Nitrogen (w-% of dry basis)	N0.3 ≤ 0.3% N0.5 ≤ 0.5% N1.0 ≤ 1.0% N3.0 ≤ 3.0% N3.0+ > 3.0% (actual value to be stated)
Informative Specifications	
Net caloric value (MJ/kg as received) or energy density (kWh/m³ loose)	Recommended to be informed by retailer
Bulk density as received (kg/m³ loose)	Recommended to be stated if traded by volume basis
Chlorine, Cl (weight of dry basis w-%)	Recommended to be stated in category Cl 0.03, Cl 0.07, Cl 0.10, und Cl 0.10+ (if Cl >0.10% the actual value to be stated)

[a]Maximum 20 w-% of the pellets may have a length of 7. 5 diameter.
[b]Sulphur is normative only for chemically treated biomass and if sulphur-containing additives have been used.
[c]After production at factory gate, at last possible place in the production site.

Table 17. Technical specifications for briquettes according to European Standard (CEN) (Tumuluru et al, 2011)

Origin	Woody biomass (1), herbaceous biomass (2), blends and mixtures (4)	
Normative Specifications		
Dimensions (mm) Diameter (D) or equivalent (diagonal or cross cut), mm	D40 D50 D60 D80 D100 D125 D125+	25 ≤ D ≤ 40 ≤50 ≤60 ≤80 ≤100 ≤125 ≥125 actual value to be stated
Length (L)	L50 L100 L200 L300 L400 L400+	≤50 ≤100 ≤200 ≤300 ≤400 ≥400 actual value to be stated
Moisture (w-% as received)	M10 M15 M20	≤10% ≤15% ≤20%
Ash (w-% of dry basis)	A0.7 A1.5 A3.0 A6.0 A10.0	≤0.7% ≤1.5% ≤3.0% ≤6.0% ≤10.0%
Sulphur (w-% of dry basis)[a]	S0.05 S0.08 S0.10 S0.20 S0.20+	≤0.05% ≤ 0.08% ≤0.10% ≤0.20% >0.20% (actual value to be stated)
Particle density (kg/dm3)	DE0.8 DE1.0 DE1.1 DE1.2	0.8 to 0.99 1.00 to 1.09 1.10 to 1.19 ≥1.20
Additives (w-% of pressing mass)	Type and content of pressing aids, slagging inhibitors, or any other additives have to be stated	
Nitrogen, N (w-% dry basis)	N0.3 N0.5 N1.0 N3.0 M3.0+	≤0.3% ≤0.5% ≤1.0% ≤3.0% >3.0% (actual value to be stated)
Informative Specifications		
Net caloric value (MJ/ kg as received) or energy density (kWh/m3 loose)	Recommended to be stated at the retail level	
Bulk density as received (kg/m3 loose)	Recommended to be stated if traded by volume basis	
Chlorine, Cl (w-% of dry basis, %)	Recommended categories: Cl 0.03, Cl 0.07, Cl 0.10 and Cl 0.10 + (if Cl is >0.10% the actual value to be stated)	
[a] Sulphur is normative only for chemically treated biomass or if sulphur containing additives have been used		

4. Biomass Briquetting in Nepal

In Nepal, rural people have been using manually made traditional animal dung briquettes for cooking since time immemorial. Animal dung particularly cow and buffalo dung as binder, is mixed with fillers such as straw, jute sticks and other biomass materials to produce *guitha,* which are traditional low-pressure bio-briquettes (Fig. 38) (Khanal, 2010). However, these traditional dung briquettes and loose biomass during combustion are inefficient and causes indoor air pollution; hence improving fuel efficiency and quality through briquetting is the key technological intervention (Bhattacharya and Shestha, 1991; Eriiksson and Prior, 1990). Table 18shows the chronological order of introduction and promotion of the different briquetting technologies. The table attempts to reflect some problems and shortcomings faced by the promoters of briquette products and the technologies in Nepal.

Fig. 38. **(left)** *Guitha*- Traditional Animal Dung Briquettes used in Nepal and **(right)** Rice Husk Briquetting Machine in Nepal

Except for the agglomeration briquetting technology, all the technologies discussed in Section 2.3 are found to be in use in Nepal. Among all the biomass briquetting technologies introduced in Nepal three technologies, the rice husk briquetting technology [Fig. 38(right)], the beehive briquette technology and briquettes from waste paper and biomass seemed to have been practiced in a wider scale and drew attention of both the government and the public (CEEN, 2012; Singh et al, 2010a).

4.1 Past Experience in Industries

The history of bio-briquetting in Nepal depicts that four types of briquette technology has been practiced in Nepal. Screw Extruder briquetting using charred rice husk, Screw extruder briquetting using biomass, Roller press briquetting and beehive briquetting. Screw extruder briquetting based on pyrolysis of rice husk has phased out due to high cost and pollution. Some screw extruder briquetting using biomass still exists and has good scope if proper technical and financial support is given. Roller press briquetting has not seen full-fledged production but has big scope for Biobriquetting and coal briquetting, where there is coal and lignite. Small scale beehive briquetting, which is very popular now, is practiced in over 50 districts of the country.

4.1.1 Briquetting of Pyrolyzed Rice Husk

The first biomass briquetting plant Nepal Bio-Extruder Industry Pvt Ltd in Nepal was established in 1982 in Thapathali, Kathmandu. This was followed with similar factories in Butwal (1984) and a third one followed in Dharan (1984). These industries used rice husk pyrolyzing technology, which was found to be very polluting and showed many technical problems during operation. (NIDC, 1990; WECS, 1988). The technology was obtained from India initially, followed by ones locally manufactured by Pradhan Engineering Company (“PECo”), Narayanghat. Over a dozen such factories were registered with the Department of Industries and only 5 were in operation till 1990. A list of the industries is provided in Table 19.

Table 18. Chronology of Briquetting Practices in Nepal (CEEN, 2014; Singh, 2013)

Year	Technology/Product	Entity	Product Details	Situation/Problems	Remarks
1982	Screw extruder technology from India	Nepal Bio-Extruder Industry P. Ltd. (Thapathali, Kathmandu)	Charred (pyrolyzed) rice husk pellet (Brand name Jwala briquette). 900 ton/year	Environmental pollution, wearing of the screw, issues with coal tar, etc. Shut down long time ago	PECO (Nepal) was involved in fabrication of briquette machines at the time and later manufactured in Nepal
1984	Screw extruder technology-Nepcoal: from India; 1200 ton/year Kosi: from Nepal (PECO).	Nepcoal Pvt. Ltd. (Butwal), Kosi Briquette Fuel Industry (Dharan)	Charred rice husk briquette. 600 ton/year	High cost of machine, repair and maintenance for imported technology, high maintenance for pyrolyzer, high cost and seasonal availability of rice husk, drying issues, low quality product, pollution and lack of proper cooking/heating devices.	Screw extruder made in Nepal (PECO) first introduced in Kosi Briquette Industry. Nepcoal was shut down and Kosi Briquette's equipment were sold as scrap
1985-86	Research on charred rice husk pellets using molasses as binder; Self-made local technology	Mr. Mohan Dhoj Basnet (Tehe Bhal, Kathmandu) supported by RONAST	Charred rice husk pellets	Individual effort, No moral and financial support (NAST offered some financial support later)	Small scale attempt to address problems of screw extruder/charring
1986	Coal briquettes imported from India	Imported by Fuel Corp, Baneshwor	Pillow type coal briquettes	Introduction of product without any study/assessment of product and stoves	Lack of public awareness and unavailability of proper stoves
1986	Screw extruder from Fuji Conveyor (Japan)	Khumaltar Agricultral Complex (Patan)	Rice husk briquettes	Demonstration event supported by Japanese Embassy	Event fostered establishment of many such industries
1987-88	Screw extruder from Taiwan for rice husk briquetting.	Chitwon Briquette Koila Udyog, Jan Coal (Simara), Quality wood & Fuel Industry (Hetauda), Chawasoti Briquette Industry (Birgung) (Transferred to kawosoti in Nawalparasi renamed Mhepi Industry later)	Rice husk briquettes and saw dust briquettes	High cost of machinery & loan payment, screw wear, no proper stoves, high cost of raw materials, market problems, no R&D, technical or governmental support, high energy costs from electrical heaters at Jan Coal and Quality Wood	Private initiatives with no government support; Some technical support from RONAST from 1992; Mhepi- the only industry still operational currently
1990	Screw extruder with pyrolyzed rice husk. Both from PECO (Nepal); 600 ton/year	Trishakti Husk Coal Briquette (Narayanghat), R.S. Briquette Factory (Kathmandu)	Charred rice husk briquette	High maintenance for pyrolyzer, repair and maintenance issues, high cost and seasonal availability of rice husk, drying issues, low quality product, pollution	Both companies sold their equipment as scrap

Year	Technology/Product	Entity	Product Details	Situation/Problems	Remarks
1990-92	Screw extruder (locally made) for rice husk briquetting. Simple & cheaper than Taiwan Technology.	Himalayan Briquette Udyog (Naryanghat) and Bageswori Briquette Udyog (Nepalganj)	Rice husk briquettes	Technical problem of screw, market and raw material issues, no R&D and technical support	Private initiative with no government support. Some technical support from RONAST from 1992.
1992-95	Pillow type coal briquettes, coal beehive briquettes and Biocoal briquettes	(RO)NAST and JICA Joint Research Project	Coal beehive briquettes, pillow type coal briquette and Biocoal	Nepali coal is low grade and polluting; with high sulphur	Biocoal was tested for cooking at Muglin, Khairenitar
1992	Manual Coal ball briquetting	Locals of Dang area	Manually made coal briquettes from coal dust, cow dung and clay	Briquettes were neither durable nor stable; excessive smoke, smell and sulphur oxides emission	Manually produced and used for cooking instead of wood and coal
1994-95	Roller press briquetting machine	Jongbu Sherpa (Dang)	Pillow type coal briquettes	Second hand machine was old and not operational for a long time	Introduced to make strong and pollution free briquettes
1995	Briquetting of municipal solid waste	NESS Research	Fuel briquettes from municipal solid waste	Research carried out by NESS. Test results were promising	The heat content was high, and the fuel was easy to ignite, especially due to presence of plastic
1997	Manual beehive (honeycomb) briquetting	Center for Energy and Environment Nepal (CEEN), Kathmandu	Beehive/honeycomb briquettes from charcoal and clay	Came to limelight after receiving NAST Award	Became popular among the rural communities as it is simple to and cheap and local availability of materials. Produced and used in more than 50 districts for cooking, space heating & oil massage.
1999	Screw extruder briquetting machine	NAST and AIT through “RETs in Asia” Project	Rice husk briquettes	Experimental unit to conduct research only but lacked promotion	Introduced as simple and cheap alternative to Taiwanese technology
2000	Roller press briquetting machine from Calcutta, India	Institute for Himalayan Conservation (IHC), Japan	Pillow type biocoal briquettes	Demonstration/experimental unit to conduct research, trial production and testing only	Taken to Jhapa to produce Biocoal briquettes to replace compressed coal dust briquettes
2002	Piston press briquetting machine from Gorakhpur, India	Entrepreneur in Kalaiya, Birgunj	Rice husk and sawdust briquettes	Production started but closed because of marketing problems	The plant operated for about one year only
2003-04	Manual compression technology (Local)	Foundation for Sustainable Development (FOST), Kathmandu	Briquettes from waste paper and biomass	Production and sales of briquettes and stoves. Also regular training provided to interested group/communities.	Simple & compact mould. Used by many people as replacement for wood, gas, kerosene, etc. Received NAST Promotional Award

Year	Technology/Product	Entity	Product Details	Situation/Problems	Remarks
2005	Rice husk briquetting (Chinese machine)	Mr. Harish Todi of JDA Apparel (Biratnagar)	Rice husk & saw dust briquette	Production/operation issues with the die. 3 piece die with different cross sectional areas. Briquette formation very difficult. Plant sold out to India.	Approached NAST with screw and die, but denied small financial assistance
2009	Screw extruder briquetting (portable multipurpose briquetting unit)	Center for Energy & Environment Nepal (CEEN)	Sawdust, rice husk, Mikania, RDF, charcoal briquette, etc	Small prototype machine operated by micro hydro. Needs improvement in machine and motor power.	Fabricated and introduced with AEPC support and installed in Tandi, Chitwan
2010	Rice husk briquetting (Chinese machine)	Ganesh Trading Center, Birgunj	Rice husk briquette (Production not started)	Similar machinery like JDA apparel imported but not yet installed.	Owner has automatic rice mill and rice husk is by product. Currently selling rice husk only
2010	Rice husk briquetting (New design similar to Bangladeshi machine)	Center for Energy and Environment Nepal (CEEN)	Rice husk briquettes	Introduced through support from RENP, KU. Also introduced improved version of Portable unit.	Being tested in NAST & RECAST premises
2010	Rice husk briquetting (Bangladeshi machine). Similar to "RETs in Asia" machine but with different power transmission system.	Jaibik Urja Udyog, Bhairawa	Rice husk briquette	High cost of rice husk. Irregular supply of electricity. Shortage of technical manpower. Non-availability of spare parts.	Establishment took more than a year for selection of technology. Bangladeshi unit was cheaper and but transportation is problematic
2011	Piston Press briquetting (from India)	Watabaran Nepal (Budhanilkantha, Kathmandu)	Sawdust briquette	Factory shut down due to political intervention	Factory being shifted to Chitwan. Now running under the name Subha Biomass Pvt Ltd
2012	Screw extruder briquetting (Second hand from Taiwan). Biomass drying unit designed and made by Narayani Engineering works (Nepal)	Namuna Briquette Industry	Rice husk briquettes. (2 x 100 kg/hour)	High wear and tear of machine, screw and blower in winter as moisture content in raw materials is high. Heat management in die. Market establishment and Marketing challenges.	Production capacity is not sufficient; plans to purchase 2 more units, use different raw materials like pine needle, sawdust and to develop different types of stoves for briquettes.
2013	Piston press from India	Shubha Biomass Pvt Ltd	Sawdust, sugar cane bagasse, banmara. 75 tons/month.	Factory shifted from Kathmandu	Production started from February 2013
	Piston Press from India	Indira Sugar Mills Pvt Ltd	Sugar cane bagasse	Established within Sugar Industry. Sugarcane bagasse has high moisture content, requires dryer. Briquettes are costlier than fuelwood hence requires subsidy	Product analyzed by CEEN
	Piston Press briquetting	Mahakali Sugar Mills P. Ltd.	Sugar cane bagasse	Established within Sugar Industry	Product analyzed by CEEN

Table 19. Briquetting Plants based on Rice Husk Pyrolyzing Technology (WECS, 1988).

Name	Location	Year of Establishment	Origin of Technology	Capacity (ton/year)
Nepal Bio Extruder Industry	Kathmandu	1982	India	900
Nepcoal Pvt. Ltd	Butwal	1984	India	1,200
Kosi Briquette Fuel Industry	Dharan	1984	PECo, Nepal	600
Trishakti Husk Coal Briquette	Narayanghat	1990	PECo, Nepal	600
R.S. Briquette Factory	Kathmandu	1990	PECo, Nepal	600

These factories exhibited significant pollution levels, giving out a lot of smoke and odour from the charring units. Moreover, they also had certain technical problems involving screw extruder and coal tar during production leading to their closure. Some of the issues faced by these industries are given as follows (AEPC, 2014):

1. The cost of imported machinery/equipment was high and repair/maintenance of the pyrolyzer, screw and other components were frequent and costly.
2. Plant operation and repair/maintenance was difficult due to shortage of technical manpower.
3. The Pyrolysis plant in the process was very polluting to the environment in terms of harmful emissions (carbon monoxide, smoke and sulphur compounds) as well as formation of coal tar.
4. Raw material (rice husk) was very abrasive, costly and only seasonally available.
5. Drying the raw material and product was costly.
6. The product was not of high quality as the heat content was low (<4000 kcal/kg) and the ash content was high (>20%).
7. Appropriate cooking/heating devices were lacking, and marketing of briquette product was difficult.

4.1.2 Screw Extruder Briquetting

The screw extrusion technology to produce rice husk briquettes was first demonstrated in 1986 in Khumaltar Agricultural Complex by a Japanese private company, Fuji conveyor and was supported by Japanese Embassy. After demonstration the briquetting unit, donated to the Agricultural Complex at Khumaltar. This unit was later taken to Janakpur Tobacco farm to replace the fuel wood for curing tobacco in curing barns [shown in Figure 4.2 (left)]. This demonstration event seemed to have fostered the promotion of rice husk briquetting industries in Nepal. Over two dozen briquetting industries were registered in the Department of Industries (WECS, 1988).

During 1987-88 four extrusion type briquetting plants were imported from Taiwan by private parties and rice briquetting factories were established in Simara, Hetauda, Chitwan and Parwanipur. Normally these industries were running 8-hour shifts. However, during the trade transit conflict with India in 1999, the Chitwon Briquette Koila Udyog running 3 shifts (24 hours) had saved many industries, including the Brikuti Paper Factory of Gaidakot, by providing briquettes as boiler fuel to many important industries.

The high cost of this imported technology, even led to fabrication of simple briquetting units within Nepal. Two more industries using similar type of technology came in operation in Chitwan (Himalayan Briquette Udyog) and in Nepalgunj (Bageswori Briquette Udyog) (Singh et al, 2010a). These briquetting industries were in operation till 1995. Despite the struggle and effort of these industries, most of them had to close down due to technical, market and bank loan problems along with lack of government support. Nevertheless, Mhepi

Briquette Udyog (Kawasoti) which uses technology from Taiwan [Fig. 39 (right)] is operational up to today.

Fig. 39. **(left)** Fuji conveyor briquetting unit in Janakpur and **(right)** Mhepi Briquette Industry.

The issues faced by these industries include the following:

1. High cost of the imported technology leading to issues in loan repayment issues
2. Wearing of the screw due to high ash content of rice husk
3. Lack of skilled labour for operation and repair/maintenance of equipment
4. Lack of technical support and R&D (Research and Development) in the country
5. Marketing issues due to lack of awareness, publicity and promotional programs
6. Lack of policies, programs and conducive environment. There were neither concessions, subsidies, tax incentives nor motivation to these briquetting industries
7. Raw material issues- The cost of rick husk grew, and availability was only seasonal. Some industries ventured into other types of raw materials like sawdust, *banmara* (Ageratina adenophora; catweed), biomass waste under the high-tension lines, and to produce charcoal.

Despite the closure of old industries, it is interesting to note that, new industries - JD Apparels Industry (with Chinese machine) in Biratnagar (2005), Ganesh Trading Center (with Chinese machine) in Birgunj (2010) and Jiabik Urja Udyog (with Bangladeshi machine) in Bhairawa (2011) were established, showing that there is still ample scope and potentials of rice husk briquetting industries (Singh et al, 2010a). Furthermore, in 2013 more industries with bigger production capacities have been established in the private sector- Shubha Biomass Pvt Ltd (Chitwon), Indira Sugar and Agro Industries P. Ltd, Nawalparasi (Mahakali), Sugar Industry Pvt Ltd (Rampur Bilaspur VDC). All of these are using the piston press (Ram Piston) technology from India to briquette saw dust and sugar cane bagasse (CEEN, 2013a; 2013b; 2013c).

4.2 Research and Development

i. During 1992-95, Nepal Academy of Science and Technology ("**NAST**", previously known as RONAST) and Japan International Cooperation Agency ("**JICA")** first introduced pillow type coal briquettes from Hasimoto Sangio Co., Japan and coal beehive (honeycomb) briquettes along with stoves. Both these products could not be promoted because Nepalese coal was low grade and had a lot of sulphur. Later in view of utilizing the low grade coal (including lignite), NAST tested and introduced *Biocoal* (a blend of coal, biomass and de-sulphuring agents) different places of Muglin and Khairenitar (Yoshida and Singh, 1995).

ii. During 1999 to 2000, Institute for Himalayan Conservation (“**IHC”**) of Japan in cooperation with NAST and King Mahendra Trust for Nature Conservation introduced a roller press briquetting machine [shown in Fig. 40 (left)] for production and demonstration of Biocoal briquettes (Sharma, 2003). This machine was later taken to Jhapa [shown in Fig. 40 (right)] to supply briquettes for the Bhutanese refugee camps as the Indian compressed coal dust briquettes in use were very polluting and riddled with issues.

Fig. 40. **(left)** Biocoal briquettes from Roller Press Machine Introduced by IHC and **(right)** The roller press briquetting machine in Jhapa.

iii. Around the same time in 2000, NAST joined the “Renewable Energy Technologies (RETs) in Asia” Project in Asian Institute of Technology (AIT), which introduced a simple screw extruder biomass briquetting technology from Bangladesh. This technology proved to be far simpler in operation and cheaper than technology from Taiwan. In addition, the project addressed the technical issue of screw wear using hard facing welding rods, smoke removal systems, briquette burning devices etc. (Bhattacharya & Kumar, 2005)

iv. In 1997, Beehive (honeycomb) briquettes from charcoal and clay after some adaptive research was introduced and promoted by the Center for Energy and Environment Nepal (“**CEEN**”). This technology became popular among the rural communities as it is simple to adapt, cheap, requiring local materials only (Shrestha, 2006). This work was recognized by NAST in 2005 and awarded the Mohan Dhoj Basnet Renewable Energy Award, which brought this technology in the limelight. Currently this technology is practiced in more than 50 districts in Nepal. In 2010, the demand for beehive briquettes in Kathmandu alone is over 500,000 pcs and the government have a target of promotion of these briquettes as cooking and heating fuel to 200,000 urban households in the 8th Three-Year Plan (2010/11-2012/13) (NPC, 2010).

v. During 2002-2003 Foundation for Sustainable Development (“**FoST**”) introduced the concept of making briquettes from waste materials using simple compression technique. Training and promotional programs were organized; different types of stoves and briquettes produced from waste paper and biomass [shown in Fig. 41 (left)] were promoted as a substitute for fuelwood (CEEN, 2013c). Recognizing this genuine effort NAST awarded the S&T Promotional Award to FoST in 2010.

vi. In 2009 CEEN initiated a project on biomass briquetting with NAST as research partner and Mhepi Briquette Udyog as industrial partner through the Renewable Energy Program (RENP) of Kathmandu University. This project introduced a new design of portable screw extruder briquetting machine [shown in Fig. 41 (right)]; which is similar to the briquetting machine of RETS in Asia Project. Besides using different hard facing welding rods, it also introduced the Eutectic (Spray) welding technology to address the wearing of the screw. Also, different types of cooking and heating devices using briquettes were tested and demonstrated (Fig. 42). (Poudel et al, 2012).

Fig. 41. **(left)** Compression Briquetting of Waste Materials by FoST and **(right)** Portable Screw Extruder Briquetting Machine

Fig. 42. **(left)** Space Heating Stove and **(right)** Low-Cost Tin Stove

In 2012, it introduced another technology from China to produce pellets from rice husk. The rice husk pellets are 20mm square shape and are around 3-6cm in length. Trial production was conducted, however technical difficulties were faced, and production could not be smooth, and the pellets have not come to the market yet. Moreover, in 2013, Mhepi has again ventured into beehive briquetting and introduced a hydraulic briquetting machine, which can produce about 40 pieces of beehive briquettes in one minute. The production process is smooth, but the product has yet to come to the market.

4.3 Issues associated with Biomass Briquetting in Nepal

Upon an extensive survey, a number of issues faced currently by biomass briquette manufacturers and users in Nepal have been identified. The issues reported as follows:

1. High cost of briquetting technology (especially foreign technology) leading to high capital investment.
2. Wear and tear in screw and die, piston, blower and machine surfaces. High moisture content of raw materials is one of the causes for wear and tear of machines.
3. Irregular supply of electricity leads to interruption in production. Moreover, low quality of electricity (voltage lower than 300 V) may lead to jamming of the screw feeder.
4. Drying technology for moisture removal are expensive and inefficient.

5. Management of heat in the die is problematic.
6. High level of CO emissions during the combustion of briquettes, especially the charred briquettes.
7. Inadequate stove and boiler designs leading to inefficient combustion of briquettes
8. Difficulty in assessing the quality and consistency of briquettes.
9. High cost and local unavailability of spare parts (piston and die, screw and die).
10. Lack of financial incentives (subsidies, tax, soft loans etc.) as well as policy measure supporting the briquette industry.
11. Lack of technical support and manpower from R&D and academic institutions
12. Challenges associated with marketing and promotion of briquettes.

4.4 Resources for Briquetting

One of the important components for establishment of briquetting industries is the cheap and abundant residual biomass, which includes agro-residues, forest residues and other waste biomass. The scenario of biomass resources in Nepal is detailed in the following subsections. It is worth noting that, statistical data for a wider range of biomass resources need to be assessed in Nepal.

People in Nepal have been using agricultural residues from crops (such as straw, stalks etc.) and residue from industrial processing of crops (e.g. rice husk, bagasse, coffee husk etc.) for various purposes including cooking and heating. In addition, people have been utilizing forest wastes as fuel for cooking, animal bedding and compost preparation. However, despite being available plentifully, forest wastes are not utilized as much as agricultural residues. Moreover, forest residues can be fire hazardous during the dry season, which warrants proper measures for control.

The total biomass materials which can be available for biomass briquetting can be categorized as follows- Agricultural crop residue, forest residue materials, wood-based industries, residues from medicinal and herbal plant processing, municipal solid waste (MSW) and other biomass residues (CEEN, 2014; Singh, 2013).

4.5.1 Agricultural Crop Residue

Residual biomass is the biomass remaining from crops after separating the grain or produce. Researchers use different methods for determining the residue. One such method makes use of the factor indicating the ratio of the weight of the residual biomass to the weight of the total biomass. Total biomass takes into account the grain and the entire residue. This ratio is known as the Residue Index (RI). This term can be expressed as follows- Residue Index (RI) = Weight of the Residue/Weight of the Total Biomass. On the other hand, many researchers use a similar indicator called the Residue to Product Ratio (RPR) of Crops. This takes into account the yield of the crops having a definite relationship with the residue that is left after extracting the produce. The RPR is defined as the gravimetric ratio of the residue to the actual produce of the crop. The accuracy of the RPR value has been found to give near-practical estimates of the total residue generated. It can be expressed as follows- Quantity of crop residue generated (tonnes) = RPR x Y. Where, RPR = Residue to Product Ratio and Y is the Crop Yield (tonnes) (Koopmans and Koppejan, 1997).

The residue estimates of some cereal crops and cash crops are given in Table 20 and Table 21 respectively. It can be deduced that, a huge amount of paddy residue is generated every year. Along with this, maize, rice husk and wheat straw are also present in abundance. In addition to cereal crops, there are a large number of cash crops yielding significant amounts of residue directly after harvesting. Industrial processing of these crops also yields residue, such as in the case of sugarcane which produces bagasse.

Along with these, other agricultural waste includes lentil stalk/straw, walnut kernels, tobacco waste, tea waste, coir pith, jute sticks, mustard stalks, and wastes from cardamom and banana etc. In order to fully understand their potential, assessment studies need to be conducted to know the amount available.

Table 20. Details of Cereal Crop Residues in Nepal (CEEN, 2014; MoAD, 2012)

Crop Type	Area (ha)	Crop Production (Tons)	Residue Type	Residue to Product Ratio	Total Residue Production (Tons)
Paddy	1,531,493	5,072,248	Husk	0.267	1,354,290
			Total residue	1.68	8,521,376
Maize	871,387	2,179,414	Stalk	2	4,358,828
			Cob	0.273	594,980
			Husk	0.2	435,883
			Total residue	2.473	5,389,691
Millet	278,030	315,067	Stalk	1.08	340,272
Wheat	765,317	1,846,142	Straw	1.75	3,230,748
Buckwheat	10,339	10,021	Straw	1	10,021
Barley	27,966	34,829	Straw	1.75	60,952

Table 21. Details of Cash Crop Residues in Nepal (CEEN, 2014; MoAD, 2012)

Crop type	Area [Ha]	Crop Production (Tons)	Residue type	RPR	Total Residue Production (Tons)
Oil Seed	214,835	179,145	Stalk	4.01	71,837
Sugarcane	64,472	2,930,047	Bagasse	0.29	849,714
			Tops/Leaves	0.3	879,014
			Total		1,728,728
Jute	10,540	14,424	Stick	2	28,848
Soybean	29,281	28,269	Straw	2.5	70,674
			Pods	1	28,269
			Total		98,944
Black Gram	27,496	22,482	Straw/stick	1.66	37,320
Cotton	135	133	Sticks	2.75	365
Coconut	-	-	Husk	0.419	-
	-	-	Shell	0.12	-
Coffee	1,780	425,000	Husk	2.1	892,500
Groundnut	2,736	3,869	Husk	0.477	1,845
			Straw	2.30	8,899
			Total		10,744

Table 22 shows the distribution of rice production and the potential for briquetting of rice residue. It can be deduced that the Terai region of the south have a briquetting potential four times greater than the Hill region in the north. Taking into account road accessibility, 25% of the husk is assumed to be available for briquette production in the hills region and 50% in the Terai region. Most of the agro-based briquetting plants in Nepal are located in the Terai region as majority of the agricultural activities take place there.

Table 22. Potential of Briquetting from Rice Husk in Terai and Hills region (MoA, 2004)

Physiographical Region	Paddy Production	Rice Husk Production	Husk Available	Briquette Producing Potential
	tons			
Hills	999,865	249,966	47,876	43,088
Terai	3,342,260	835,565	417,783	376,004
Total	4,342,125	1,085,531	465,659	419,092

4.5.2 Forest Based Biomass Resources

Forests are great sources of raw materials for biomass briquetting. The residue produced includes twigs, leaves, sticks; pine forest residue such as pine cones and needles; invasive plants and herb processing waste as well as waste biomass from pruning of vegetation from agricultural land.

Around 39.6% of the total land area of Nepal is covered by forest and shrubs. According to a study conducted by Forest Resources Survey Department the potential assessment of total growing stock (i.e. total biomass of stems, branches, leaves of tree from ground level to the top) is nearly 285 million cubic meters while the available volume per hectare is about 131 cubic meters (WECS, 2010). Forest residues can be mainly classified into residues coming from management of vegetation and waste generated from the forest itself. Along with this, there are wood-processing waste and herb-processing waste (described later in this section). The resources available from forests are shown in Table 23 and described thereafter.

Table 23. Estimates of some Forest Residues (Poudel, 2010; Singh and Shakya, 1994)

Residue	Amount (tons)	Project Area (ha)	Project/Source
Banmara	8800	11,000	Sagarnath Forestry Development Project (1994)
Bhanti	1.5 tons per hector	-	Sagarnath Forestry Development Project (1994)
Pine needles	1,727,785	345,557 (35 districts)	Rosin and Turpentine factory, Dhangadhi
Mikania micrantha	91,088 (dried material)	27,960*	Chitwon National Park survey

*30% Coverage with total Project Area at 93200 ha

(i) Forest Waste

Waste generated from forest itself such as leaves falling from the different trees, weeds and invasive plants, etc. can be used for briquetting (Fig. 43). A lot of trees (Sal) shed leaves regularly during the winter season and produces a thick bed of leaves in their vicinity. Likewise, a thick layer of pine needles as well as pine cones are found in pine forests. All these residues are plentifully available and are very fire hazardous during the dry seasons, being known to cause tremendous amounts of damage (Tyagi, 1990). There are also a lot of invasive species such as *Banmara, Mikania macrantha*, *Besarmi jhar* etc, which have proliferated into the forests as well as grasslands, and may prove as a threat to habitats. *Lantana camara* (*Dhungri Phul)*, *Bokshi Kanda* and Mugwort (*Tite Pati*) are invasive biomass similar to Banmara. On the other hand, water hyacinth is creating issues in various water bodies including Fewa Lake. Many more such waste biomass (e.g. *Bokshi Kanda,* bamboo waste) exists in different parts of the country but the amount of coverage and the data are yet to be established. (Singh, 2013).



Fig. 43. **(left)** Dhungri Phul; **(centre)** Tite Pati; **(right)** Bokshi Kanda

Some of the well-known forest residues in Nepal are detailed as follows:

(a) Saal Leaves: Saal trees in Nepal are a source of a hardwood which is used in the housing and construction sector. Saal trees have slow to moderate growth rate. They can attain heights of around 30 to 35 m and a trunk diameter of up to 2-2.5 m. The leaves are 10–25 cm long and 5–15 cm broad. In wetter areas, they are evergreen. While in drier areas, they are dry-season deciduous, shedding most of the leaves (Fig. 44) in between February to April, giving rise to a bed/carpet of leaves, 8-12 inches high and leafing again in April and May. Timely disposal of this material is necessary as it can induce forest fires that can devastate the forest area. An estimate has shown that a total of 3,654 million ha of forest area requires improved management, of which Saal forest occupies an area of 1.32 million ha in Nepal (Ojha et al, 2008).

Fig. 44. **(left)** Saal leaves on the forest ground and **(right)** Collection of leaves in Saal forests**.**

There is a considerable amount of litter fall annually in tropical dry deciduous forests. According to Burges (1958), the total litter fall in tropical deciduous forests may reach up to 1.53 thousand kg/ha/yr. Taking this figure into account and translating it to the total Saal forest area in Nepal- the amount of leaf litter comes to around 2,019,600 tons per year (Soni et al, 2011).

In earlier times, fresh green leaves of saal found limited use traditionally for making *tapari* (a traditional leaf plate used in Nepal). Contemporarily, they are also being used as raw materials for industrial production of these traditional plates and bowels, consuming large amounts of leaves. One such industry alone has around 5 tons of waste materials, which do not find any use (CEEN, 2014). Since these leaves have good heating values and low ash content they can be used as raw materials for briquetting. These leaves have higher calorific values than other waste biomass, at about 4880 kcal/kg (CEEN, 2014).

(b) Pine Needles and Cones: Chir pine (*Pinus roxburghii*) is an essential indigenous coniferous tree species in Nepal. They dominate the coniferous forests of the country, which comprise 17% of the total area. The total Chir pine forest area in Nepal is reported to be 382,944 hectares (CEEN, 2014), with an average of 50 pine trees with stem diameter greater than 30 cm in each hectare. Between 1981 and 1982, around 57% of all the trees planted during the Community Forestry Development Project were chir pine. From the seventy-five districts in the country, forty-eight districts have pine forests (Table 26). Western regions of Nepal house a higher percentage of pine forests. Accham, Baitadi, Doti, Salyan, Dailekh, Jajarkot, and Pyuthan have crossed the 25% mark.

Pine woods are a good raw material for timber used in making furniture and plywood. Resin from chir pine trees is used to manufacture turpentine, rosin and other products. The only wastes from pine trees are the pine needles and cones. They form a thick carpet on the forest floor around the trees every autumn. Since pine needles are loose forest residue that decay slowly, they can be a major cause of forest fires especially during the dry season. Thus, pine needles need to be collected to minimize such risks. Moreover, the accumulating carpet of needles on the forest floor makes it unfavourable for many common plants and trees to grow.

At some places, locals gather these needles in large bundles in order to make bedding for their cattle for the whole year. Thus, pine-needle collection could generate employment opportunities for the villagers. It is estimated that one family can collect up to 100–200 kg of pine needles in a day depending upon the time they spend in collection. A pine forest area of 1 m^2 can yield around 1.19kg of pine needles and 115 ha of pine forest area can produce around 1350 tons of pine needle annually. Translating this to the total the pine forest area in Nepal (i.e. 382,944.80 ha), around 4.5 million tons of pine needles can be available as raw material every year. (CEEN, 2014). Moreover, an equal amount of pine cones can be expected from these forests as well, which can prove to be a potential raw material base for biobriquetting.

Furthermore, pine needles is being used as raw materials for various purposes like biomass gasification for electricity generation, briquetting and pellet production. In Berinag, Uttarakhand, India, it is used for gasification and villagers get Rs 1,000 for every ton of needles collected. Hence, the material itself is free of cost, except the cost of collection (MNRE, 2012).

(c) Banmara: Banmara (meaning the forest killer) or *Adenophorum Eupatorium* is an invasive seasonal plant which is believed to have propagated from Latin America. It has many species and can be found throughout the country in forest areas, agricultural land as well as on the sides of roads and highways (Fig. 45). This plant can be threatening to other plants around it and even to large forest areas. Similar to pine residue, banmara is fire hazardous during the dry season and the seed of this plant can be carried over long distances during forest fires. The Sagarnath Forestry Development Project undertaken in 1994, performed a preliminary study over an area of 11,000 hectares and reported that an average of 0.8 tons of Banmara can be collected from one hectare. An estimated amount of 8800 tons could be generated from the project area and the collection cost cames to Rs 40 for 70 kg per person.

An assessment carried out in 2014 for the amount of Banmara in some parts of the country showed that the amount of dry matter that can be obtained is about 17 tons/ha annually (Table 24). The total area of coverage of Banmara has not yet been established, but the visibility of A huge amount of banmara was found along the highways (East West Highway and other roads) and degraded forest areas, especially the areas under the high-tension electricity lines. The exact coverage area of Banmara needs to be established in order to evaluate the total amount available in the country.

Table 24. Amount of Banmara obtained from a few areas in Nepal (CEEN, 2014)

Site location	Weight of Wet Biomass Per Unit Area (kg/m^2)	Weight of Dry Biomass Per Unit Area (kg/m^2)
Makwanpur (Bhaise)	10	2.5
	11	2.75
Nawalparasi	6	1.5
	6	1.5
Dhading	6	1.5
	3.5	0.85
	7.5	1.85

Fig. 45. Banmara growth in Nepal (CEEN, 2014)

(d) Mikania macrantha: Mikania macrantha also known as Mile-a-minute, is one of the many invasive plant species, which has been found to cause severe damaging effects on young trees, shrubs and grasses in mixed and riverine forests as well as grasslands. It has reduced the availability of food for wildlife species found in Koshi Tappu and Parsa Wildlife Reserve and Chitwan National Park areas. Its infestation of Chitwan National Park area is estimated to be covering 30% of the entire area. Moreover, it is a threat to the rhinoceros habitats. The spreading of this plant can lead to reduction of the forest's productivity and regeneration ability, leading to degradation.

It can neither be used as a good feed for animals nor does it have any other use. Thus, briquetting can be a suitable method for utilizing it. Singh and Poudel (2013) and Poudel (1994) has reported that Mikania can be used to produce various types of briquettes – screw extruded briquettes, beehive briquettes and charcoal pellets using clay as binder. A survey conducted jointly by NTNC, TCN and NAST in Chitwan National Park has shown that 91,088 tons of dried Mikania or 34,158 tons of Charcoal from Mikania is available for briquetting purposes annually. The results of this study are tabulated in Table 25.

A study showed that over 20 districts in the Terai region has been infested with Mikania with approximately 600,000 tons produced annually (Sapkota, 2007). Therefore, the potential of using Mikania as feedstock for briquetting in these areas is commendable. Further assessment and quantification is required for prudent utilization of this plant in the briquetting industry.

Table 25. Estimation of Mikania biomass in Chitwan National Park (CEEN, 2014)

Parameter	Amount	Unit
Number of times Mikania can be collected in a year	2	-
Moisture content	86.6	%
Average fresh weight of Mikania from a 25 m^2 plot	30.39	kg
Total area of Chitwan National Park	932	km^2
Mikania coverage	30	%
Effective area of Mikania coverage	279	km^2
Total weight of Mikania biomass in Park	339,881	tons
Total biomass yield from 2 collection phases in a year	679,763	tons
Recovery of dried Mikania for direct densification	91,088	tons
Recovery of Mikania after charring/charcoal briquetting	34,158	tons

Table 26. Total Forest Area and Chir Pine Forest Cover in the Nepalese Districts (CEEN, 2014)

District	Total Forest Area (Ha)	Chir Pine Forest Area (Ha)	Percentage Chir Pine Forests (%)	District	Total Forest Area (Ha)	Chir Pine Forest Area (Ha)	Percentage Chir Pine Forests (%)
Salyan	79,598	52,539	66.01	Baglung	98,045	1,841	1.88
Jajarkot	135,615	36,460	26.88	Mugu	111,098	1,776	1.6
Doti	144,689	35,573	24.59	Panchthar	57,706	1,391	2.41
Baitadi	78,720	31,708	40.28	Palpa	71,172	1,313	1.85
Surkhet	177,855	31,046	17.46	Myagdi	84,452	1,056	1.25
Achham	88,097	22,122	25.11	Nuwakot	49,654	1,056	2.13
Dadeldhura	115,891	21,620	18.66	Parbat	19,997	1,040	5.2
Dailekh	78,137	18,496	23.67	Kathmandu	13,752	741	5.39
Pyuthan	72,694	16,373	22.52	Sindhupalchok	162,543	724	0.45
Kailali	231,093	15,761	6.82	Dhankuta	36,385	601	1.65
Rolpa	94,097	15,219	16.17	Bhojpur	77,887	542	0.7
Bajhang	113,179	8,813	7.79	Kaski	89,943	400	0.44
Argakhache	73,133	6,247	8.54	Gorkha	112,534	344	0.31
Sindhuli	62,043	6,159	9.93	Bardia	127,682	295	0.23
Gulmi	40,663	5,973	14.69	Lalitpur	20,727	161	0.78
Makwanpur	167,453	5,879	3.51	Tehrathum	24,627	160	0.65
Dang	197,273	5,253	2.66	Rasuwa	52,290	118	0.23
Rukum	136,452	4,796	3.51	Taplejung	139,167	96	0.07
Ramechhap	66,151	4,525	6.84	Dhading	92,855	3,495	3.76
Okhaldhunga	47,346	3,746	7.91	Kavre	72,949	3,343	4.58
Dolakha	94,477	3,660	3.87	Khotang	79,553	2,913	3.66
Bajura	98,646	2,506	2.54	Udayapur	138,916	2,185	1.57
Darchula	97,538	2,714	2.78	**Total**	4,270,700	382,944	8.96

(e) Besarmi jhar Besarmi jhar (Fig. 46) is found in abundance in the Terai region. It grows wildly in water logged areas along the highways and roadsides. A sample survey of the plant shows that from an area of 2 m^2 about 8–10 kg of wet biomass can be collected. This yields around 5-6 kg of dried biomass which can be used for briquetting. As of yet, the total area coverage by this plant is not known and requires detailed assessment.

Fig. 46. Besarmi Jhar in Nawalparasi (CEEN, 2014)

(f) Biomass under High Tension Lines

An important resource which is often neglected wasted is the biomass obtained from the vicinity of high tension lines. Climbers and trees below high-tension lines need to be cut annually so that they do not damage these power transmission lines. The report by NIDC (1990) on fuel briquetting states that a huge amount of biomass under the high-tension lines is cut annually and wasted. The report also recommends this biomass as a very good raw material which should be distributed free of cost to the existing briquetting industries. Studies directed towards quantification and utilization of this resource is essential.

(g) Pruning of Trees at Plantations

Another potential source of forest-based biomass is the wood residue generated in perennial crop plantations during pruning of vegetation that is carried out before replanting of useful trees. Perennial crop plantations such as for coconut, palm oil and rubber generate considerable amounts of wood residues from these activities. Further studies (both qualitative and quantitative) are required in order to evaluate their true potential for biomass briquetting.

4.5.3 Herb Processing Waste

Nepal has a rich biodiversity with various types of medicinal and aromatic herbs that are processed by the herb industry. After processing of the herbs (e.g. extraction of oil), around 90-95% of the remaining weight is left as residual biomass (HPPCL, 2017). These residues can be potential raw materials for briquetting as well. Around 28 species are used in the herb industry including Bojo, Jatamasi, Taxus, Eucalyptus, Citronella and Lemongrass etc (Table 27). The residues of these plants will have good heat content as there will be residual oil in it. Potential availability of residues from the herb-processing industry on an annual basis is nearly 7,016 tonnes. (Shakya, 2006).

4.5.4 Waste from Wood-Based Industries

Waste from wood processing plants include wood residues from logging, saw-milling, veneering and manufacturing of plywood and particle board. Logging residues consist of branches, leaves, lops, tops, damaged or unwanted stem wood. After obtaining the logs, around 12% is separated as waste in the form of bark. Slabs, edgings and trimmings amount to about 34%, while sawdust constitutes another 12% of the log input. After drying the wood in kilns, further processing may take place resulting more waste in the forms of sawdust (8%), trim end (2%) and planer shavings (6%). In order to quantify the waste, a yield factor of 50% has been considered (38% solid wood waste and 12% sawdust) (IMWB, 1999; Eriksson and Prior, 1990). This indicates the huge amount of waste generated from wood processing.

Table 27. Estimation of Mikania biomass in Chitwan National Park (HPPCL, 2017)

Medicinal Plant	Oil Production (kg/year)	Raw Material Used (ton/year)	Residue Yield (%)	Residue (ton)
Jatamasi	500	25	98	24.5
Sugandha Kokila	1000	20	95	19.0
Timur	200	10	98	9.8
Bojho	1000	20	95	19
Bikh	500	5	90	4.5
Asuro	1000	10	90	9
Sunpati	400	40	99	39.6
Dhupi	400	40	99	39.6
Cintronella	9000	900	99	891
Taxus	500000	5000	90	4500
Tulsi	500	50	99	49.5
Palmorosa	2000	200	99	198
kachur	200	20	99	19.8
Titepati	50	5	99	4.95
Pudina	4000	400	99	369
Machina	1200	120	99	118.8
Eucalyptus	3500	350	99	346.5
Caoomile	300	30	99	29.7
Lemongrass	3000	300	99	297
Total				**7016.25**

(i) Sawdust

There are various saw mills (both private and public) under the Timber Corporation of Nepal, located throughout the country. A study conducted in the early 1980s had reported that the Timber Corporation of Nepal (**"TCN"**) in Hetauda was generating 14,800 tons of wood wastes annually in the form of sawdust, bask, trim-ends, etc. It further showed that 10 tons of sawdust alone is produced on a daily basis. It is worth noting that a piston press briquetting plant with production capacity of 8 tons/day had been proposed during the early 1970s (NIDC, 1970). This shows that sawdust and wood waste has had a large potential for briquetting for decades.

Similarly, substantial amounts of sawdust is generated from veneer (detailed later in this section), plywood production and particle board production. The cases of particle board and plywood industries need to be assessed for the potential of residual biomass generation.

TCN had presented some estimates of wood waste produced in the saw mills, although the number of saw mills operating is not known. It is assumed that around 9-11% of sawdust is obtained during the processing of timber. Taking the average at 10%, the volume of sawdust obtained is shown in Table 28. Moreover, during processing of timber substantial amount of the biomass such as twigs and branches are also obtained (Table 28).

In spite of having such a large resource base for briquette production from sawdust and wood waste has not been a priority. This is due to lack of interest as well as genuine knowhow about briquetting technology coupled with ignorance which tempts the villagers and sawmill owners to simply burn the obtained residue without briquetting.

Table 28. Statistics of Timber Usage and Wood Waste obtained in 2004-2009 (Department of Forest, 2009)

Year	Timber Used (ft^3)	Volume of Sawdust & Wood Waste (ft^3)	Twigs and Branches (ft^3)
2004	1,227,740	122,774	21,650
2005	924,843	92,484	1,464
2006	1,266,009	126,600	1,871
2007	1,271,516	127,152	1,713
2008	1,359,099	135,910	1,939
2009	673,275	67,328	893

(ii) Waste from Veneer Industries

According to the Nepal Veneer Producers Association, there are around 200 veneer industries established all over NepaI, with only 54 of them registered in this association. In Birtamod alone there are around 38 veneer industries, which are using *Utis*, *Malato* and *Mauwa* logs (costing around Rs 150 per cubic feet) from Ilam and Panchthar. Along with this, around 20 industries are situated in Morang districts. The Nepal Veneer Producers Association also stated that currently 25% of the waste from these industries are being consumed locally as fuel for cooking and boilers and 75 % is unused. (Nepal Veneer Producers Association reported in CEEN, 2014)

One such industry - Shree Hari Om Veneer Udyog in Ataarmani, Jhapa – processes around 300 - 500 ft^3 of logs per day. Along with the veneer product the industry generates a huge amount of different types of waste. Mainly five different types of waste are generated in the factory (tabulated in Table 29 and shown in Fig. 47)- bark of the logs, the remainder of the central part (locally known as *golla* or *gollia*), sawdust, small chunks/pieces of wood and small pieces/straps of unusable veneer. A part of the waste is sold to a tea factory, which uses about 8 tons/per week as fuel in gasifiers for drying the tea leaves. Some amount of the waste is sold to the local people as fuel for cooking. These wastes from the veneer industry could be a potential raw material for briquetting. Since the wood used is mainly soft wood, they also are good raw materials for producing wood pellets. According to Ms Shri Om Veneer Udyog, the estimate of waste generated in the factory comes to about 30% of the processed wood. However, on sight observation indicate a higher value.

Table 29. Various Waste obtained from Veneer Industries in Nepal (Source: Shree Hari Om Veneer Udyog reported in CEEN, 2014)

Material	Cost (Rs/kg)	Purpose
Bark	2	Making alcohol
Gollia/*Golla*	6-7	Cooking/Tea factory
Sawdust	1	Cooking
Small Strips	3-4	Cooking/Animal Feed
Very Small Pieces	1	Cooking/Tea Factory

For veneer industries, Koopmans and Koppejan (1997) reported that the main forms of waste from the logs are log ends and trims (7%), bark (5%), log cores (10%), green veneer waste (12%), dry veneer waste (8%), trimmings (4%) and rejected plywood (1%). These constitute the largest amount of waste, while sanding the plywood sheets results in another loss of 5% in the form of sander dust (FAO, 1995). For calculation purposes a yield factor of 50% has been used, with 45% solid wood residues and 5% in the form of dust. Considering 50% as the waste factor and the average processing capacity of each factory to be 400 ft^3 per day, an estimated 200 ft^3 of waste is generated daily. Therefore, in Jhapa alone, some 7600 ft^3 of waste is generated daily.

Fig. 47. The various waste obtained from the Shree Hari Om Veneer Udyog factory (clockwise from top left): Bark; Remaining Central Part (*golla/gollia)*; Sawdust; Small Pieces of Wood; and Unusable Veneer (CEEN, 2014)

Currently, only 25% of the waste is being utilized by the locals and a few industries as fuel for boilers and tea drying. Around 75% remains unused as waste. Simple calculations using the density of softwood as 670 kg/m^3 (Engineering Toolbox, 2018), around 568,830 tons of wood waste is being generated in a day and this waste can be a good starting raw material for biomass briquetting. The results are tabulated in Table 30.

Table 30. Estimation of Waste Generated by Veneer Industries in Nepal (CEEN, 2014)

Particular	Volume of Logs Processed Per Day (Ft^3)	Waste Produced Per Day (Ft^3)	Density of Softwood (kg/m3)	Total Mass of Daily Waste (tons)
Waste from Sri Om Veneer	400	200	670	3.8
Estimation for 200 industries	80,000	40,000		758.44
Use by local population (25%)	-	-		189.61
Unused Waste (75%)	-	-		568.83

(iii) Other Waste from Wood Industries

There are many other wood processing industries such as the ones manufacturing furniture, handicraft, wooden frames etc. These factories also generate huge quantities of wood waste of a different nature. One of such an example is the Bira Furniture in Patan Industrial District ("PID") which processes around 3 trucks of wood (around 30 tons) every month to produce furniture, giving rise to around 10-15 tons of wood waste per month (CEEN, 2014). This waste too can be a potential raw material for briquetting.

Another factory in PID, Lalitkaltmak Kastha Udyog involved in the manufacture of wooden frames, also generate wood waste in the form of sawdust and small cut pieces during production. Around one truck (~0.5 tons) of sawdust and 1-1.5 tons of wooden strips are generated every week (CEEN, 2014). There are many such furniture, handicraft, parquet and other industries spread throughout Nepal that process huge amounts of wood. This posits the fact that huge amounts of wood waste are generated from these entities, which needs to be studied and quantified.

4.5.5 Municipal Solid Waste

Various countries in the modern world is viewing municipal solid waste **("MSW")** (commonly known as thrash/garbage) as a resource rather than just refuse materials including Japan, China, Singapore Taiwan, U.A.E. South Korea, Brazil, Sweden, Denmark, Germany, Italy, U.K., U.S.A. and so on. The MSW produced in urban areas have been utilized in various countries for power generation, making compost and recycling into useful products. Waste to energy generation is an economical and environmentally friendly method for waste utilization. The waste materials can be used to produce Refuse Derived Fuels ("**RDF**") such as solid waste fuel briquettes. This technology has been adopted in a number of cities in Japan, especially in the form of MSW fuel briquettes used for heating purposes. The huge amounts of MSW produced in Kathmandu can be reused as such as solid waste fuel briquettes.

The rising urban population undoubtedly correlates with the increasing production of municipal solid waste. The combustible portion of MSW can be utilized for energy generation. This fraction is considered to be a reliable source of energy, utilized in various forms (including briquettes) in countries around the world (SWMRMC, 2008). In place of imported Indian coal, MSW fuel briquettes can be used in brick kilns, industrial boilers etc. Nepal Environmental & Scientific Services (**"NESS"**) has carried out studies in the field of fuel briquettes in 1995. They reported that the presence of high plastic content in the waste showed promising results in terms of RDF with high energy content and easy ignitability (NESS, 1995). The average composition of MSW of Kathmandu valley, which consists of compostable waste (decaying organic matter), combustibles (paper, plastics, textiles) and incombustible inorganic matter such as glass and metal from different years are given in Table 31.

The five municipalities in the Kathmandu Valley generated approximately 468 tons of solid waste per day (SWMRMC, 2008). An older study showed that the five municipalities generated approximately 435 tons of solid waste per day, out of which more than 70% comes from Kathmandu Metropolitan City alone (CKV, 2005). This trend of increase in solid waste by 7.64% in a span of four years can be attributed to the increasing population in Kathmandu valley.

Nepal has 58 municipalities in total and the amount of waste generated by them stands at around 2,813 tons per day. Out of which around 76.9% (i.e. 2164 tons) of this waste is collected. The average combustible composition (% weight) of this waste can be subdivided into paper (8.59%), plastics (8.36%), textiles (1.66%) and woody matter (0.68%) (SWMRMC, 2008). This translates to around 186 tons of paper, 181 tons of plastic, 36 tons of textiles and 15 tons of woody matter on a daily basis. These are suitable raw materials for RDF and offer a great potential for large scale fuel briquette production.

Table 31. Composition of Municipal Solid Waste from Kathmandu from 1976-2000 (JICA, 2005; SWMRMC, 2008)

Type of	197	1981	1985	1988	1995	1999	2000	2004	2008

waste	6							
Combustible Waste								
Organic	67.8	60	67.5	58.1	65	67.5	69.84	67	68
Paper	6.5	19.3	6	6.2	4	8.8	8.5	10	10
Rubber	0	0	0	0.4	1	0.3	0.54	0.24	>1
Wood	2.7	1.6	0	0.5	3	0.6	0.73	-	-
Plastic	0.3	3.6	2.6	2	5	11.4	9.17	16	13
Textile	6.5	5.3	2.7	2	3	3.6	3.02	4	2
Incombustible Waste									
Leather	-	-	-	-	-	-	0.12	-	-
Bone	-	-	-	-	-	-	0.23	-	-
Ferrous metal	4.9	3.4	2.2	0.4	1	0.9	0.87	1	-
Aluminium	-	-	-	-	-	-	0.05	-	-
Metal	-	-	-	-	-	-	-	-	1
Sand dust	-	-	-	-	-	-	-	-	1
Glass	1.3	3.4	4	1.6	1	1.6	2.5	1	4
Construction debris/Others	10	3.4	15	28.9	17	5.3	4.33	1.24	1

4.5 Analysis of Raw Materials available in Nepal

Shakya et al (2006) analysed biomass briquettes produced from several resources in Nepal. The results of the proximate analysis of various biomass materials carried out by these researchers are tabulated in Table 32.

Table 32. Proximate Analysis of some Biomass Residues in Nepal (Shakya et al, 2006)

Biomass	Ash (%)	Volatile Matter (%)	Carbon (%)	Moisture (%)
Agricultural Residues				
Rice husk (Khumaltar)	15.93	57.83	15.64	10.60
Rice straw (Khumaltar)	16.25	53.03	12.67	18.05
Wheat straw	4.21	73.28	13.30	9.21
Forest Residues				
Saw dust	1.50	68.47	19.55	10.48
Banmara (KTM)	1.89	73.62	15.27	9.22
Khar (Sarlahi)	5.98	70.19	15.05	8.77
Pine bark	1.79	59.36	25.28	13.57
Pine needle	2.97	59.34	25.22	12.47
Medicinal Plant Residues				
Jatropha	8.73	64.51	16.49	10.27

It can be deduced that indicate that sawdust, banmara, and pine bark have the lower ash content, while rice straw and rice husk have higher ash content. Rice straw was also found to have higher moisture content. On the other hand, pine residue was found to have higher carbon content which indicates good energy value. As mentioned previously, several raw materials are available in Nepal which is suitable for briquetting or pelleting. A literature survey was conducted to determine the appropriate technological practices for each raw material. The findings are tabulated in Table 33.

Table 33. Briquetting Technology Selection for Various Raw Materials

Raw Material	Densification Technology	Pre-Processing	Binder	Reference
Rice husk and corncobs	Manually operated hydraulic press	Size reduction (0.6mm) using Hammer mill	Starch (5% by weight of starch)	Oladeji (2010)
Rice husk	Screw extrusion process (heated die)	Size reduction (0.6mm) using Hammer mill		Ahiduzzaman (2007)
Wood residue, rice husk and coffee husk	Piston press type (both mechanical and hydraulic)			Felfli et al (2010)
Sugarcane – baggase (sugarcane baggase size reduction)	Hydraulic press	Size reduction	Corn starch/ cassava(or monioka) starch	Teixeira et al (2010)
Rice straw	Piston mould press	Smashing and grinding	Rice bran, the soybean residue and saw dust of acacia confuse	Chou et al (2009)
Rice husk and eucalyptus woods	Hydraulic press	Carbonization of raw material, crushing and sieving	Char	Amaya et (2006)
Maize stover and coffee husk	Motorized screw press, mould box press machine, Piston press and manual press	Drying and carbonization	Fine clay, cassava flour, wheat flour, molasses, soaked waste paper, red soil	Ngusale et al (2014)
Dry leaves, Wheat straw, Sawdust	Manual press technology	Drying and grinding	Paper pulp and cow dung	Roy et al (2015)
Sawdust (Pine) and Wheat straw	Hydraulic press	Air drying (sawdust for 1 week), Drying and size reduction for wheat straw by hammer milling		Wamukonya and Jenkins (1994)
Raw Material	Densification Technology	Pre-Processing	Binder	Reference
Pine needle	Piston press	Drying, Grinding	Clay (20%)	Pandey and Dhakal (2013)
Soybean and pigeon pea stalk	Piston press			Khardiwar et al (2013)

Mikania micrantha	Screw extruder, beehive briquetting and charcoal pelletization	Sun drying, Charring/Grinding	Clay (30%)	Singh and Poudel (2013)
Azadirachta indica (Neem)	Hydraulic press	Air drying	Cassava starch and gum arabic	Sotannde et al (2009)
Water hyacinth	Damp briquette extrusion	Drying (for two to three weeks), chopping, grinding, carbonization	Porridge made from poisonous cassava	Rodrigues et al (2017)
Lantana camara	Manual pressing/ compaction	Drying, grinding to suitable size, filtering the dust		The Shola Trust
Municipal Solid Waste	Piston press	Drying, carbonizing, grinding, binding, and mixing	Cassava starch, clay, molasses	Poespowati and Mustiadi (2012)
Straw/sugarcane bagasse/maize stalk/coconut husks/ leaves/groundnut shells/ rice husk/ sawdust and waste papers	Low pressure wet densification	Grinding, conversion of waste paper into pulp	Waste paper	Tamilvanan (2013)

Shakya et al. (2006) also carried out the assessment of compaction, production and combustion characteristics of the briquettes produced from the combination of materials (Table 34). It can be seen that different combinations of rice husk, sawdust and banmara produced good briquettes. On the other hand, bamboo dust, apple twigs and pine needles were found to have some problems.

However, further studies assessing the briquettes produced from other abundant resources are required to discover the most suitable ones. This includes agricultural residue (e.g. wheat straw, residue from maize, millet, sugarcane, coffee etc.), wood-processing waste (e.g. veneer, plywood and furniture industries etc), herb-processing waste as well as forest waste (such as saal leaves and invasive plants) and municipal solid waste. Furthermore, there is a need to extensively assess the availability of residues, their method of collection and storage, chemical composition, physical and fuel characteristics (e.g. calorific value, moisture content etc.), their environmental implications and so forth. Moreover, the proximate analysis of certain raw materials in Nepal is tabulated in Table 35.

4.6 Current and Potential Users of Biomass Briquettes

In Nepal, briquettes are currently in use for cooking and space heating in the residential and commercial sectors. They also find use in the industrial sector such as in brick kilns, textile industries and boilers etc. The current and potential users of briquettes in Nepal are detailed as follows:

Table 34. Characteristics of Biomass Briquettes produced from various feedstock in Nepal (Shakya et al, 2006)

Materials	Composition	Compaction	Remarks

RH + SD	50% + 50%	Good	*Smooth Production*
SD +BM	75 % + 25 %	Good	*Smooth Production*
RH +BM	75 % + 25 %	Good	*Smooth Production*
RH + SD	75 % + 25 %	Good	*Smooth Production*
RH + SD	25% + 75%	Good	*Smooth Production*
RH + PN	75 % + 25 %	Good	*Excessive Smoke*
RH + BD	75 % + 25 %	Not Good	*Excessive Smoke*
BM	100%	Good	*Difficult*
AT + PN	50% + 50%	Good	*Difficult*
SD + BD	75 % + 25 %	Not Good	*Difficult*

Note: RH – Rice Husk; SD – Saw Dust; BM – Banmara; PN – Pine Needles; BD – Bamboo Dust; AT – Apple Twigs

Table 35. Proximate Analysis of Selected Biomass Residues in Nepal (Shakya and Shakya, 2002)

Biomass	Ash content (%)	Volatile matter content (%)	Carbon content (%)	Moisture content (%)
Bhanti	3.42	66.01	16.13	14.44
Jatropa	8.73	64.51	16.49	10.27
Saw dust	1.50	68.47	19.55	10.48
Banmara (KTM)	1.89	73.62	15.27	9.22
Khar (Sarlahi)	5.98	70.19	15.05	8.77
Pine bark	1.79	59.36	25.28	13.57
Pine needle	2.97	59.34	25.22	12.47
Corn stalk	4.41	68.14	17.03	10.43
Rice husk (AIT)	13.38	63.06	14.49	10.60
Rice straw (Dolakha)	14.89	60.73	14.29	10.09
Rice husk (Khumaltar)	15.93	57.83	15.64	10.60
Rice straw (Khumaltar)	16.25	53.03	12.67	18.05
Vine (wild)	6.70	65.57	16.52	11.21
Wheat straw	4.21	73.28	13.30	9.21

4.5.1 Current Users

(i) Cooking

Cooking, domestic as well as institutional, is one area where a huge amount of fuel is used. These fuels are used not only for cooking but also cooking animal feed and hot water. Jiabik Urja Nepal had promoted rice husk briquettes for cooking as well Tandoori around Bhairawa market area. Namuna Briquette Udyog is distributing briquettes in Narayanghat city for cooking in different food stalls. Similarly, Mhepi had launched a campaign around its factory to use rice husk briquettes at a subsidized rate along with stoves. It has also developed large institutional stoves for community use. Indira Sugar Mills has also distributes piston press bagasse briquettes to its factory workers for domestic cooking. But it has still not reached the scale as in Bangladesh. Green City Briquette and some others have supplied to party palaces and catering services, which use briquettes for large scale cooking.

(ii) Space heating

Currently, briquettes are used for space heating during the winter season in households, major functions (wedding parties, dinners and other social gatherings) that take place in hotels, party halls, gardens and other open venues, where catering services are provided. Numerous numbers of Party palaces that have opened across big cities also use briquettes for space heating and cooking as well. Briquettes are also used for campfires as well.

(iii) Industrial users

Mhepi Briquette Udyog has been continuously supplying its briquettes to several carpet dyeing industries for a long time. It is also supplying its product to the pashmina (wool) industry. Earlier it had supplied briquettes to brick industries as well. Shubha Biomass regularly supplies its briquettes to carpet and pashmina industry as well. Occasionally it sells out briquettes to industrial boilers but not regularly, because the production capacity is still low. It has now started to supply its product to some bakeries as well. Most of the briquetting industries do not want to supply their products to industries for use in boilers as the briquette production capacity is low due to various reasons as industries using boilers require huge amounts of fuel briquettes. Shubha Biomass plans to improve productivity and establish smooth production before going for supply to industries with boilers.

Subha Biomass sells briquettes to industrial boilers occasionally as their production capacity is still low. It has now started to supply its product to some bakeries as well. Most of the briquetting industries do not want to supply their products to industries for use in boilers as the briquette production capacity is low due to various reasons as industries using boilers require huge amounts of fuel briquettes. For example, Shubha Biomass aims to improve productivity and establish smooth production before going for supply to industries with boilers.

4.5.2 Potential Users

(i) Commercial Cooking

Institutional cooking using rice husk briquettes were introduced by Chitwan Briquette Koila Udyog and Mhepi Briquette Udyog during the 1993-95 in army barracks for cooking food for the army men. Especially, where large scale cooking or cooking for community is required, there is potential for promotion briquettes, which are a good substitute for fuel wood and fossil fuels. Other potential uses include the following:

- Army, police and other institutional canteens
- Hospitals, Old-age homes, Orphanages
- School and college hostels
- Tourist and trekking areas
- Prisons and refugee camps
- Road side restaurants, food and tea stalls in cities and highways
- Sweetmeat shops, Dalmoth factory, etc
- Curd making (Dahi), momo shops, etc

(ii) Space Heating

Space heating is another area where large amounts of fuel and energy are spent annually. In the hilly and mountainous regions of the country the temperature falls drastically during the winter season. Besides cooking, heat is required to keep rooms warm. This phenomenon is more severe in the high attitude regions.

Presently biomass briquettes are popularly being used for space heating of rooms and open-fire-places in larger hotels. Large amounts of fuel briquettes are also being used in many social and ceremonial functions that are taking place in party palaces, hotels and catering services. This will continue to be a potential area for the use of briquettes. Other potential users for space heating using briquettes include:

- Party palaces and catering services
- Office rooms and buildings
- Hotels, guest houses and lodges
- Tourist and trekking routes
- Social, religious and community centers
- Space heating of lodges and restaurants in mountain areas
- Space heating in poultry farms in winter

Government support is required in terms of policies and programs for space heating as well. Likewise, appropriate heating devices will also be required. Some space heating stoves are already being tested for commercialization. Beehive briquettes although popular have certain limitations of duration and space for heating. Heating for longer duration (more than 2 hrs) and larger space require different devices. Space heating stove using rice husk briquette has already been demonstrated by CEEN. Such stoves of different capacities and size could very well serve the purpose of space heating.

(iii) Industrial Users

In the past, fuel briquettes were successfully used in Bhrikuti Paper Factory and some brick industries during the economic blockade imposed by India. Mhepi and Shubha briquette industries are already supplying briquettes to industries dealing with carpets, pashmina, baleries etc. Therefore, there is a high scope of using fuel briquettes in many industries. Also from the experience of India, briquettes can replace fuel wood and fossil fuels in boilers. Some of the potential industrial users for briquettes are tabulated in Table 36.

Table 36. Potential of Industrial Use of Briquettes in Nepal

Sector/Industry	Purpose/Process
Industries with Boilers	For steam generation and hot water in paper, rosin and turpentine etc industries
Food Processing Industries	Bakeries, Dairy products, Distilleries, Curd making, *Dalmoth*, Sweetmeat (Mithai), etc
Textile Industries	Carpet, pashmina, silk cocoon drying, Dyeing, bleaching etc.
Agro-products	Herb processing, vegetable and mushroom drying, tea drying, coffee roasting/drying, cardamom drying, oil milling, tobacco curing etc.
Clay products	Brick kilns, tile making, pot firing etc.
Gasification	Fuel for gasifiers
Charcoal	Suitable for making charcoal in kilns

4.7 Issues related to biomass briquetting in Nepal

Issues related to biomass briquetting in Nepal can be classified into three sections which are (i) feedstock related issues, (ii) technical issues, and (iii) social, economic, and other issues.

(i) Feedstock related issues

1. **1.** Only few residues are usually used for briquette production (i. e., rice husk and charcoal from woody biomass etc.
2. **2.** Lack of information on biomass resources availability (i. e., types, amount, characteristics and locations amount, characteristics and locations).
3. **3.** Lack of data on cost and energy related to the collection and transportation of residues to the processing plant.
4. **4.** Other issues/problems in utilization of forest biomass residues and resources.

(ii) Technical issues:

1. Technology mostly limited to rice husk and beehive briquettes.
2. Highly focused on charcoal briquettes making and lack of facilities for pellet production.
3. Inefficient biomass carbonization technology.
4. Need to identify appropriate binding material.
5. Need to develop suitable biomass drying system.
6. Lack of holistic approach for using bio-briquettes as clean and efficient combustion fuel in residential and industrial sectors.
7. Mainly depend on machine suppliers for troubleshooting and Selection of appropriate technology.

(iii) Social, economic and other issues:

1. Lack of analysis on cost competitiveness of biomass briquetting technologies for each feedstock type.
2. Lack of specific funds for capacity building, research and development, training programs etc.
3. Lack of public awareness, knowledge dissemination, and strong supply chain.
4. Lack of access to credits and infrastructure, and inadequate recognition for biomass briquetting/renewable energy financing.
5. Lack of database for potential suppliers and users.
6. Lack of provisions, innovative financial models, policies, incentives, and entities to look over the biomass resources and products supply chain.

5. Biomass Briquetting beyond Nepal- Status, Strategies and Policies

Biomass briquettes have been used in several parts of the developed as well as developing world from the historical times up to today. Countries including those in Europe, South East Asia, Africa as well as U.S.A. have briquette users. The stratus, strategies and policies implemented in some of the developing countries are focussed in this section.

5.1 India

Since the beginning of the 1980s there have been three different types of briquetting technologies introduced into India – PARU, Screw Extruder and Piston Press. Between 1982 and 1986 seventy entrepreneurs bought the PARU (Korean company) technology. All but six or seven of these plants became non-functional within 3 months to 2 years of start up, and neither of them are in operation now. The high failure rate was attributed to the licensees' using inferior materials in the construction of the equipment (to increase their profit margins) and altering design without consulting the developer. Entrepreneurs in South India imported twenty screw extruders from Taiwan. Although the briquettes were well accepted by the customers, there was excessive wear in the press due to the use of rice husk (a particularly abrasive material) as the feedstock (Clancy, 2001).

The Screw Extruder is considered to be more appropriate to the Indian power supply situation since the down time associated with power disruption is significantly less than that for a piston press (half our compared to four hours). The disadvantage of this type of press is the higher investment costs compared to the piston press and the need for skilled welding to repair the screw.

The piston press is the technology that has been most widely used on commercial basis in India with degree of success. The technology was first introduced in India in 1981 from a Swiss company, Fred Haussmann Corporation, but later no major imports was noticed since the costs were very high. So, a number of some manufacturers started producing the piston presses as it had a good market potential. In 1993, thirty-five plants were identified using this indigenously manufactured equipment (Clancy, 2001).

5.1.1 Incentives for Biomass Briquetting in India

The Government of India has announced series of financial incentives for promoting for biomass briquettes. The government provides a capital subsidy of 10-25% depending on the location of the industry, especially in less developed areas. In addition, the government provides
incentive on Income tax, Sales tax, VAT and Excise duty. The major incentives are as follows (Sharma et al, 2015):

i. Depreciation: The total value of plant and machinery is allowed to be depreciated up to 100% in the first year.
ii. Excise Exemption: The solid fuel briquettes are completely exempted from Excise duty. The Government is also considering exemption in the case of plant and machinery.
iii. No Licenses: The whole industry of biomass briquetting has been exempted for obtaining any license.
iv. *Clearance:* No necessity of NOC from State Pollution Boards
v. *5 Year Income Tax Holiday:* Exemption from income tax for first five years.
vi. *Financing:* For biomass briquetting projects banks, governmental and other financial organizations offer low interest loans.
vii. *Subsidy:* The Central and State Government give subsidies. The State Government is also giving subsidy up to 35% of the total plant investment in states like Gujarat, Tamil Nadu, Maharashtra, Haryana, Rajasthan, Punjab, Madhya Pradesh, etc. Central government may give up to 20% Subsidy for biomass briquette press.

5.1.2 Indian Renewable Energy Development Agency (IREDA)

Moreover, with a view to improving the briquetting scene in India, the Indian Renewable Energy Development Agency (IREDA) (a finance granting agency) has financed many briquetting projects, all of which are using piston presses for briquetting purposes. In India, the briquetting sector is growing gradually in spite of some failures. As a result of a few successes and IREDA's promotional efforts, a number of entrepreneurs are confidently investing in biomass briquetting. These entrepreneurs are also making strenuous efforts to improve both the production process and the technology. (Grover and Mishra, 1996a)

IREDA been financing biomass briquetting projects involving binder less technology since its inception in 1987. IREDA has so far sanctioned 28 projects out of which 12 are in operation and 7 are under implementation. 9 projects have yet to be implemented. The largest plant financed by IREDA is in Gujarat having a capacity of 14.2 MT/year, i.e., 50,000 Metric Tonne of Coal Replacement (MTCR)/year. Nearly 100,000 tonnes of equivalent coal will be replaced every year by the total capacity of the plants financed by IREDA so far. The total loan amount disbursed by IREDA for these projects is Rs. 48 million.

IREDA has funded a project where the main promoters are women under a co-operative society. They have developed a 100 kg/hr machine based on the experience gained from this plant. They are planning to undertake a large-scale programme envisaging the installation of portable briquetting (100 kg/hr) machines at a regional level apart from setting up a single large-scale unit in Gujarat. IREDA has sanctioned term loans for 3 projects for the weaker section of the society and 3 projects to ex-servicemen. Most of the projects sanctioned by IREDA are in rural areas creating employment for rural people.

IREDA's Development and Promotional Role

As some of the IREDA financed briquetting projects have faced problems like poor operation of the plant, high conversion cost, frequent break downs and poor capacity utilization a study was commissioned through the School of Energy, Bharathidasan University, Tiruchirapalli to assess the reasons for non-performance of these plants. Based on the recommendations of the study, IREDA subsequently set up a `Technical Back-up Cell' (TBC) at the School of Energy, during 1994-95 at a cost of nearly Rs. 1 million to provide technical backup support to the briquette manufacturers sponsored by IREDA. Further, in order to gain a fuller understanding of the overall national situation, IREDA commissioned a diagnostic study on the functioning of non-IREDA assisted briquetting plants through M/s Energy, Economy & Environment Consultants, Bangalore.

Study of IREDA funded briquetting plants by School of Energy, Tiruchirapalli

Some of the major findings of the School of Energy after focusing their attention on the IREDA funded units are as follows:

i. All the project promoters are first generation entrepreneurs and they lack the managerial experience to run an established industry such as the briquetting industry.
ii. Machine manufacturers have not set right many problems of their machinery. Promoters were also not in a position to rectify these on their own.
iii. End user's problems like loss of boiler pressure and clogging etc. adversely affect the marketability of briquettes.
iv. Cost of conversion of raw material to briquettes is very high.
v. Research is needed to increase the production capacity, to reduce the wear and tear and increase the available time of machine.

Technical Backup Cell: (TBC)

Based on the study conducted on the IREDA financed briquetting plants a Technical Backup Cell was formed at the School of Energy in March 1994 to identify the areas where modifications were required and to carry these out. The TBC has classified the issues to be studied as Technical and Operational.

In terms of the technical issues, attempts are being made to increase production, solve end user problems and design a new machine suitable for Indian raw material.

Production

i. Increasing production by introducing restraining features on the briquetting machine like variable vertical feed rate.

ii. Modifying features inhibiting continuous operation.
iii. Enhancing the wear life of components.
iv. Minimizing the raw material loss during material preparation.

Equipment

i. In order to have a sustainable production level in the industry, the following areas have been identified by TBC to be studied in detail:
ii. Balancing of machine parts
iii. Reduction of power consumption
iv. Trouble shooting of Electrical Contactors
v. To design, if possible a new machine in collaboration with reputed machine manufactures like CMTRIL for typical Indian raw materials with lesser wear and tear of parts.

Safety and environment

The following areas are being addressed:

i. Danger of fire in drier system
ii. Dust pollution of the lubricated parts of the machine
iii. Air pollution in the shed

End user

Reduction in temperature and pressure in boiler which uses the briquettes, fusion and clinker formation, increased unburns, disintegration of briquettes during combustion, quick burning of briquettes in moving grates are some of the problems reported by the end users of briquetting. These issues are also being examined by the TBC.

Operational issues

The operation, maintenance and monitoring of the machines are the main areas to be concentrated on. The following have been identified for studying in greater detail:

i. Regular maintenance of machines.
ii. Replacement of the worn-out parts at regular intervals.
iii. Change of lubricating oil daily in small quantities.
iv. Monitoring of the moisture content of the raw material.
v. Maintaining a sufficient number of spares to replace worn parts.

Operational business strategy

To help the project promoters run the unit very smoothly without any problems of raw material procurement and to reduce the cost of production the following suggestions have been given to the promoters.

i. Evaluate the availability of non-competitive and cheaper options.
ii. Managing raw material collection and storage.
iii. Optimise overheads.

Based on the above, the Technical Backup Cell has done extensive trials in the following units:

i. Gayathri Bio Fuels - Chellekare - Bangalore, Karnataka
ii. Arun fuels Ltd - Singampatti - Bhavani, Tamil Nadu

iii. Agri Carb Ltd. - Tirunelveli - Tamil Nadu
iv. Gujarat Fuel Bonanza - Lakthar - Gujarat

Outcome of the Study of TBC

The following is the gist of the outcome of the study conducted and trials undertaken by TBC at various IREDA funded units.

i. Increase in production rate achieved by varying the vertical feed screw to vary the feed rate of raw material to the feeder box.
ii. Increase in production by increasing the ram length marginally.
iii. Exchangeable bottom of feeder box was designed to reduce the gap between ram and feeder box reducing the dust pollution.
iv. Additional cooler for cooling oil to increase the uptime of machines was trial tested and found to be working satisfactorily.
v. Hollow chisel has been designed and fabricated to increase the production time available for machine, by reducing the time of chiselling out material in die during power failure.
vi. A filtration system using a recyclable ground nut shell bed has been used for reducing the dust pollution in the atmosphere.
vii. Test trials have been done with different materials like manganese, Nihard sterlite to reduce the wear of die and punch.
viii. Spark arrestor has been designed for drier system to eliminate the danger of fires.
ix. Disintegrator has been designed to pulverize the material instead of Hammer Mill which has also been tested.

Study conducted by Energy, Economy and Environmental Consultants, Bangalore

To assess the working of the non-IREDA financed Briquetting plants in the country, a diagnostic study was assigned to M/s Energy, Economy and Environmental Consultants (3EC), Bangalore. The study was conducted by 3EC on 11 briquette manufacturing units and 4 machine manufacturing units.

i. The major findings of the study are listed below:
ii. Most of the units have high equity of 70% to 100%.
iii. They are all of small size (10-20 T/day)
iv. Most of the units have only labour oriented material handling.
v. All the units use only a single type of raw material.
vi. Very small market.
vii. The overheads of the companies are very low.
viii. Family run units.

In order to broaden the base of the briquetting industry the following suggestions have been made by the consultant.

i. Reduce equity
ii. Increase plant size (70-100 T/day)
iii. Use mechanical material handling system.
iv. Use multiple raw materials available locally at competitive prices.
v. Make efforts to keep the overheads low.
vi. Widen the market.
vii. Manage units more professionally.

To achieve the economic viability of broad based unit’s R & D inputs are required in the following areas:

i. Operation and maintenance - Problems of wear and tear and lubrication.
ii. Mechanical handling system - To be mechanised from the yard to the loading point.
iii. Biomass character - The problems associated with improper combustion, clinker formation, ash deposition and wear caused by a particular raw material.

IREDA's approach towards the biomass briquetting sector

Based on the expert studies conducted by the School of Energy and Energy, Economy & Environmental Consultants, and on its own experience, IREDA proposes to continue to support this sector. It would, however, prefer to concentrate on equipment financing and would expect the entrepreneurs to supply all other project requirements. Emphasis would be given to the tail end units at the rice mills, sugar mills, pulp and paper industry, oil mills, coffee and tea gardens etc. Where raw material supply is assured, marketing linkage would of course be a prerequisite. Agro-waste based rural units would continue to be supported. In order to boost the large-scale commercialization of the technology more fiscal incentives are desirable. The proposed and available incentives are given at Annexure 2 which reveal the scope for improving upon the overall policy support to this sector (Grover and Mishra, 1996b; IREDA, 1993; 3EC, 1994).

5.1.3 Clean Development Mechanism and Carbon Credits

The major use of biomass briquettes in India, is in industrial applications usually to produce steam. A lot of conversions of boilers from furnace oil to biomass briquettes have happened over the past decade. A vast majority of those projects are registered under CDM (Kyoto Protocol), which allows for users to get carbon credits. As of 2011, around 200 Indian entities have applied for registering their CDM Project for availing carbon credits. (Gupta, 2011)

The use of biomass briquettes is strongly encouraged by issuing carbon credits. One carbon credit is equal to one free ton of carbon dioxide to be emitted into the atmosphere. India has started to replace charcoal with biomass briquettes in regard to boiler fuel, especially in the southern parts of the country because the biomass briquettes can be created domestically, depending on the availability of land. Therefore, constantly rising fuel prices will be less influential in an economy if sources of fuel can be easily produced domestically (GCM Machines, 2017).

A number of companies in India have switched from furnace oil to biomass briquettes to save costs on boiler fuels. The use of biomass briquettes is predominant in the southern parts of India, where coal and furnace oil are being replaced by biomass briquettes. A number of units in Maharashtra (India) are also using biomass briquettes as boiler fuel. Use of biomass briquettes can earn Carbon Credits for reducing emissions in the atmosphere. LANXESS India and a few other large companies are supposedly using biomass briquettes for earning Carbon Credits by switching their boiler fuel. (UNFCC, 2006). Biomass briquettes also provide more calorific value/per unit cost and along with Carbon Credits, can save around 30-40 percent of boiler fuel costs (GCM Machines, 2017).

5.1.4 Rural Renewable Urja Solutions and myclimate

This international carbon offset project was initiated by myclimate in 2009. Previously coal was used in the Indian province Uttarakhand as fuel in the brick and iron production. The carbon offset project by myclimate promotes the use of briquettes made of renewable biomass from forest and agricultural waste. In addition, restaurants, temples, schools, and hospitals are supplied with efficient, smokeless cookers. In India, many millions of tons of biomass waste accumulate annually from forestry and agriculture as well as from industrial production. Due to its low density and the high-water content, this waste material cannot be directly processed. The local organization Rural Renewable Urja Solutions Pvt. Ltd.

(RRUSPL) now utilizes this waste raw material as fuel. Biomass briquettes are produced, which are then delivered to companies producing brick kiln and rod iron in the states of Uttarakhand and Uttar Pradesh in the north of India. The climate-friendly energy supply is thus replacing coal, a greenhouse gas-intensive fuel, in the kiln and iron production. The briquette machine is already successfully used in many of India and reduces the local population's dependence on fossil fuels. The project not only includes the manufacture of renewable, clean fuel, but also the distribution of an efficient and smokeless cooker (chulha) for restaurants, temple complexes, day schools and hospitals. These rural institutions in India were previously very dependent on liquefied petroleum gas for cooking. (CloudSigma, 2017)

Moreover, they are also involved construction of 3,000 biogas plants in households in rural areas in Uttarakhand. By substituting wood as a fuel with biogas, greenhouse gases are being reduced. (myclimate, 2017)

5.1.5 Research and Development

Both national and international agencies have funded projects to improve the existing briquetting technology in India. In the past, the Indian Institute of Technology, Delhi in collaboration with the University of Twente, the Netherlands carried out research to adapt the European screw press for use with Indian biomass. The two major impediments for the smooth working of the screw press -- the high wear of the screw and the comparatively large specific power consumption required --were overcome by incorporating biomass feet preheating into the production process. The recent successes in briquetting technology and the growing number of entrepreneurs in the briquetting sector, are evidence that biomass briquetting will emerge as a promising option for the new entrepreneurs and other users of biomass. (Grover and Mishra, 1996)

5.1.6 Briquette Manufacturers in India

According to estimates by the All Gujarat Biomass Briquette Association (AGBBA), there are at least 500 briquette manufacturers across the country, giving direct and indirect employment to 100,000 people. About 200 of these are in Gujarat; the other major producers are in Maharashtra and Rajasthan, along with other northern states.

Raw materials such as rice-residues which were once takeaways are not free anymore. If the rice husks wastes are used for briquetting, the rice-mills charge up to 250 INR/ton (20 US$/t) though a more usual price is 100 - 150 INR/ ton. Food processing industries, distilleries and agro-product developers can harness this potential opportunity and one can expect that the price of biomass waste feedstock will be on uphill. Briquetting plants in India are using saw dust, bamboo dust, bagasse, cotton stalk, coffee husk, groundnut shell, mustard husk/stalk, pine needles, rice husk, sugar mill waste, jute waste, coir pith and other wastes. Also, residues like castor shell, red gram stalk, tobacco stem, tea waste, sander dust, tree bark, wild grasses and shrubs and sander dust etc. can be also be briquetted individually or in combination without using any binders.

5.1.6 Briquetting Machine Manufacturers

There is a well-established capability and capacity for manufacture of related equipment for use of biomass for energy including harvesters, balers, briquetting equipment, handling and firing equipment, pollution control systems etc. (MNRE, 2017) Many local as well as multinational companies have set up manufacturing facilities in the country for such equipment. After a review of IndiaMart (online marketing website), it was found that several Briquette machine manufacturers operate as of now in Gujarat, Tamil Nadu, Punjab, Andhra

Pradesh, Haryana, Maharashtra, and Karnataka. Data regarding industrial usage of briquettes in various states in India is shown in Table 37.

In conclusion, the Indian experience shows that briquetting is a big business and receives adequate support from the government. There are special organizations (IREDA) which give financial support as well as technical consultations. Briquettes are used mainly as industrial fuel and as a substitute for fuel wood and fossil fuels. They are used in small amounts as domestic fuel for cooking.

Table 37. Facts about the Industrial Usage of Briquettes in India (CEEN, 2014)

State(s)	Type of Industry	Fuel Replaced
Punjab	Solvent extraction oil mills, brick kilns	Coal
Tamil Nadu, Kerala and Karnataka	Tea factories, rubber factories, pharmaceutical industries	Wood, leco
Madhya Pradesh and Maharashtra	Textule industries, pharmaceutical industries, brick kilns	Coal
Gujarat	Texitle, dye and chemical industries	Coal
Uttar Pradesh	Leather industries, brick kilns	Coal

5.2 Bangladesh

Briquetting Technology mainly used in Bangladesh is the heated screw press type. The screw extruder briquetting was first started (around 1992) in Sheikh Ghat, Sylhet by importing machines from Taiwan. These machines were from the same company (Sun Chan, Taiwan) which Nepal had also imported. Because of the high cost of imported technology, similar types of machine were fabricated locally which gave continuity to the work. Gradually the technology was spread to Khulna, Chittagong, Rajshahi, Barisal, Dinajpur, Rangpur, Bogra, Jessore, Satkhira and several places of Bangladesh (Table 38).

Table 38. Briquetting Machines in the Districts of Bangladesh

District	Total No. of Briquetting Machine	No. of Foreign machine	Total
Sylhet	233	15	248
Khulna	174	2	102
Chittagong	135	-	103
Rajshahi	268	-	60
Barisal	32	-	23
Dhaka	47	-	4
Total	**889**	**17**	**906**

In Bangladesh rice husk is the main raw material used for making briquettes as the country produces 3 crops of paddy annually, generating huge amounts of rice husk. Total rice husk available for densification only is estimated at 1.0462 million metrics. Total production of rice husk briquette fuel was estimated as 0.942 million metric ton equivalent to 0.493 million ton of coal which is 2.34 times of imported coal (0.211 million ton) in the year 2002-2003 in Bangladesh (Ahiduzzaman, 2007). Analysis of the wide spread promotion and distribution of rice husk briquetting business in Bangladesh reveals that various factors played very important role in the success of rice husk briquetting.

User group can be divided into mainly two sectors - household and commercial. Major consumer of densified briquette fuel is the commercial sector consuming about 60%. These are restaurants and sweetmeat shops. About 25% is used in tea stalls around the city and 15% is consumed by different street food stalls. The households who could not avail the gas grid connection are using densified biofuel. It is used as an alternative fuel for cooking food in parties and group cooking. It is also used in road construction to melt the bitumen and asphalt. Industrial boilers also use it boiler fuel [16]. However, the densified biofuel is still not being well accepted by small industries such as bakery because the present system was not suitable for firing this fuel. However, briquette fuel is slowly finding use some industries such as brick kilns, rice mills, etc).

As per the assessment of KUET, some important points which made rice husk briquetting successful in Bangladesh even without any support from the government [16-17].

i. Scarcity of fuel wood and environment benefits of briquettes
ii. Cheap and abundant raw material (rice husk) is available everywhere because rice production is very high. Cost of rice husk is 5 takas per kg.
iii. Cheap and simple technology – One unit will cost around BDT 50,000-60,000
iv. Fabrication of technology as well as repair and maintenance capability has been well developed.
v. Cheap and wide variety of heating and cooking devices
vi. Technical support from Research Institutions like KUET and availability of trained manpower
vii. Availability of skilled and trained manpower
viii. Easy access to hard facing materials and hard facing technology
ix. Reliable power supply to industries
x. Cheap and economical lifestyle of rural people

In Bangladesh rice husk briquettes are used mainly for cooking food for domestic and commercial purposes:

i. Domestic use for cooking food
ii. Commercial cooking
iii. Road side tea stalls
iv. Restaurants
v. Sweetmeat shops
vi. Street food stalls
vii. Community cooking and parties

The two important and critical issues that led to the success story of briquetting in Bangladesh seem to be- (i) Development of technological capability in the country to fabricate cheap briquetting units along with the ability to carry out repair and maintenance works and (ii) Tangible technical support from KUET and other institutions. These issues will also play a deciding role for the promotion of biomass briquetting in Nepal

5.3 Cambodia

Sustainable Green Fuel Enterprise (SGFE) was created in 2008 with the aim of alleviating poverty and reducing deforestation in Cambodia, as well as improving waste management in urban areas, by developing a local economic activity: manufacturing charcoal using organic waste, mostly coconut. SGFE was initiated by the NGOs- GERES Cambodia and PSE (Pour un Sourire d'Enfant) through a joint project: PSE added its social commitment to GERES's environmental and technical expertise. The goal of SGFE as a real social business is to provide long-term employment to its workers so that they can get a regular, secure and fair income. Thus, the economic viability of the business is crucial, and profits are to be shared among the stakeholders and employees, and reinvested in the company's development. Currently, SGFE employs 16 people who used to work as waste pickers on Phnom Penh's municipal landfill.

SGFE charbriquette manufacturing begins with the collection of organic waste in and around Phnom Penh through a network of dedicated suppliers. After drying and sifting coconuts and other raw materials, they are efficiently carbonized, crushed and mixed, then shaped into a convenient and efficient size, and finally dried to guarantee high performance. Furthermore, the production process has been modified to be as energy efficient as possible: the kilns used to carbonize the coconut and biomass ensure efficient combustion, reducing the emission of harmful gases and air pollution; and, the energy generated by the carbonization process is recovered and used to increase efficiency.

Sustainable Green Fuel Enterprise is manufacturing two types of products: Premium and Diamond briquettes. Their tubular shape provides better heating properties compared with traditional charcoal, and is perfectly adapted to cookstoves and barbecues.

All char-briquettes are sold on the local market to shops (retailers who further sell them to households) and food businesses (restaurants and street food vendors). Shops and restaurants tend to prefer premium, while interestingly street food vendors choose the higher quality product (diamond) which has a duration of up to 5 hours. This is because households don't need to cook for long time and restaurants, which use a high amount of char-briquettes, prefer the cheaper product, while street food vendors, cook all day with small quantities of char-briquettes and therefore even though the diamond is more expensive, at last it is financially more convenient for them.

The current production rate is at about 40 tons/month (with a growing trend). Regarding the sales capacity, SGFE currently sells the entire production (the demand is higher than what they can produce) and therefore they are planning to expand the production capacity this year. (SGFE, 2017)

5.4 Congo

The Legacy Foundation has developed a set of techniques to produce biomass briquettes through artisanal production in rural villages that can be used for heating and cooking. These techniques were recently pioneered by Virunga National Park in eastern Democratic Republic of Congo, following the massive destruction of habitat of the mountain gorilla for charcoal. (Virunga).

A list of marketing tools to support the sales of briquettes in developing countries is suggested as follows (Source: Legacy Foundation):

- Buyers of large quantities can receive discounts or a gift.

i. Some fuel briquettes can be exchanged for the delivery of raw materials.
ii. Pro-environmental conservationists can be included in marketing briquettes.

iii. Conducting open air cooking demonstrations (e.g. in market centres)
iv. Participating in shows and exhibitions.

5.5 Zambia

Emerging Cooking Solutions is combining the sales of clean cooking stoves with pellets as fuel. ECS introduces to the market a unique cooking-system using an inexpensive, abundant and largely untapped source of energy for cooking: they are (at the moment) using a mix of pine and eucalyptus sawdust and peanut shells. The sawdust is a waste product from local sawmills that get their wood from state owned plantations, no virgin or indigenous trees are touched. ECS has also experimented with a variety of biomass, ricehusks, maize and straw to name a few and will use these at a later stage, but the reason they use sawdust is that it is there, in one place, and is waste. They only wish to use agro- and forestry waste so original forests can be spared, that's their vision. These wastes will be made into pellets.

Together with clean-burning, micro-gasifying stoves for homes and restaurants, ECS sells pellets at below market price of the equivalent in charcoal, leading to substantial savings. Today focusing on the Philips stove, but the company is stove-neutral: ECS will provide the best stove for a particular user-group. This can be done at favourable financial terms for the company due to the new product concept and industrialized production and distribution systems. Starting modestly in 2010 with 40 households, ECS, by their own admission, now has the capacity to produce clean, renewable cooking fuel for thousands of households. During the fall 2013 they made about 30 tons per month. Their equipment can make 5-600 kg per hour, but they haven't had the need to run it full speed yet, since they are a start-up and building a customer base. Their clients are BOP citizens who today use charcoal for cooking, people in townships in Lusaka and Kitwe, and who have no alternative until now. (Mashable, 2017)

5.6 Kenya

According to Cohen et al (2013), there are over 70 entrepreneurs who either are, have in the past, or will in the near future, engage in commercial briquetting activity in Kenya. The businesses experiencing the least challenges were observed to:

i. Focus on a few clients with capacity to absorb most of the production
ii. Have in house equipment fabrication and maintenance capacity, and therefore understanding of optimal inputs to produce quality briquettes
iii. Retain in house feedstock collection and product delivery capacity
iv. Be strategically located, in close proximity to the feedstock source and/or a major client
v. Have largely been self-funded, due to a lack of viable and financing options. As such interventions towards supporting the enterprises incorporated into the CARE2 program should aim to build these capabilities within the companies.

A company named Chardust Ltd. was founded in 2000 to produce substitutes for charcoal on a commercially sustainable basis. Chardust making use of low-priced raw materials, ample labour supply and a good measure of innovation, set out to produce fuels that could sell directly into traditional charcoal markets and compete head-to-head on both price and quality. Today, daily sales are in excess 7 tonnes. Chardust's centre of operations is a 2-acre plot in the Lang'ata area of Nairobi. This is the company head office and home of the briquetting operation and Chardust's programme of research and development. Chardust's main product is the Vendor's Waste Briquette - 'VWB'. It is made from charcoal dust and fines that are salvaged from charcoal traders across the city of Nairobi. These briquettes are for space heating and water heating applications, as well as cooking and roasting. VWB is sold to institutional customers such as poultry farms, hotels, lodges and restaurants, as well as to charcoal dealers and individuals for direct sales into the domestic market. Chardust also produces a premium charcoal briquette made from selected vendors' waste and natural binders. This lower ash product is designed for the domestic barbecue market and is sold mainly through supermarkets within the city of Nairobi. Finally, in 2010 chardust introduced agglomeration machinery to their production line for the fabrication of spherical briquettes which are called FireBalls. These are also aimed at the urban mid-scale market (Chardust, 2017).

5.7 Community Involvement in Biomass Briquetting

Community involvement is imperative for enhanced usage of biomass resources. Public or private entities can be established or encourage who will collect, process and supply biomass products to end-users. For example, Punjab Renewable Energy Systems Pvt. Ltd. (PRESPL) which was commenced in 2011 with the aim to supply biomass to biomass based energy industries and other industrial sectors. It is operated based on types of activities at different stages which are described below.

Pre-Operation Activities

i. Starts 4-5 months before harvesting
ii. Survey and feedback recording and analysis
iii. Identify and set up collection centers according to the available data
iv. Advertisement and awareness programs in the catchment area via mass media, social societies, community and religious centers.
v. Request help from local administrative to prevent open burning
vi. Identify and contracting with labor and fuel contractors.

Post Harvest/Operational Activities

i. Fuel Processing in fields – Cutting, Baling etc.
ii. Transportation of fuel from fields to biomass collection centers.
iii. Continuous and multi-level training and skill honing of Field Officers, Technicians, Collection centers, Contractors (Balers, laborers).

Ensuring uninterrupted biomass supply

i. Develop biomass calendar for each specific region.
ii. Biomass collection centers will be installed such a way that will cover the overall catchment area of the targeted zone.

The PRESPL has developed agricultural waste calendar based on the availability of different types of agricultural wastes availability.

This initiative has provided positive socio-economic impacts and contributed for rural development by creating job opportunities, developing skills, and creating sources of additional income by selling biomass residues. At the same time helping to reduce outdoor air pollution by stopping open field burning practices by encouraging village entrepreneurs to get involved in biomass residue supply businesses.

5.8 Transforming Araria District in India

The economy of the villages is thriving because 70% of the total revenue of operations pumped back into the villages in the form of payment for feedstock and salary to the local staff. The productivity of the farming sector has gone up due to low cost of irrigation and regular profits in the local enterprise because of assured power supply. Encouraged youngsters find employment in the village itself instead of migrating to nearby city or towns. The electricity tariff structure of the Baharbari Village is shown in Table 39.

Table 39. Electricity tariff structure of the Baharbari Village

Households	Unmetered: $0.03/day/CFL; Metered with unlimited load: $0.23/kWh
Irrigation	$0.75/hr for 6 irrigation pumps of 50HP each
Battery charging	$0.45/charge of 12V battery
Computer institute	$ 0.25/kWh
Vebra village	$ 0.23/kWh; lower than diesel based electricity
Gaiyari village	Rice mill: $ 0.18/kWh; Others: $ 0.23/kWh

5.9 Local Entrepreneurship for Biomass Briquette Production from Crop Residues

The plant is situated in Nhavare, India, which is in sugarcane production, agriculture and dairy activities. Residues of the sugarcane industry were subject to open field burning or used inefficiently that resulted emissions of carbon and particulate matters. Shri Vilas Parbhane, one of the entrepreneurs, has taken the initiative to produce briquettes from these crop residues. The total cost of the project incurred was around Rs.40lakhs excluding land cost (Rs.15 lakhs own investment and received Rs.3.7lakhs from the Government of Maharashtra. Two semi-skilled and 14 unskilled labors were employed and farmers are receiving benefits by selling crop residues. Briquettes are sold to the industries which were switched from fossil fuel boilers to biomass based heat application.

5.10 120 kW pine needle based gasifier, Uttarakhand, India

Pine needles are highly responsible for causing forest fire. The community has taken initiative to collect and use pine needles for electricity generation (Figure). Gasification system has been adopted for electricity generation. The produced charcoal is used to produce briquette. The overall process is shown in Fig. 48.

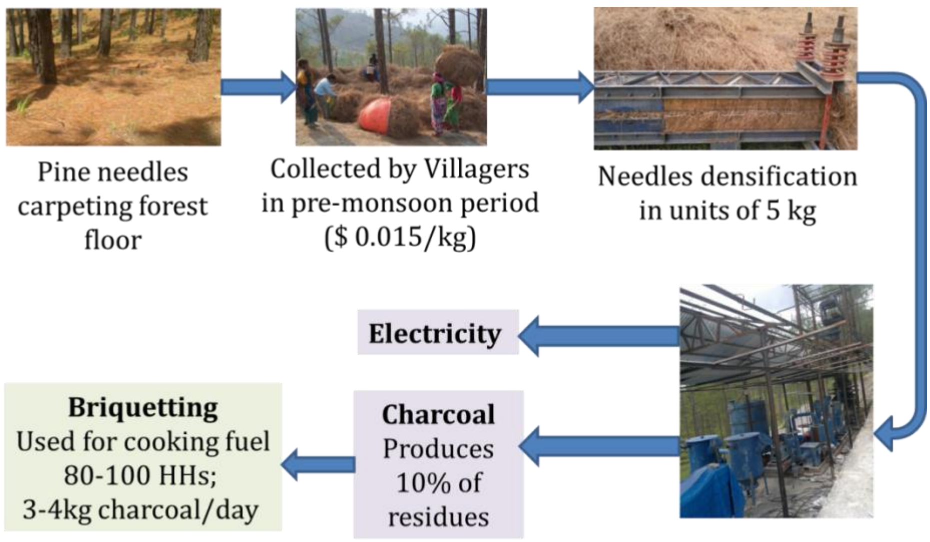

Fig. 48. Pine needle to electricity and briquette production process.

5.11 Rice Husk Briquette based Biomass Gasifier System for Irrigation

The water resource utilization department (WRUD) replaced 36 sets of diesel engine in 2008- 2009, 41 sets in 2009-2010, 33 sets in 2010-2011 with rice husk briquettes based gasifiers for irrigation of 7,276 ha of paddy field. This initiative has reduced 157,536 gallons of diesel consumption and 1,840 tCO_{2e} of emissions. The system requires a capital cost of USD 23,000.

6. Conclusions and Recommendations

6.1 Conclusions

1. Briquetting technologies imported from India and China are expensive and negatively affect the feasibility of briquette production in Nepal. This lead to the local adaptation and fabrication of briquette machines, which was comparatively cheaper. This reduced the required capital investment and improved the feasibility of production. This phenomenon has also been observed in neighbouring India and Bangladesh. Thus, it is essential to promote locally manufactured technology rather than imported ones.

2. The technical capability of local engineering workshops has improved since the 1990s. Repair and maintenance is integral for briquetting machines due to the wear within the moving parts. Several workshops are operational and spread out around Kathmandu, Chitwan, Bhairawa, Kawasoti etc. However, there is also much room for improvement in the technical sector. Briquetting technology (especially the imported ones) can be complex and require special technical skills and training for operation as well as repair and maintenance. Skill development and training programs (such as those conducted by KUET, Bangladesh) needs to be organized by the government and other concerned institutions to improve this scenario. The condition can be further improved by implementation of policies to support and develop the local engineering workshops.

3. Spare parts such as the screw, piston and tapered die, imported from China and India can be expensive. Design and manufacture of these parts should be encouraged in Nepal. In case of imported parts, measures need to be taken to make them more available and less expensive.

4. In the past rice husk was the sole raw material used for briquetting. Since then, several new raw materials have been identified including- (i) agricultural waste such as sugarcane bagasse, wheat straw, maize etc.; (ii) forest residue such as saal leaves (which has high heating value and low ash content), pine needles, banmara, Mikania micrantha (as well as many other invasive plants) and biomass obtained from clearing of vegetation (especially near high tension lines and plantations) etc.; (iii) wastes from wood proceeding industries (sawmills, veneer, plywood, furniture, handicraft, industries etc.); (iv) combustible portion of municipal solid waste and so on. Most of these raw materials are available with the collection cost as the only expense. Proper initiatives need to be taken to make these materials available for briquetting including assessment and quantification. The collection of materials can also open up income opportunities for the poor and low-income section of the population which has been observed in countries such as Cambodia. This can also help in women empowerment.

5. In the 1990s the prices of fuelwood, kerosene and other conventional fuels were low while the price of briquette was higher comparatively. This situation has reversed in the current times. This economic advantage of briquettes as well as the environmental deterioration associated with fossil fuels and fuelwood indicates that briquetting needs to be promoted similar to other popular renewable energy technologies.

6. In the past, it has been observed that briquettes were used successfully for large-scale cooking in army and police canteens. Such programs need to be reinstated with the support of the government and other agencies. Moreover, they can be expanded to other areas such as hospitals, prison wards, old-age homes, orphanages, schools, hostels and so on.

7. Currently, briquettes are being used extensively for space heating and cooking in hotels, catering services at events and so on. This can be further expanded to tourist and trekking destinations in the hill and mountain regions.

8. Some of the briquetting industries (namely Mhepi, Indira Sugar Mills and Jaibik Urja) were found to have encouraged the locals to use briquettes for residential as well as commercial cooking purposes. Mhepi, in in particular has a well-functioning market network and promotional strategies using flex charts, brochures etc. as well as conducting exhibitions and seminars for the dissemination of product information. These promotional and marketing practices should be encouraged for other industries and can be further expanded through promotion by the government.

9. From the survey conducted by AIT, further issues related to briquettes were identified-

1. High level of CO emissions from charred briquettes.
2. Difficulty in ensuring quality consistency of briquettes.
3. Inadequate stove and boiler designs.
4. Lack of affordable and efficient dryer technology for moisture removal.

6.2 Recommendations

Issues related to biomass briquetting in Nepal can be classified into three sections which are (i) feedstocks related issues, (ii) technical issues, and (iii) social, economic and other issues. A set of recommendations for each section are listed below which could be adopted for developing the sustainable biomass management strategy of Nepal and to disseminate energy efficient biomass briquetting technology throughout the country.

(a) Prospective solutions for feedstock related issues

1. The Government could take initiative to launch region-specific biomass resource availability assessment programs to develop a national inventory of biomass feedstocks. The inventory could be a useful guideline for the policy makers to develop biomass resource management strategy. The national inventory may provide necessary information such as:

    i. Residue-to-production ratio (RPR), growth rate and cultivation cycle.
    ii. Population density, household energy demand, and the form (heat and electricity) of energy demand.
    iii. Identify, estimate, and evaluate the potential of available biomass resources for briquetting in each specific region.
    iv. Create region-specific database for biomass feedstocks availability and analyse characteristics.
    v. Assess the ease of access and suitable mode of transportation that requires for collecting biomass feedstocks.
    vi. Biomass waste availability calendar for specific-region which will show which type of biomass resource(s) is(are) available during which period of the month in a year.

2. Communities could be involved in collection, preparation and supplying of biomass briquettes to market or end-users (industries or households or commercials). These requires conducting of field survey for assessing farmers' perception on biomass supply, and identify practical barriers that need to be addressed in the biomass waste management strategy. Also, the installation of briquetting plants for demonstration and promotion of mobile briquetting systems to facilitate small/micro-community may attract local entrepreneurs to get involved in biomass supply chain.

3. Knowledge dissemination on the negative impacts of indoor air pollution and monetary values of achievable direct and indirect economic and environmental benefits of using biomass briquettes as fuel may help to create public awareness. Televisions, newspaper articles, workshops, technology fair, leaflets, flyers, posters, social communication medias etc. can be used as media to disseminate knowledge and enhance public awareness.

4. A sustainable forest management policy could be developed to ensure sustainable harvesting or collection of forest biomass residues for briquette production. The forest management policy may help

i. To combat against illegal logging, and illegal trade.
ii. To support sustainable economic development of the communities live near forest areas and poverty eradication.
iii. To conserve uniquely mega-biodiversity in Indonesia and address climate change.
iv. To meet increasing demand for legal timber from sustainable managed forests.

(b) Prospective solutions for technical issues

1. Hydraulic or mechanical press briquetting system could be adopted which offers several advantages such as:
    i. Offers high lifespan of the equipment, and able to operate in absence of heat in the briquetting process.
    ii. Suitable technology for small-scale briquette production even at household level, and can be operated without electric energy.

iii. Easy to fabricate using locally available materials that does not need skilled labor, and easy operation.

2. Research for the identification of optimal condition for briquetting of different biomass residues using hydraulic or piston press technology could be explored.
3. Efficient biomass carbonization technology could be adopted such as retort kiln which is known as the Improved Charcoal Production System (ICPS) or adam-retort. Retort kilns recirculate and combust pyrolysis gases internally to generate heat for pyrolysis that help to reduce combustible product gas (mixture of CO, CH_4 and particles) emissions. It offers a charcoal production efficiency of about 30-42%, whereas the efficiency of traditional charcoal production methods is about 10%–22%. Low investment costs (about ~500 Euros for materials and work) and a simple construction with locally available materials.
4. Biomass torrefaction is also an efficient solution for high solid and energy yield charcoal production which could be adopted. It is slow heating (mild pyrolysis) of biomass in an inert environment to a maximum temperature of 300°C for volatile removal, and results final product that has about 70% of the initial weight and 80-90% of the original energy content.
5. Hybrid densification system could be adopted which has the potential not only to produce biomass briquettes also can produce pellets.
6. Biomass pellets could be considered as potential biomass derived solid fuel which has several advantages such as higher burning rate and higher unit density, and easy to handle compared to biomass briquettes. A huge global market is open for biomass pellets which are solely dominated by wood pellets.
7. Co-densification of biomass resources for briquette production could be considered as an efficient way to maximize/optimize biomass resources utilization. Hence, research could be conducted to identify optimal mixing ratio of different biomass residues for producing good quality briquettes.
8. Waste heat utilization for preheating and drying of biomass feedstock before compaction could help to enhance energy yield by reducing thermal energy demand.
9. The integration of biomass gasification system with hot briquetting system has the potential to meet thermal energy demand for biomass briquetting and drying. The adoption of solar-biomass hybrid drying system is another prospective solution.

(C) Prospective solutions to promote biomass briquetting/pelletization

1. Financial analysis could be conducted for Community scale biomass briquetting systems including the monetary values of direct benefits (fuel cost savings by replacing fossil fuels and reducing fuel consumption, and income by supplying or selling raw or processed feedstock), indirect benefits (saved fuel collection time, opportunity cost of additional income generating activities, and health benefits by avoiding indoor air pollution), and investment costs (machine purchase, installation, operation and maintenance, training related costs). Sensitivity analysis also could be conducted to identify the policy measures which need to be addressed in the biomass resource management strategy.
2. Training programs (for communities) could be designed/ developed considering each community as a part of the biomass briquette/ pellet supply chain. Also, workshops need could be organized on the aadvantages and importance of modern solid biofuels usage over traditional biomass and technologies to produce modern solid biofuels (briquettes and pellets) at household and industrial scale. Moreover, hands on training on feedstock collection, preparation, and storage, operation of biomass densification (briquetting and

pelletization) systems, and quality testing of densified products may help to enhance knowledge and expertise.

3. Organizing workshops and demonstration programs for community training by the government and non-government organizations could attract investment and encourage entrepreneurs to involve in biomass briquetting businesses.
4. The Government of Nepal could establish a separate entity which will act as a non-bank financial institution for bridging financing gap in developing small or medium to large-scale infrastructure and renewable energy projects.
5. The Government could take innovative policies, financing and incentive mechanisms for promoting biomass briquetting and encouraging stakeholders to invest and involve in biomass briquette/pellet production and usage. Some policy incentives are essential which could be introduced are:
    i. Tax exemption on the importation of biomass briquetting related equipment
    ii. Reduction or exemption of income tax for a specific time period.
    iii. Easy access to credits at low interest rate and easy repayment policy.
    iv. Introducing emission constraints and taxes (for fossil fuel).
    v. Feed-in –tariff for biomass briquette based electricity generation industries.
    vi. Subsidies on electricity tariff for energy intensive industries who switched from fossil fuel system to biomass briquette based system.
6. A holistic approach could help for using biomass briquettes as clean and efficient fuel to meet thermal energy demand of households, commercial and industrial sectors. Hence, biomass value chain could be developed identifying energy demand of each sector and suitable technology to meet energy demand in which biomass briquettes can be used efficiently.

(d) Ensure safety and health in on-farm biomass production and processing

Actions could be taken to avoid/prevent hazards from self-heating and fire, and dust and gas explosions such as:

i. Avoid storage and transport of large volumes if the fuel's tendency of self-heating is unknown.
ii. Avoid storing biomass with moisture contents greater than 15 wt.% (w.b.).
iii. Moisture damaged pellets from ocean shipment should never be put into the storage.
iv. Avoid mixing different types of biomass fuels in same storage.
v. Avoid mixing fuel batches with different moisture contents.
vi. Avoid large amounts of fines in the fuel bulk.
vii. Measure & monitor temperature distribution & gas composition within the stored material.
viii. Monitor both the storage compartment & adjacent spaces for CO and O_2 to avoid entry into hazardous environment.
ix. Limit storage time & follow the storage principle "first-in-first-out"
x. Control the delivery of fuel with respect to allowed maximum temperature

(e) Research and development, capacity building and hands-on training programs

Research, development, capacity building and hands-on training programs could be conducted/ organized enhance knowledge and develop skills of the government officials are imperative. This is an interactive way of knowledge and technology transfer which may contribute for future development of the country in the long run. In this regard several actions could be taken to resolve major issues related to biomass briquetting such as feedstock related issues and technical issues which are described below.

1. Actions that could be taken to overcome feedstock related issues

Capacity development programs on:

i. Availability and potential assessment of biomass resources, and development of national inventory.
ii. Development of biomass feedstock supply chain through adopting the concept of "decentralized distributed production and utilization".
iii. The development of sustainable forest management policy to facilitate biomass briquetting industry.

Research and development programs for the estimation and prediction of future prospective of biomass resources to meet heat and electricity demand through household assessment, field survey, and key informant interviews.

2. Actions that could be taken to overcome technical issues

Capacity development and training programs on:

i. Characterization of biomass feedstocks to identify suitable briquetting technology.
ii. Biomass densification technologies for the production of biomass derived solid fuels in the form of briquettes and pellets.
iii. Advanced biomass pretreatment and carbonization technologies.
iv. Suitability assessment of biomass derived solid fuels usage in energy conversion technologies.
v. Design, development, testing, and dissemination of biomass derived solid fuel based improved cookstoves (ICSs).

Research and development programs

i. To identify opportunities for producing quality briquettes/ pellets through co-densification.
ii. To design, development and fabrication of biomass briquetting equipment and ICSs using locally available materials.

Capacity building and hands-on training programs to improve technical skills of the government technical experts who will conduct local training programs at community level for knowledge dissemination, create public awareness, and increase acceptability.

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APPENDIX

A.1 List of Stakeholders

Organization	Technology	Raw Material	Contact Person	Contact address
Himalayan Naturals Pvt. Ltd	Beehive , Pellet press, Hydraulic press	Waste biomass	Mr. Sushil Gyawali	sushilgyawali@gmail.com
BioEnergy Nepal			Mr. Anil Maharjan	anil.maharjan@staricnepal.org
MinErgy Nepal			Mr. Suyesh Prajapati	suyesh.prajapati@minergynepal.com
Mhepi Briquete Udyog	Screw extruder, Disc matrix, Hydraulic press	Rice husk Waste biomass	Mr. Surendra Gorkhali	mbu1994sure@hotmail.com
Shubha Biomass Pvt. Ltd	Piston press Pellet press	Sawdust, rice husk, bagasse	Mr. Prachin Lal Shrestha	shubha.biomass@gmail.com
Namuna Briquette Industry	Screw extruder, Beehive Hydraulic press, Roller press (with drier)	Rice husk Waste biomass	Mr. Chandra Mani Bhattarai	arjun105bhattarai@hotmail.com
FoST	Low pressure compression briquette	Paper pulp, waste biomass	Mr. Sanu Kaji Shrestha	sanu.kaji009@gmail.com
Organic World Pvt. Lts	Beehive, pillow shaped briquette	Waste biomass	Mr. Dili Bhattarai	bhattarai771@gmail.com
Himalayan Bio Products Ltd.	Piston Press and Pelletizer	Waste biomass, Pine needles, saw dust	Mr. Buddhi Prasad Sapkota	buddhisapkota@gmail.com
Universal Biomass Briquette Industry	Piston press	Waste biomass, Saw dust, bagasse	Mr. Kanhaiya Bhagat	kanhaiya.bhagat@yahoo.com
Green Biomass Industries, Budhanilkantha, Kathmandu,	Disc matrix pellet press	Saw dust, banmara	Mr. Kakong Sonam Sherpa	greenbiomassnepal@gmail.com

A.2 Technology Capability

In the past, constructing and running a briquette plant was difficult due to the lack of technical knowledge about the equipment and fabrication capability. The country relied on imports of machines, parts as well as manpower. The use of hard surface materials and techniques to address the wear of the briquetting screw were neither available nor known. Repair work (even the minimal cases) had to be sought from Raxaul, India (situated in the India-Nepal border).

The condition has much improved in the recent times. Technology fabrication along with repair maintenance capabilities has developed in the country with several engineering workshops already producing briquetting equipment. Some of them which are located in Kathmandu valley are tabulated in Table. Similarly, there are many other workshops which have developed technological capabilities in fabrication and repair and maintenance in other parts of the country like Chitwan, Bhairawa, Kawasoti and so on.

Table: Technological capability of engineering workshops

Name	Technological Capability	Repair and maintenance	Remarks
Powertech Nepal, Patan	Fabrication of briquetting unit, screw and die	Screw and die and welding for hard surfacing	Fabrication of screw extruder briquette machine for NAST
General Engineering, Khumaltar, Patan	Fabrication of briquetting unit, screw and die	Screw and die and welding for hard surfacing; Eutectic welding capability for hard surfacing	Fabrication of screw extruder briquetting for NAST, several portable briquetting units for AEPC project and RENP project
Absolute Engineering, Swayambhu,	Fabrication of briquetting unit, screw and die	Fabrication of briquetting unit for RENP project	-
Valley Engineering, Teku	Fabrication of briquetting unit, screw and die	Screw and die and welding for hard surfacing.	Fabrication of briquetting unit for RENP project
Balaju Yantra Shala	Fabrication of briquetting unit and screw propeller	-	Screw propeller for NAST
Purna Metal, Patan	Fabrication of screw	-	Fabrication of screw for NAST
Narayani Engineering Works	Fabrication of screw and die, biomass dryer and transport system.	Screw and die and welding for hard surfacing.	Screw and die and biomass drying system for Namuna Briquette industry.

ANNEX 2

A BUSINESS ACTION PLAN

PROMOTION OF SUSTAINABLE BIOMASS BRIQUETTE USE IN NEPAL

Submitted to:

Centre for Technology for Climate Network (CTCN)

Submitted by:

Energy Program

Department of Energy Environment and Climate Change

Asian Institute of Technology, Thailand

September 2018

Table of Contents

1. Introduction

1.1 Relevance of Action Plan

Seventy-five percent of Nepal's population (4 million out of 5.43 million households) use solid biomass (firewood, cattle dung, or agro-waste) as their primary fuel. At the same time, Nepal wishes to attain economic growth that targets sustainably, without threatening the local environment and public health by using polluting and inefficient technologies, while dealing with serious threats to the local environment and public health. Indoor air pollution is one of the biggest health risks in the country, and much is attributed to cooking and indoor heating using solid biomass, mainly firewood. Excessive firewood consumption by traditional cook-stoves exerts enormous pressure on forest resources in Nepal. In addition, they require rural women to spend more time collecting firewood and cooking, in turn limiting their ability to participate in income-generating activities.

Nepal has therefore been striving to make steady progress in promoting more efficient biomass energy technologies, including improved cook-stoves and biogas, and now biomass briquettes. This action plan intends to encourage pathways for promotion of sustainable use of biomass briquettes.

1.2 Scope of Action Plan

The preparation of this action plan is guided by Nepal's Biomass Energy Strategy 2017, which aims to make indoor air pollution free Nepal by 2022 through the promotion of clean cooking technologies in all households; and to ensure the availability of modern clean energy in all the households using solid biomass by 2030. It also aims to reach the annual production of 20,000 metric tonnes of pellets and briquettes.

The action plan will be implemented to holistically address the needs for upscaling briquette industries throughout Nepal and creating a steady market for its commercialization. It considers the collaborative efforts of a wide range of stakeholders including policy and decision makers, donor organizations, private enterprises, academic institutions and communities for its successful implementation.

2. Background

2.1 Global Status of Biomass Energy

The potential of biomass as a renewable energy source has been recognized globally (Demirbas, 2004; Balat and Ayar, 2005). Biomass is a versatile energy source that can be converted into solid, liquid and gaseous fuels. The use of biomass energy, however, differs across developed and developing countries. It is primarily used in the developed nations as an alternate to fossil fuels, while in the case of latter, the use of biomass energy is more traditional. Biomass use in developing countries dominates the domestic fuel, especially in rural areas where energy security issues are prevalent (World Energy Council, 2016). Biomass energy currently constitutes about only 14% of the world's final energy use, and it has potential to increase by three times by 2035 (World BioEnergy Association, 2017).

The worldwide supply of biomass can be categorized chiefly into: (a) forestry, (b) agriculture, and (c) waste. Worldwide, woody biomass comprises about 87% of the energy annually derived from biomass. Agriculture sector contributes 10% to biomass supply - via the use of animal by- products, agricultural by-products and energy crops. The third sector of waste to energy accounts for the remaining 3% with energy generated from Municipal Solid Waste (MSW) and landfill gas. Although this sector has a lot of scope and potential, it has not been utilized properly (World BioEnergy Association, 2017).

Various studies estimate the global bioenergy potential to range a few hundred to more than 1,000 EJ (depending on the assumptions they make on agriculture, yields, population, etc.) (Fritsche et al., 2006). Progressive depletion of fossil fuels and global commitments to curb emissions have increased the interest in biomass energy in recent years (Caputo et al., 2005). Growing interest in biomass energy is driven by the following facts among others (Karekezi et al., 2004):

- it contributes to poverty reduction in developing countries;
- it meets energy needs at all times, without expensive conversion devices;
- it can deliver energy in all forms that people need (liquid and gaseous fuels, heat, and electricity);
- it is carbon dioxide-neutral and can even act as carbon sinks; and
- it helps to restore unproductive and degraded lands, increasing biodiversity, soil fertility, and water retention (Balat, M., 2009).

Bioenergy is the largest contributor of global renewable energy supply. An array of bioenergy technologies and conversion processes are now well-established and fully commercial. Total primary energy supplied from biomass in 2016 was approximately 62.5 exajoules (EJ). The supply of biomass for energy has been growing at around 2.5% per year since 2010.

The largest shares of fuelwood (as well as other traditional fuels such as dung and agricultural residues) are consumed in Asia, South America and Africa. Bioenergy (mostly from solid biomass) accounts for around 7% of all industrial heat consumption, and its use in industry has not increased in recent years. This use is concentrated in bio-based industries such as the pulp and paper sector, timber, and the food and tobacco sectors.

2.2 Solid biomass densification

Densification of loose solid biomass into compacted briquettes or pellets results in increased energy density. This can consequently translate into reduced transportation costs and storage space requirements, as well as uniformity in feedstocks. Briquetting and pelleting are the two main and most common forms of biomass densification. They have similar process components and production stages but vary in product sizes. Briquettes encompass the products with larger diameter (e.g., 40 mm) while smaller diameter products (e.g., 10 mm) are referred to as pellets (Tumuluru et al., 2011). These can be used for residential heating in stoves and boilers, for the generation of heat, steam and electricity in the service industry, manufacturing and power generation, as well as for cooking purposes. Some common available methods for solid biomass densification include piston press, screw press, roller press and pelletizers. These technologies are widespread and have been localized in different countries to suit their needs (Manickham N et al., 2006). The international market has also seen some promising development in biomass conversion technologies recently. Torrefaction of wood enables the production of pellets with a higher energy density and results in a product compatible with systems designed for coal. Although commercialisation of the technology has been slower than expected, some promising developments occurred in 2016 (REN21, 2017)

2.3 International Market for Solid Biomass

International trade of densified biomass is driven by pellets. The global wood pellet market has increased dramatically since 2011, with an average increase rate of 14% per year, and reaching a production of 28 million tons of pellets in 2015. New countries have entered the market for both, pellet production (such as those from South-East Europe) and pellet consumption (such as East Asia). This increase in use of biomass energy in the international market is due to countries’ pledges to reduce greenhouse gas emissions and shift from fossil fuel towards renewable energy sources.

Table 1: Worldwide production of pellets (2012- 2015)

	World	Africa	Americas	Asia	Europe	Oceania
2012	19.7	0.09	6.72	0.30	12.5	0.03
2013	22.3	0.04	7.64	0.62	14.0	0.03
2014	26.0	0.04	8.91	1.50	15.4	0.14
2015	28.0	0.03	9.44	1.99	16.3	0.15

All values in million tonnes. Source: FAOSTAT

International market of pellets is dominated by trade between US and the UK. U.S. stands out as the largest pellets producer by far with 7.4 metric tonnes (Mt) in 2015 (FAO-Estimate) and 6.3 Mt in 2016. Canada is the country with the most dynamic development, having increased the export from 1.6 Mt in 2015 to 2.4 Mt in 2016. In 2016, Europe accounted for some 70% of global demand for pellets for heating, led by Italy, Germany, Sweden and France. The United States is the largest exporter of wood pellets.

The global market for pellets is mostly demand driven (especially industrial demand). Demand markets are still influenced to a large extent by policy framework providing incentives in different forms to biomass combustion. Supply capacities to date have reacted to policy and demand projections. Demand and supply for pellets vary across regions and is dynamic in nature. The markets in the west have been targeted at residential as well as industrial sectors, where pellets are used for residential heating and power supply, and in industries for generating heat, steam or electricity.

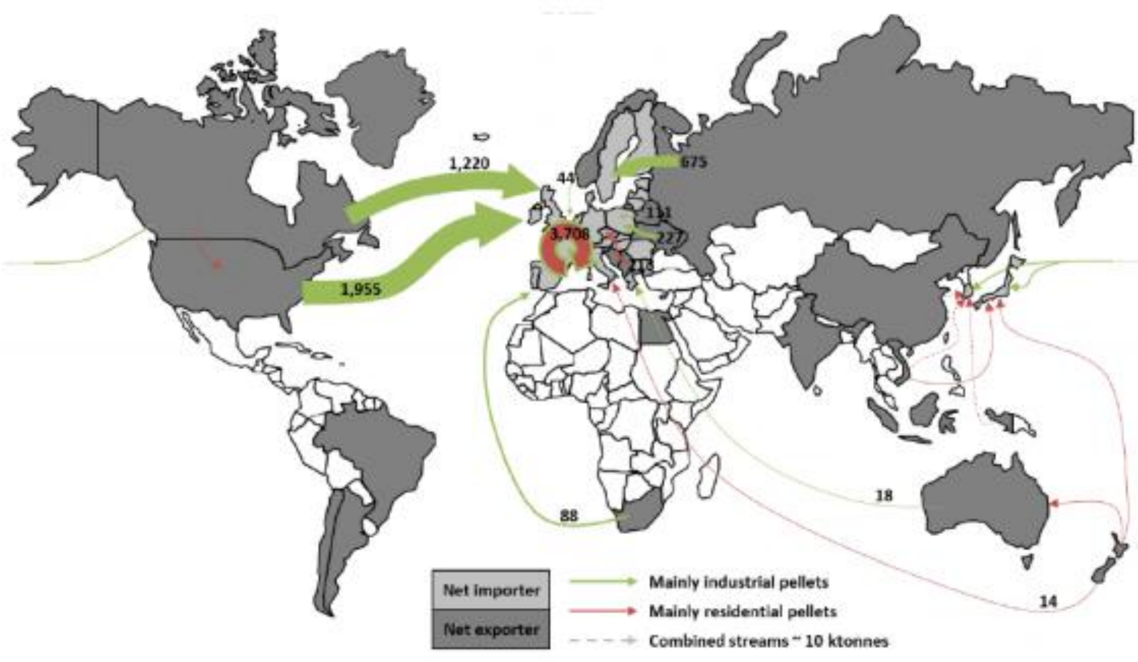

Figure 1: Global Wood Pellets Trading Flows in 2012 (Source: Lamers P. et al., 2013)

Pellet industries in the South America have not fostered yet. Several barriers exist for the industry, including:

(i) Cultural barriers and lack of knowledge about pellets as biofuel;
(ii) Security of supply of biomass for pelletizing and seasonality of the price of wood waste;

(iii) Variation of pellet quality offered in the market;
(iv) Exclusive use of residual biomass impedes production at larger scales.
(v) lack of knowledge about its advantages and the technical and economic feasibility of pellets production.
(vi) Variations in quality and prices

These barriers have resulted in a lack of internal market demand for both pellets and pellet equipment (Moreno-Lopez, 2016). There are no standards for wood pellets in South American nations, which also fail to reach the quality and scale required for the European market, and negatively hampering the market.

In Africa, Kenya, Rwanda, Uganda, and Tanzania are pioneer countries in biomass densification, producing both charred and uncharred briquettes and pellets.

2.4 Market in Asia

The market for solid densified biomass in Asia is still immature compared to the European market. However, Asian markets are emerging and show robust growth with large-scale power markets in East Asia rapidly picking up. Japan and South Korea are the biggest importers of pellets in Asia, while China, Thailand, Vietnam, Indonesia and Malaysia are exporters. However, China has set out a goal of using 30 Mt of biomass pellets consumption in 2020 to replace 15 Mt of coal, which can significantly increase China's proportion of consumption of the biomass fuel.

Within Asian markets, competition for Korean markets exist between China and Vietnam. In 2014, China exported 287 kt of wood pellets to South Korea. In 2015, the export fell sharply as Chinese producers had to compete with Vietnamese producers for cheaper wood pellet prices; however, it gained a growing Japanese biomass market which supports growth in the coming years (Argus Media, 2016). High production costs as results of tight wood resources supply renders Chinese wood pellets less competitive as price increases (€105/t).

In case of Japan, under this Feed-in Tariff (FIT) Scheme for Renewable Energy (2012), electric utilities are obliged to purchase electricity generated from renewable energy sources such as solar PV and biomass on a fixed period contract at a fixed price (METI, 2012). Pellet consumption in Japan has grown rapidly since then. Along with domestic production, there is import from China, Vietnam and Canada.

Indonesia and Malaysia have exported about 150 and 60 kt of wood pellets respectively to South Korea in 2014 and 2015. Palm kernel shells (PKS) are exported from these two to Japan but the supply markets are still rather small (Bioenergy International, 2015). Vietnam is the main exporter dominating 70 % of South Korean market, it also offers a competitive wood pellet price at about 90 €/t to Japanese and South Korean markets (Murray, 2016).

Vietnam has limited use of briquettes, where it is used primarily for cooking and space heating purposes and is limited to household use. In the Philippines, the conversion cost from biomass to briquettes is very high, and therefore, the commercial production is limited. Briquetting plants with both small and high production capacities can be found in Thailand. Widespread promotion and distribution of rice husk briquetting business is present in Bangladesh. Briquette use here is targeted at domestic consumers in tea stalls, restaurants and student housings, and the business is fostering. In case of India, the major use of biomass briquettes is in industrial applications, primarily to produce steam. Various raw materials are used in India, including rice husk, pine needles, saw dust, bagasse, coffee husk, etc. Numerous briquette industries are present in Nepal that are based on rice husk, saw dust, bagasse or forest residues. Beehive briquettes have been widely popular for space heating purposes. The use of pellets is now increasing in Nepal, particularly in institutional cooking sector.

2.5 National Status of Biomass Energy in Nepal

According to the National Survey of Energy Consumption and Supply situation of Nepal (2011/ 2012), biomass comprises of approximately 80% of the fuel mix in Nepal (WECS, 2014). As per the National Census 2011, nearly 4 million out of 5.4 million households in Nepal are still using the traditional biomass energy including firewood for cooking (AEPC, 2017). The lower efficiency usage of these fuels trigger indoor air pollution (IAP) as one of the major problems in Nepal. World Health Organization (WHO) estimated 2.7% of Nepal's burden of disease is attributed to solid fuel use, which results in nearly 7500 deaths per year. Improved cook stoves (ICS) have been identified as one of the most simple and cost-effective technologies to address IAP in rural homes. The Biomass Program under AEPC has been successful in installing ICS in the mid hills through collaboration with local non-governmental organizations (NGOs) and governmental organizations (GOs), without direct subsidy to households (K.C., S. et al., 2011). Biomass briquetting has been in existence in Nepal since 1980s, but several market barriers have led many industries to close down. Currently, about 40 private organizations and communities are producing briquettes using several technologies (piston press, screw extruder, pelletizer, beehive briquetting, hydraulic press, roller press, etc) and different raw materials (rice husk, saw dust, forest residue, bagasse and paper pulp).

Nepal has a tremendous potential for biomass briquettes as it produces enormous amount of crop and forest residues, and municipal and industrial organic solid wastes. Briquettes could therefore be good substitutes to wood, kerosene, coal and LPG at the household level for cooking, and boiler and brick kiln fuels at the industrial level. Bio-briquetting is a low-cost simple technology that is free from geographical and climatic limitations, and is ideal for both cooking and space heating, and has potential in reducing IAP by up to 90%. However, there are some setbacks to commercial large scale production of bio briquettes. Production during monsoon season is affected by proper storage and drying requirements. Other limitations of bio-briquette are its low volatility and long ignition time compared to fire wood, and its incompatibility in the traditional stoves (K.C., S. et al., 2011).

2.6 Policy, Legislation and Institutions

Prior to the Biomass Energy Strategies, there had been several policies in place that supported the promotion of biomass energy.

2.6.1 Industrial Policy 2011

- This policy identifies insufficient energy availability, weak industrial infrastructures, low productivity, and absence of technology acquire capacity as some of the barriers for industrial growth
- Aims to create a conducive environment for private, public and collaborative sector to participate and contribute in the national goal of poverty reduction
- Aims to establish the industry sector as one of the most reliable and dependable sector by promoting the use of modern technology and environment friendly production processes
- Provide financial and technical support to proactive industries on adopting environment friendly and energy saving technologies
- Initiate special programs to establish green industries and make the existing industries pollution free and zero carbon.

2.6.2 Foreign Direct Investment Policy 2015

In the context of promoting private sector investment in the cleaner technologies and cleaner industries through the market mechanism like Clean Development Mechanism or Sustainable Development Mechanism (Paris Agreement), this policy is important.

- Private investment and also the technology transfer require permission from the government as per this policy.
- Long-term goal of this policy is to attract the foreign investment on nationally prioritized sector.
- The objectives include not only to attract the foreign money but also equally prioritizes the investment on modern technology, management skill, and high technical skills to ensure the productive and competitive industrial growth.

2.6.3 Rural Energy Policy 2006:

- In this policy rural energy is known as renewable energy
- Overall goal of this policy is to contribute to rural poverty reduction and environmental conservation by ensuring access to clean, reliable and appropriate energy in the rural areas.
- Sets sector specific working policies on -micro and small hydro power; biogas; fuelwood, charcoal, briquette, biomass energy, and biomass gasification; solar energy technology; wind energy technology; improved cook stove technology; improved water mill technology; and rural electrification
- Specific strategy on subsidy for renewable energy promotion

2.6.4 Renewable Energy Subsidy Policy 2016:

Introduced for the implementation of REP 2006:

- Provides the subsidies for different renewable energy technologies and defines the procedures for distribution of subsidies to the recipients.
- Involves the qualified private sector institutions in the distribution of subsidies also.
- A latest policy of the GON to promote renewable technologies with the use of economic instruments.

2.6.5 Forest Policy, 2015

The policy includes different activities like:

- afforestation in public and private land;
- private forest for the private sector;
- provision of necessary technology and different financial instruments like subsidy, credit and insurance facilities for promoting forest enterprises and commercial nurseries;
- financial and technical support to the users of alternative energy, biogas, bio-briquettes, improved cooking stoves, biofuel etc.

Effective institutional mechanism and co-ordination among the relevant institutions is crucial in ensuring successful implementation of the strategies. A Central Coordination Committee has been formed for inter-institutional coordination, with the Secretary of Ministry of Population and Environment (MoPE) as the coordinator. Likewise, it has been proposed that Biomass Energy Strategy Implementation and Monitoring Unit be established at the central level each in the Ministry of Forest and Soil Conservation, Ministry of Agriculture Development, Ministry of Population and Environment, Ministry of Federal Affairs and Local

Development, Ministry of Energy, Water and Energy Commission Secretariat, and Alternative Energy Promotion Centre.

3. Biomass Briquette Promotion Action Plan

3.1 Goal

To increase the access to biomass energy and hence contributing to the environment conservation by transforming traditional biomass energy use into modern, sustainable and clean energy.

3.2 Objectives

- To contribute to energy supply and energy security by generating energy through management of agriculture forest residues and organic wastes from municipal urban and industrial areas.
- To support the employment and income generation through the entrepreneurship development in biomass energy; and to reduce the existing dependency on imported energy through effective, efficient production and utilization of biomass energy.

3.3 The Business Plan

3.3.1 Business Models in Renewable Energy

Business models structure how business investments must be designed, implemented, and managed, and incorporate critical financing, service, and monitoring features. The most appropriate business model for a given project will depend on local conditions, the financial and regulatory environment, and the institutional framework and support mechanisms in place. The scale and purpose of the project or service must be well defined, together with the end consumers.

Several business models are present for Renewable Energy Technologies (RETs). For the purpose of this study, the models that can be replicated in biomass densification have been identified and discussed in the following section.

i. Result Based Financing Approaches (Sida, 2015)

The World Bank defines RBF as "any program that rewards the delivery of one or more outputs or outcomes by one or more incentives, financial or otherwise," after the principal has verified that the agent has delivered the agreed-upon results (Musgrove 2010). The main aspects of RBFA, or Payment by Results are:

- payment is based on achieved results and
- the relationship between payment and results is pre-defined

There are two major dimensions to RBFA: first the extent to which financing is paid up-front before the results have been achieved, or ex-post on delivery of the results (as shown on the y-axis). The second-dimension measures where on the results chain the financing is determined, i.e. at the input level, the output level or the outcome level (as shown on the x-axis). While a traditional project is situated at the lower left side of the diagram, i.e. donors pay for the input needed to implement the project and to reach the intended results, in case of an RBFA project, it will be situated towards the upper part of the diagram (i.e. payments are delivered only once the pre-agreed results have been delivered). Payments can be made for final outcomes, intermediate outcomes, outputs or even activities, depending on the degree of risk sharing between implementers and donors. Part of the financing can be results based while other parts are traditional input financing.

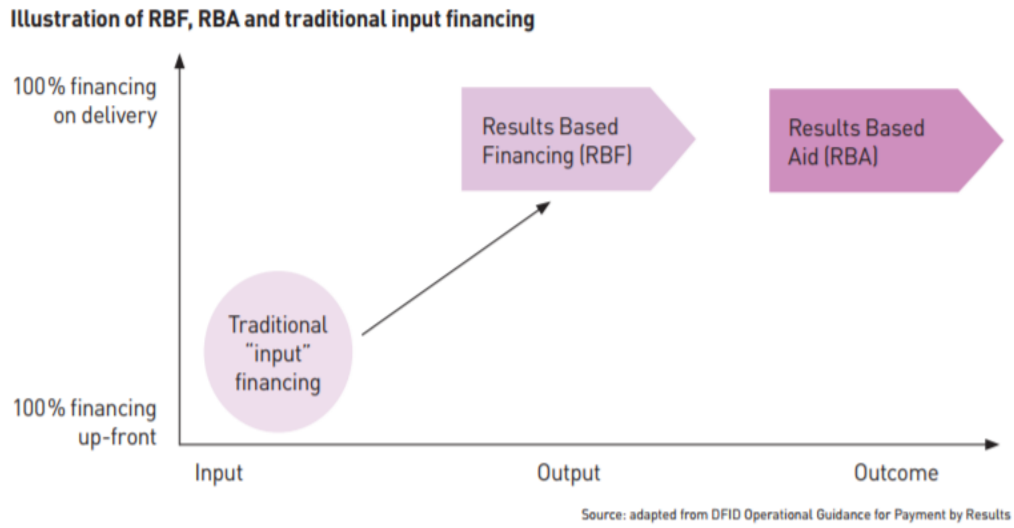

Figure 2: Illustration of RBF, RBA and traditional input financing

SNV's recently launched Results-Based Financing (RBF) for Pico-Solar project in Tanzania works by creating a temporary post-financing product within mainstream banking to players in the solar sector. The finances available to import-suppliers come in the form a sales incentive that can only be claimed for payment after the sales of approved solar product are verified (Kleijn M., 2014).

ii. Developing Value Chain (EEP, 2015)

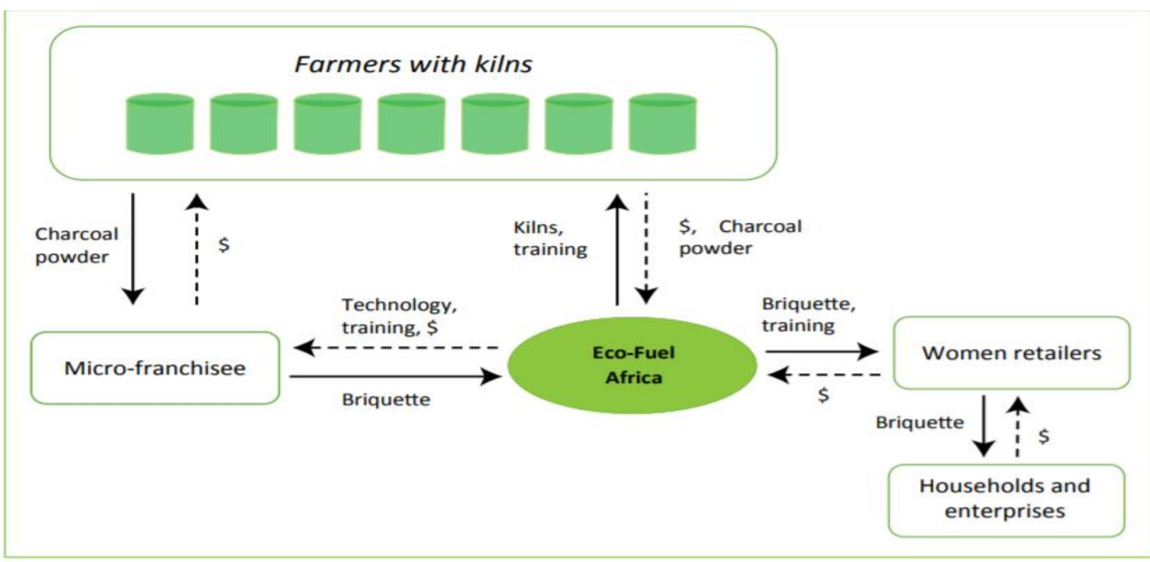

Figure 3: Business Model based on value chain development

This business model is based on the idea of creating the entire value chain of briquettes: from producers to consumers.

Eco – Fuel Africa is a start-up enterprise based in eastern Kampala that initiated in 2010, and operates on this business model. It received a seed grant of US$10,000 from the Government of Uganda for biomass briquette production. It has been training marginalized farmers to turn locally sourced biomass waste (coffee husk, sugarcane waste and corn waste) into char using simple, locally made kilns. Farmers are trained for five days and after the training, they take home a kiln on a *lease-to-own* basis, and begin to make char. This has created about 6,000 jobs. The briquette machines are developed in-house, and have a production capacity of 250 – 400 kg of briquettes per day (around 100 tons per year). These are packaged in transparent plastic bags printed with their logo and contact details before being distributed via a network of women retailers who buy briquettes and sell them to domestic users in nearby slums and urban centers. Eco-Fuel have successfully implemented a distributed supply chain, leasing carbonization kilns to farmers trained in the production of char that they bring to collection points set up in market centers.

iii. Cash-at-gate Policy

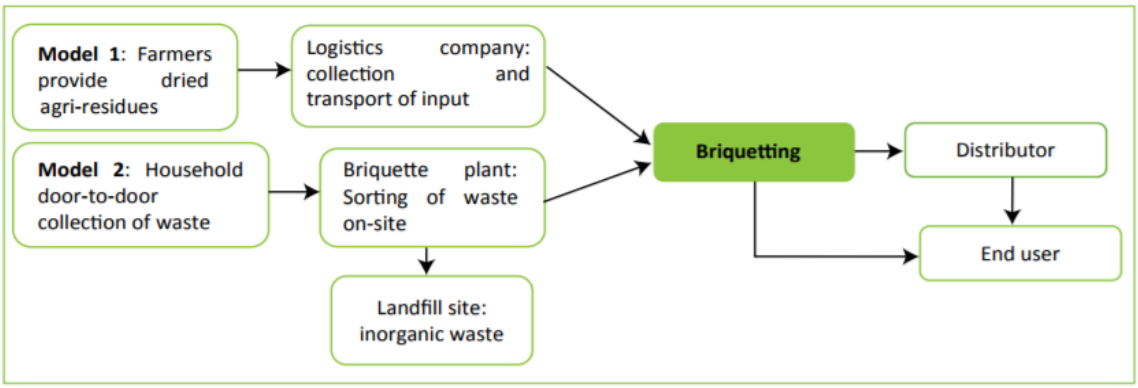

Figure 4: Business Model Based on Cash- at- gate Policy

In this business model, carbonized agricultural waste that is bought from people with a 'cash at the gate' policy, allowing them to develop a large network of people who provide a continuous supply of raw material of multiple type. This ensures raw material diversification as well as efficient supply chain networking.

iv. Lease or Hire Purchase Model

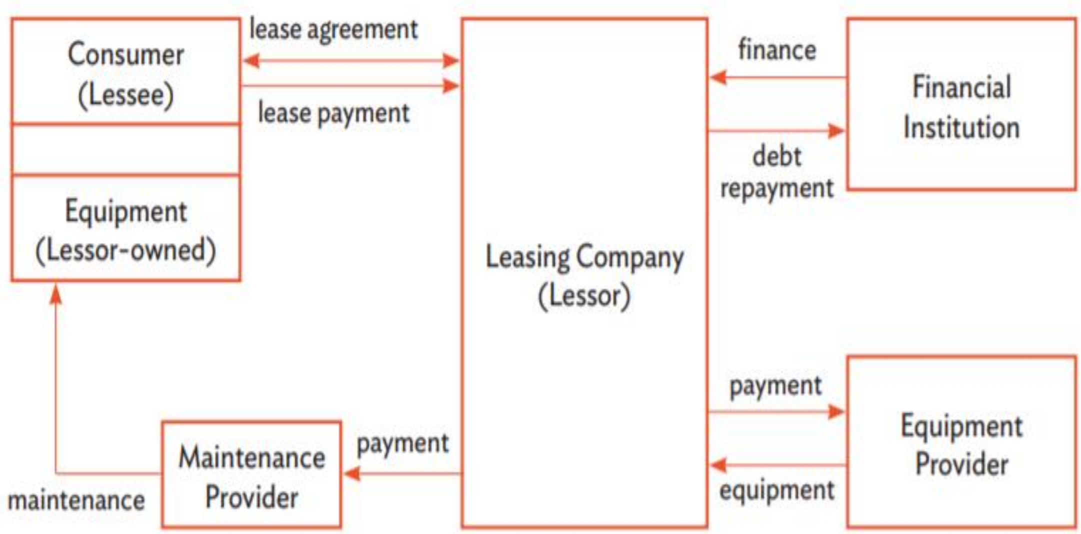

Figure 5: Business Model based on Lease or Hire Purchase Model

Lease of Hire Purchase model typically enables users to purchase equipment in installments. A leasing company (lessor) or equipment supplier provides the equipment to the end user for a contracted period of time in exchange for regular payments. The lessor is responsible for sourcing, financing, and installing the equipment, and for maintaining it during the contract period. Depending on the provisions of the contract, at the end of the contract period ownership of the equipment can either remain with the lessor or pass to the lessee (sometimes for an additional amount). Mailhem-Ikos, a biogas company in India is using this model to lease out biogas plants in six different locations in the country.

v. Third Party/ Consumer Financing

In this business model, consumers finance their access by relying on 3rd party financing, such as the revolving funds set up by donors, micro-credit facilities or rural banks to purchase technologies. Options include providing a combination of credit to cover a deposit and additional monthly payments to cover the balance. Micro- financing institutions (MFIs) have been used for cookstoves, which has worked well because across the financial sector, MFIs offer the best potential for clean cooking consumer finance due to their focus on similar segments of the population.

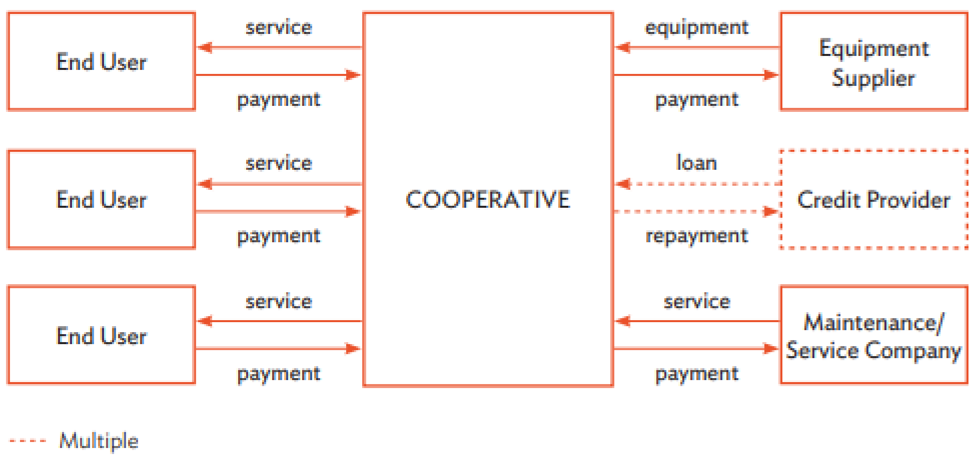

Figure 6: Third Party Financing Business Model (Source: ADB, 2015)

3.3.2 Business Models in Nepal

In the context of Nepal, two distinct types of bio- briquette industries are present: uncarbonized and carbonized briquettes. The fundamental difference between these two is that carbonized briquette production is carried out in close collaboration with community forest user groups (CFUGs) as the raw material is char produced from anaerobic oxidation of forest residues. Uncarbonized briquettes, on the other hand, is produced from agricultural residues. Because of this difference, the working model of these businesses are also different.

i. Business Model for Uncarbonized Briquettes

The briquette industry in Nepal currently follows BOOM (Build- Own- Operate- Maintain) model, with the use of a single type of raw material (either rice husk or saw dust or sugarcane bagasse).

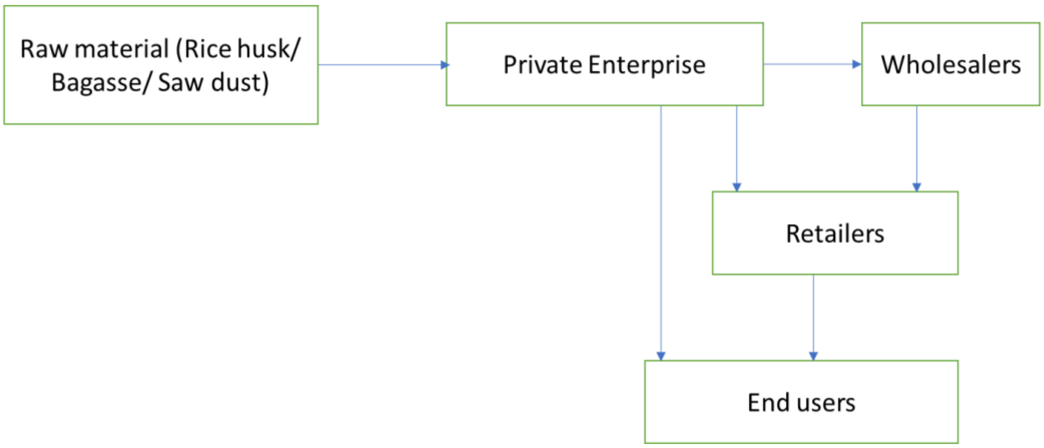

Figure 7: Current business model for uncarbonized briquette production

The private enterprise buys the raw material from farmers (for rice husk) or industries (for saw dust), and is responsible for the entire value chain, from production to marketing, sales and distribution. Efficient marketing mechanisms are still lacking and a strong value chain has not been formed yet.

The business model proposed here is also BOOM type, however, it includes diversification of raw materials as well as products.

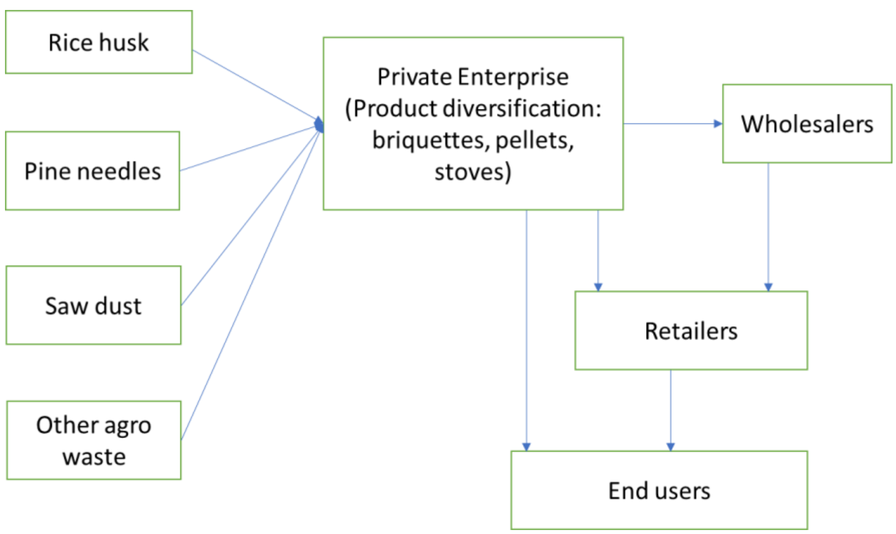

Figure 8: Proposed business model for uncarbonized briquette production

In this model, the private enterprise manufactures briquettes not only based on a single raw material, but diversifies the raw material base depending on the price and availability, as previous studies reveal that different agro-wastes can be fed into the same briquetting system to produce uncarbonized briquettes. A cash-at-gate policy can be used to ensure strong supply chain and regular supply of varied raw materials. Product diversification, where there is production of briquettes, pellets, pillow briquettes as well as the stoves that these briquettes require, is also proposed. Production of briquette stoves can ensure that customers do not have to venture elsewhere to find suitable stoves.

However, it is important for the private enterprise to invest in consumer awareness, with demonstrations about use of briquettes. Likewise, differential pricing can be done at different levels of distribution. Strong networking with the distribution chain is also encouraged, which can then be used for customer support.

ii. Business Model for Carbonized Briquettes

The current business model comprises of a community- private enterprise model, working in collaboration with grassroot levels (CFUGs) who are responsible for forest management and collection of forest based residues for char production. Char making occurs in the forest itself, which is then transferred to the small community enterprises that are responsible for char storage, grinding, mixing, molding and drying of briquettes, quality assurance and wrapping and packaging. The role of private enterprises is to obtain the legal permits for transportation of char, transportation of raw material as well as end-product, storage of briquettes, advertisement and marketing, sales and distribution to wholesalers and/ or retailers.

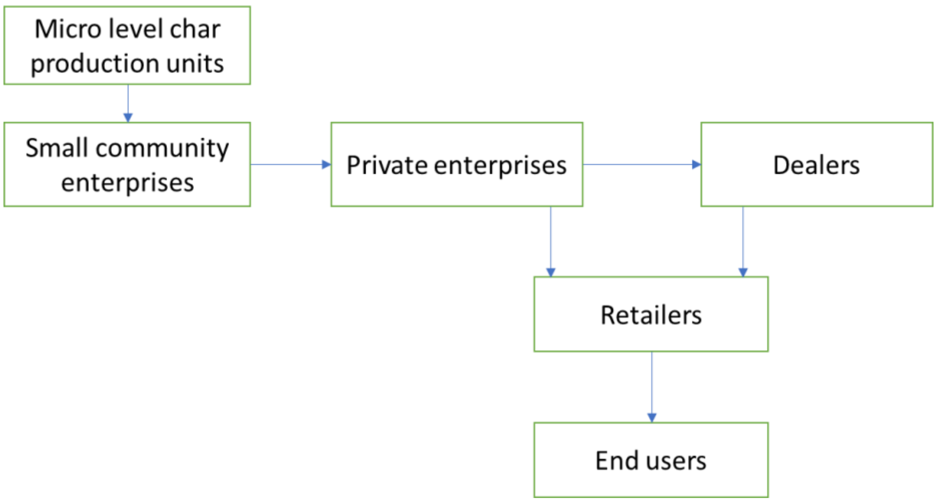

Figure 9: Current business model for carbonized biomass briquettes

We propose that this model of business value chain can be replicated further with inclusion of micro finance institutions to support the small community enterprises in obtaining the necessary equipment for production phase, and to scale up production.

The private enterprise can assist high-potential community based enterprises (CBEs) further to access motorized machinery. CBES can also partner with microfinance institutions (MFIs) and rural banks that already provide financing in target markets or through an arrangement in which the organization absorbs the initial capital cost of the machine but reclaims the cost from the producer through a low rate pay-back arrangement. The role of private enterprise also involves creating sales networks through improved branding and marketing and improve networking to provide a buy-back guarantee for any char powder produced by the Community Based Enterprises (example: ARTI in Africa).

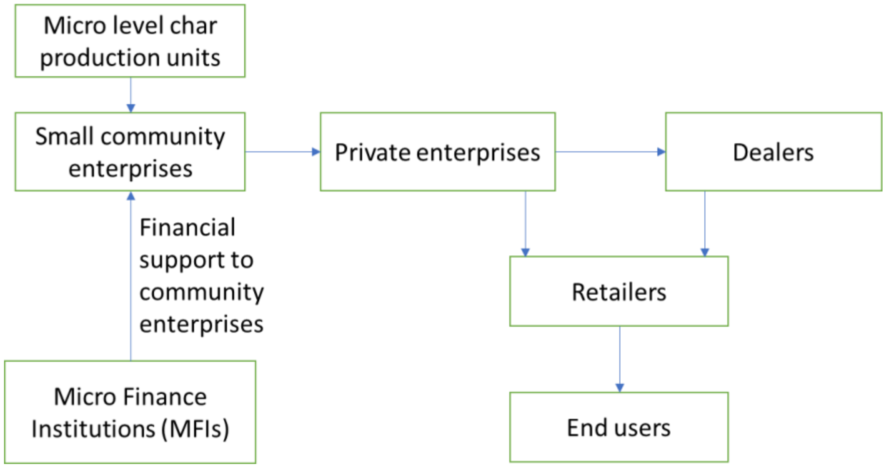

Figure 10: Proposed MFI- based business model for briquette production

Marketing and Distribution

Marketing and distribution of biomass briquettes, either carbonized or uncarbonized, needs to be effective. Distribution can be done via four channels:

- Channel 1: Producer →Consumer
- Channel 2: Producer →Retailer→ Consumer
- Channel 3: Producer →Wholesaler →Consumer
- Channel 4: Producer →Wholesaler →Retailer →Consumer

Figure 11: Different distribution channels

The higher the number of intermediaries in the distribution channel, the higher is the price the consumers have to pay. Setting up a factory outlet enables lower prices for sales at factory, and this can be done to target a few customers, but those with large demands (eg. Industries).

On the marketing front, much work needs to be done on consumer awareness. Demonstrations on use and storage, as well as handling instructions on packaging is required. After sales service is another area that enterprises should invest in, particularly in customer support, by linking them with stove manufacturers.

3.3.3 SWOT Analysis

SWOT analysis was carried out for both the proposed business models. The results of the analysis are presented in the following SWOT Table 2:

Strength	Weakness
- Global availability of technology and technological capability, only need to customize the technology - Local capacity for technology services has improved - CFUGs availability and their positive outlook on briquette - Socio- environmental impact of the industry (prevent forest fire, reduce poverty, improve women empowerment) - Growing market and awareness - Possibility of using climate financing	- Price sensitivity of the industry - End use device shortage - Lack of competitiveness with other fuels - Misappropriation of cheap financing (good governance and transparency) - Lack of proper monitoring of stove quality and fuel quality - Lack of inter ministry co- ordination - Lack of risk minimization tools - Lack of political commitment and awareness - Lack of investors and large financing - Uneven play field (Other RETs have subsidies, briquettes don't) - Lack of industry support programs - Less preferred by policy
Opportunities	**Threat**
- Opportunities to use forest biomass - Briquette market exists (but needs segregation) - Opportunity to use resources such as forest biomass under high tension lines - Ease of collection of some biomass - Agricultural residue as a resource (husk, straw, bagasse, stalks) - Price of fossil fuel is increasing - Affordability of stoves when the industries scale up - Technology innovation for densification present in global scenario	- Competition from other kinds of fuels and sectors - Labor cost is high, and labor supply is low - Cost of spare parts (Foreign currency threat) - Political instability - Lack of financing - Provincial laws have not yet been fixed - Price of oil and coal could reduce - Nepal could find natural gas - Conflicting policies between energy and forestry sectors - Competition from other sectors' investments

Favourable policies need to be developed to harness the opportunities and mitigate the threats.

3.4 Actions

3.4.1 Setting and delivering on ambitious and achievable biomass energy targets

Nepal is looking to increase sustainable energy production in the country by utilizing agriculture, forest residues and organic wastes. The current production capacity of briquettes and pellets is estimated at 7,000 metric tonnes annually. BEST has set an annual target of 20,000 metric tonnes by 2030.

3.4.2 Streamlining biomass energy projects processes and approvals

The action plan calls for coordination among relevant agencies to ensure smooth, timely and efficient procurement of biomass briquetting related machinery and raw materials.

3.4.3 Creating an enabling policy environment

This action plan aims to develop a policy framework that not only encourages private sector investment in biomass briquetting, but also a public private partnership where government is involved in risk management in the sector. An enabling policy environment consists of provision for including biomass briquetting sector as a special protection/ priority sector, making it eligible for low interest loans. Likewise, tax and customs exemption on briquetting equipment as well as raw materials, and accelerated depreciation on machinery need to be carried out.

3.4.4 Standardizing mechanisms and certification schemes

Quality consistency in briquettes and pellets is still lacking. Therefore, this action plan calls for development of quality standards as well as certification schemes for both carbonized and uncarbonized solid densified biomass fuels. This could be done in close collaboration with the Renewable Energy Test Station (RETS).

3.4.5 Encouraging continuous R&D

Research and Development in briquetting needs to increase to increase technological and human capacity development in the sector. The action plan recommends that AEPC work in close collaboration with research institutions including universities, Centre for Energy Environment- Nepal (CEE-N), Research Centre for Applied Science and Technology (RECAST) and National Academy of Science and Technology (NAST). R&D is required especially in terms of alternate raw materials, binder options and stove technologies. Mechanisms for technology transfer also need to be developed.

4. Monitoring and Evaluation

Monitoring will be based on the specific outputs of the project. It will cover the intermediate outcomes, immediate outputs, the actions and inputs necessary to achieve the outputs and outcomes. The logical framework analysis given below forms the basis for monitoring and evaluation:

Qualitative parameters in M&E are centred towards Gender Equality and Social Inclusion (GESI), primarily addressing how the project incorporated GESI issues and improve the socio- economic conditions of communities involved. Also, the M&E focuses consumer perception towards biomass briquettes to ensure the project can work to meet the demands of consumers.

Table 3: Logical Framework Analysis for Promotion of Sustainable Use of Biomass Briquettes				
Narrative Summary	Indicators	Means of Verification	Responsible Agency	Risk/ Assumptions
Impact: To increase the access to biomass energy and hence contributing to the environment conservation by transforming traditional biomass energy use into modern, sustainable and clean energy.	- Level of confidence on modern biomass energy - Market growth of biomass briquette technologies	- Final project evaluation report, market study reports and stakeholder consultation interviews	- AEPC - BEAN	- Political will to effectively promote biomass energy as an alternative or complementary source of energy
Outcome: **1. To contribute to energy supply and energy security by generating energy through management of agriculture forest residues and organic wastes from municipal urban and industrial areas.**	- The level of confidence on modern biomass briquettes and implementation mechanisms promoted	- Interviews with consumers	- AEPC	- The targeted beneficiaries accept the proposed technologies and implementation mechanisms
2. To support the employment and income generation through the entrepreneurship development in biomass energy; and to reduce the existing dependency on imported energy through effective, efficient production and utilization of biomass energy.	- Number of people employed in biomass briquettes based enterprises - Proportion of imported energy sources replaced	- Employee records - Project evaluation report	- BEAN - Third party	
Outputs: **1. To increase production of sustainable biomass energy**	- Increase in number of biomass briquette enterprises	- Number of new	- AEPC	

by utilizing agriculture, forest residues and organic wastes.	and their production capacities	enterprises registered - Sales records	- BEAN	- Private sector is willing to invest in biomass briquetting
2. To contribute to increased access to clean cooking technologies for all Nepali households through means of modern biomass energy	- Increase in number of households using biomass briquettes	- HH survey data	- AEPC	
3. To increase effectiveness and efficiency in the utilization and production of biomass energy.	- Increase in uptake of biomass briquettes	- Market study - HH survey	- AEPC - AEPC	
Activities: **1.1 To arrange appropriate contributions from the government, private sector and beneficiaries/ consumers in order to make the production and utilization of biomass briquettes/ pellets reliable and sustainable; to provide financial and technical assistance and easy loan for the production and utilization of modern, affordable and efficient technologies**	- The level of provision for public- private partnership for financial incentives - The financial data of systems installed - Number of trainings held (administrative/ technical/ financial/ marketing)	- Project reports - Project Reports - Monitoring Reports - Training attendance sheets	- AEPC - BEAN - AEPC - AEPC	- Policies for PPP as well as financing and fiscal incentive for biomass briquettes are well defined - Commercial banks and MFIs invest in biomass briquetting - CFUGs agree to engage in biomass briquetting - Interest of targeted stakeholders for training can be created through prospect of business opportunities - Government and Private enterprises invest in capacity building
1.2 To promote biomass briquettes together with sustainable forest management	- Number of CFUG members involved in briquette enterprises	- MoUs signed with CFUGs		

1.3 To ensure necessary capacity building, promotion and technology transfer for the production and commercialization of biomass briquettes through the utilization of biomass energy from municipal and industrial wastes, and forest and agricultural residues	- Number of identified and trained individuals who can continue to operate on a self-sustaining basis after the end of the project - The level of follow- up activities of the trained individuals	- Project Reports - Training attendance sheets		
1.4 To encourage private sector for production and marketing for improved and modern biomass briquette technologies	- Number of private enterprises registered using biomass briquette technologies	- Registration records	- AEP C	
2.1 To reach the annual production of 20,000 metric tonnes of pellets and briquettes by 2030	- Amount of pellets and briquettes produced	- Production records	- BEA N	- Adequate demand for biomass briquettes can be created through the project - Adequate market volume to justify the certification system
2.2 To formulate and revise timely, as per need, quality standards of biomass energy technologies for their quality assurance	- Status of quality standards/ requirements and certification system	- Production Reports - Project Reports	- BEA N - AEP C	
3.1 To provide technical and financial assistance for research and study on modern efficient, and affordable biomass briquette technologies	- Number of research institutions involved in biomass briquetting R&D - Level of provision of funds for research	- MoU signed with research institutions - Project reports	- AEP C	- Institutions with research interest on biomass briquettes exist - Promotional activities will help increase uptake of biomass briquettes - Supply chain and distribution channel networking are strong
3.2 To carry out public awareness and promotional activities with the participation of local stakeholders for effective and	- Number of customers reached by promotional activities - Information dissemination materials (pamphlets, brochures, etc.)	- Participants list/ Market surveys	- AEP C	

efficient use of biomass briquettes				- Women and marginalized members are interested to engage in bio briquette manufacturing
3.3 To develop appropriate system and market for commercialization of biomass briquettes and to ensure the sales and distribution of sales of briquettes and hence the benefits	- Market growth of briquettes - Level of customer satisfaction	- Project evaluation report	- Third party	
3.4 To ensure the participation of women, indigenous and marginalized people in production, collection and commercialization of biomass briquettes, as well as ensure their access to the benefits of the same	- Number of Women's groups and marginalized people employed	- Project reports - GESI Reports	- AEP C	
INPUTS **1. Human Resources: Trainers, Researchers, CFUG members, business operators, manpower** **2. Technology: Briquetting plant, raw materials** **3. Financing: Loans, Investments**				

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<u>ANNEX 3</u>

ANNEX – 3(a)

Policy Framework on "Promotion of Sustainable Use of Biomass Briquettes in Nepal"

Submitted to:

Centre for Technology for Climate Network (CTCN)

Submitted by:

Energy Program

Department of Energy Environment and Climate Change

Asian Institute of Technology, Thailand

September 2018

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1. Background

Nepal is heavily reliant on biomass energy for domestic fuel use. Traditional biomass comprised about 80% of total primary energy consumption in Nepal during 2013- 2014.Urban and peri- urban households in Nepal depend on imported LPG (provided at a subsidized rate) for cooking purposes, which is unsustainable in the long- term. Nepal must pursue other avenues of efficient, affordable and renewable energy sources that can meet the increasing energy demands in a sustainable manner, given the high costs of grid connection, the low consumption rate, and the scattered population, especially in remote areas. . Renewable energy technologies that can be used in Nepal include (i) micro-hydro (up to 100 kW); (ii) biomass and biogas (coal briquettes, gasifiers, improved cooking stoves); (iii) solar PV (solar home systems, solar water pumps, solar battery chargers); and (iv) solar thermal energy (solar water heaters, solar dryers, solar cookers) (ADB, 2017).

Many solar energy and micro/ pico- hydropower projects are already running successfully in several communities across Nepal. However, biomass energy is not yet being optimally tapped into, as the use of biomass energy is largely limited to traditional use (for household cooking). Biomass densification can not only result in increased energy efficiency, but also provide a means for livelihood generation and reduce the dependence on unsustainable fossil fuels. As an agriculture based economy, Nepal has an abundance of raw materials for briquette production. This raw material base combined with forest residues provide a strong opportunity for bio briquette production. As a renewable fuel, biomass briquettes and pellets are suitable for household, commercial (army and police canteens, hospitals, schools and colleges, restaurants and hotels) as well as small to medium scale industries such as paper making industries, food processing, textile and clay products.

2. Policy Framework

The regulatory environment can play a key role in both the deployment of and adoption of bio briquettes in Nepal. Many of the business models that are based on new and innovative revenue models or financing schemes are actually driven by incentive schemes initiated and financed by government. Therefore, a favorable policy framework is central to the promotion of sustainable use of bio briquettes in Nepal.

Biomass Energy Strategy (BEST, 2017) was formulated to address the need of an appropriate strategy for supporting the environment conservation through the sustainable production of biomass energy for proper and efficient utilization of available biomass resources. This policy framework is prepared in alignment with BEST, with the same vision, mission and long-term goal.

2.1 Vision To promote the biomass energy as reliable, affordable and sustainable energy resource to address the increasing energy demand of Nepal.

2.2 Mission To enhance the living standards of people by modernizing the use of biomass energy through research and studies on biomass energy; through creating public awareness; through market development, technology transfer and capacity development in biomass energy; as well as through efficient use of biomass energy.

2.3 Goal To increase the access to biomass energy and hence contributing to the environment conservation by transforming traditional biomass energy use into modern, sustainable and clean energy.

This policy framework is guided by the target to reach the annual production of 20,000 metric tonnes of pellets, briquettes by enhancing the production capacity by 2030.

3. Past Efforts

Several policies and acts are already in place that support BEST directly or indirectly.

I. Industrial Enterprises Act, 2017

Permission shall be granted for a reduction of up to 50% from the taxable income for the investment of an industry on process or equipment, which has the objective of controlling pollution or which may have minimum effect on the environment. Such remission may be deducted on a lumpsum or on an installment basis within a period of three years.

II. Financial Act, 2016

According to this act:

- Briquette, Pellets or other related objects under the same category are considered as objects of basic necessity and **VAT will not be applied to these**.
- Mills, Machinery and their components, and chemicals imported to generate bio energy will receive **Customs Exemption**.
- Cooperatives that generate bio energy from forest produce will receive **Income Tax Exemption**.

III. National Agricultural Policy, 2006

It supports development of agro-forestry as well as conservation, **promotion and proper use of natural resources**, environment and biodiversity to control deforestation. This prohibits the forest destruction, promotes forest protection and appropriate use of natural resources, environment and bio-diversity by developing agriculture forest system.

IV. Rural Energy Policy, 2006

It targets poverty reduction and environment conservation in rural areas by incorporating the diverse sources of energy used in the rural household, socio economic purposes into rural energy sources and enhancing access to **clean, appropriate, sustainable and reliable energy**. The policy has proposed for the preparation of separate **action plans for the promotion and use of** biogas, firewood, **briquette**, biofuel, biomass gasification and improved cooking stoves. Various action plans have been prepared and implemented as envisaged by the policy. This policy also has strategies for a broad stakeholder involvement to ensure the whole process of technology development to project identification, design and implementation, as well as an effective cross-sectoral and donor coordination of rural energy programs.

V. Industrial Policy, 2011

The Industrial Policy of Nepal includes the following:

a) To increase contribution of industrial sector in the balanced regional development by mobilizing **local resources, raw materials, skills and means**.
b) **Special emphasis** shall be given to promote the industries that use **local resources, raw materials, skills, labor and technology**.

c) The industrial base shall be made strong and sustainable having identified and utilized the areas of **competitive benefits and comparative advantage**.
d) For the **protection of national industries**, provision of encouragement shall be made for purchase by governmental and Government-owned agencies of the industrial products that involve at least 30 percent value addition in Nepal.
e) To establish **industrial entrepreneurship as a sustainable and reliable sector** by utilizing latest technology and environment friendly production process.
f) **Technical and financial assistance** shall be made available to the industries that use environment-friendly and energy saving technology on their own costs
g) Special measures shall be taken to **promote green industries** and to make the established industries pollution free and zero to carbon emission

VI. Forest Policy, 2015

It includes different activities like afforestation in public and private land; private forest for the private sector; **provision of necessary technology and different financial instruments like subsidy, credit and insurance facilities for promoting forest enterprises and commercial nurseries; financial and technical support to the users of alternative energy**, biogas, **bio-briquettes**, improved cooking stoves, biofuel etc.

VII. Renewable Energy Subsidy Policy, 2016

This policy has provisions of **subsidies for the promotion of biomass energy technologies** such as biogas, improved cook stoves, gasifiers, etc. **Subsidy provision** for biogas has been made for domestic biogas and **energy from wastes** (energy from commercial, institutional, community and municipal wastes).

VIII. Fourteenth 3rd Year Plan, 2017

The fourteenth plan incorporates biomass briquettes as a renewable energy source. The strategies in the plan includes promotion and development of briquette technologies to reduce dependence on fuelwood, as well as creation of enabling environment for banks and financial institutions to invest in renewable energy.

Apart from these, AEPC has been devising mechanisms to promote biomass briquette use in the country, including:

- Recommendation for 1% custom duty charge on import of biofuel producing machinery and parts
- Provide training on production of briquettes at community level, as well as demonstration workshops on use and handling of briquettes
- Inventory of Biomass Briquetting in Nepal
- Support for biomass testing laboratory at RETS/NAST for testing biomass stoves as well as biomass fuels
- Promotion of non-carbonized Pellets in MSME Sector Via technical and market assessment in Nepal.
- Collaboration with relevant partners on dissemination

4. Best Practices from other countries

Countries throughout the world have adopted several policies and measures for promoting biomass energy in an attempt to increase their share as renewable energy. Some of the best practices from other countries across the region are:

i) China (Zhang et al., 2010)

- Low-interest loan: China has provision for low interest loan for renewable energy projects. The projects listed in the national renewable energy industry development guidance catalogue and which meets the credit conditions are eligible for discount interest funds. This is determined according to the actual bank loans in place, contract rate of interest and the actual amount rate of interest paid; the discount period is 1-3 years and the maximum annual discount rate does not exceed 3%.
- Tax relief: The government of China has provisions for tax relief on VAT for products manufactured from agricultural and forestry residues. The specific proportion of tax rebates are respectively 100% in 2009 and 80% in 2010. There is also provision for a 90% income tax relief for industries whose main raw materials are resources specified in Catalogue of Resources for Comprehensive Utilization Entitling Enterprises to Income Tax Preferences.
- Quota system: Under the Renewable energy law, quota system policy has been introduced in the fields of biomass power generation, thus turning the policies completely rely on government financial support in the past to the market mechanism under the control of the government to create conditions for the large-scale development of biomass energy.
- Environmental protection measures: the government of China has issued instructions for the ban on burning coal, restrictions on automobile exhaust and air pollutants emissions promote the development of biomass briquette fuel. Also, environmental protection indexes for the ban on burning straw guarantee the adequate supply of biomass.

ii) India

The Indian policy on biomass energy is characterized by: i) higher emphasis on market instruments compared to regulatory controls, ii) reorientation from technology push to market pull, and iii) enhanced role of private sector. The policy incentives are:

- Accelerated depreciation: The Indian policy has provision for 100 per cent depreciation in the first year of the installation of the project
- Exemption/reduction in excise duty: Provision for exemption from Central Sales Tax, and customs duty concessions on the import of material, components and equipment used in RE projects is available.
- Subsidies: The State of Maharashtra provides 20% subsidy on cost of machinery or INR 4 lakh (whichever is minimum) as a promotional policy in favor of biomass energy.

iii) Bangladesh

Bangladesh's policies on renewable energy includes:

- Renewable Energy Policy (2008): 15% VAT exemption for renewable energy equipment and a 5 year exemption from corporate income tax for renewable energy projects
- Climate Change Strategy and Action Plan (2009): Establishment of the Climate Change Trust Fund, USD 100 million from national and international sources each year for three years (2009-2012), totaling up to USD 300 million which is used to finance public and private sector projects

iv) Japan

Japan's biomass energy policies include:

- Construction of the efficient collection and transportation system for unused thinning material as well as promotion of the integrated-intensive energy use from wood-based power plants
- Promotion of commercialization through the creation of high value-added products

v) Thailand

The Department of Alternative Energy Development and Efficiency (DEDE) in Thailand has recognized the need to study the potential of biomass database development in order to determine the amount of biomass available in different areas as well as to see the use of biomass for energy production. Apart from this, following provisions have been made:

- Defined areas (Zoning) to promote the use of crops for renewable raw materials.
- Develop and promote the use of other materials as fuel sources, such as agricultural residues, waste from the manufacturing process in the industry by integrating with various agencies
- Standards for material, equipment, installation and system performance testing of technologies
- Encourage the systematic management of raw materials such as transportation systems and contract farming.
- Promotion the production of renewable energy products for use as fuel or co-use with another fuel such as biomass pellets

vi) South Korea (IEA, 2012)

The South Korean government provides financial support for wood pellet manufacturing facilities. As of 2010, 13 facilities have been supported by the government and five other facilities have been supported by private-sector investments. To increase demand for wood pellets, therefore, small wood pellet boilers have been distributed to agricultural and mountainous villages since 2009 and horticultural greenhouse heaters have also been deployed since 2010.

vii) Indonesia

Indonesian government has been responsible for creating a domestic market for biomass energy. Under the Ministry of Energy And Mineral Resources Regulation (2013), biofuel usage is mandatory for fossil fuel substitutions on transportation, industry, and electricity generation as a percentage to fossil fuel consumption.

viii) Vietnam (GIZ, 2013)

Vietnam has several policy incentives for biomass energy promotion:

- A corporate income tax incentive rate of 10% for a period of 15 years to newly-established enterprises investing in power plant projects is available. This has a possibility of being extended up to 30 years if the projects are classified as large scale projects, using high or new technology and in special need of investment. A tax exemption for the first 4 years followed by a 50% tax reduction for the next 9 years is also available.
- Exemption of import duties for equipment and machinery imported to create fixed assets of the RE projects.

- Special encouraged projects have exemption/reduction of land use fee/rental fees. However, this can depend on the location of the projects.
- Projects can access low-interest loan from Vietnam Development Bank. They can obtain loans of up to 70% of the investment cost, with the maximum term of 12 years at an interest rate equivalent to government bond interest rates with a term of 5 years plus 1%.

ix) Philippines

Plan Renewable Energy Act (2008) of Philippines has provisions for:

- duty-free importation of RE machinery, equipment and materials including control and communication equipment,
- 0% VAT rate on the sale of fuel or power generation
- 0% VAT rate on purchases of local supply of goods, properties and services needed by RE developers
- tax rebate on all or part of the tax paid for the purchase of RE equipment for residential, industrial, or community use
- Special realty tax rates on equipment and machinery not exceeding 1.5% of their original cost
- Corporate tax rate of 10% on net taxable income after 7 years of income tax holiday

A study by IRENA on renewable energy policies in South East Asia identified a number of barriers for renewable energy:

- weak/ slow implementation of enabling policies;
- non-existent enabling policies in some countries;
- long and complicated permitting process;
- perverse fossil fuel subsidies

Developing a policy framework needs to incorporate lessons learnt from other countries and should identify strategies to overcome the key barriers identified. Efforts for RET promotion as of now are mostly focused in supply side, and very limited efforts exist in demand side. A way forward has been proposed for Nepal in section 1.5.

5. Way Forward

A conducive regulatory framework for promoting sustainable use of biomass briquettes requires further policy support. Government's role in developing an enabling policy environment that promotes the use and fosters market growth of biomass briquette is crucial. The following are the recommendations for policy framework based on the stakeholder consultation workshop:

i. **Ambitious Target:** A target of annual production of 20,000 metric tonnes by 2030 has been set by the Biomass Energy Strategies. However, this target is based only from clean cooking perspectives in households. The realistic target that encompasses use of bio-briquettes in commercial and industrial use is yet to be determined.
ii. **Special Protection for Bio-briquette Industry:** There exists provision to include bio-briquette industry under 'national priority industries' category according to the Industrial Enterprise Act 2017. This provision should be made explicit and the industry needs to be given all privileges accordingly, including priority sector loan. In addition to this, public procurement and institutional use of briquette in government offices and others can also be encouraged by launching special

programs in governmental organizations such as army, police, hospitals, prisons, orphanages and old age homes.

iii. **Renewable Portfolio Standards for Selected Industries:** A mandatory renewable energy portfolio for selected types of industries (such as brick, dye, boiler-based industries) that currently use fossil fuel can be made, such that these industries progressively have 5% (?) of input energy mix to be biomass-based by 2025.

iv. **Technology Support:** Support for technology information, problems and assessments for:
   a. production of different types of bio-briquettes/pellets using different raw material
   b. Stove/burners for different types of bio-briquette/pallets
   c. quality assurance and standardization
   d. public-private R&D support, testing and sharing (equipment, raw materials), information sharing
   e. training for operators of technologies on ground (industry and commercial facilities)
   f. technology demonstration and exhibition
   g. enhance links between technical-experts and industry's real-life problems
   h. regular newsletter/info provision

   Creation of bio-briquette Technology Support Facility (BBTSF) under MoEWRI/AEPC with participation of stakeholders could also be done. This facility would then act as the chief technology support and dissemination centre.

v. **Industry Information and Education Campaigns:** Information gaps are still pertinent in the bio-briquette sector, where producers as well as consumers do not have full information about the sector. Therefore, industry information and education campaigns are required to:
   a. acquaint the public with the importance of bio-briquettes as well as, to incentivize industry and to keep industry informed of successful projects and emerging opportunities
   b. maintain a regular and frequent supply of information to ensure that the program has a high profile and to counteract any adverse publicity

   This can be accompanied by demonstration programs that focus on the use, handling and storage of briquettes as well as stoves.

vi. **Tax Reduction and Exemption:** Hydro, solar and bioenergy operators that start generating by mid-April 2024 receive 100% corporate tax exemption for the first 10 years and 50% for five years after that. This reduction has not been extended in bio briquette sector. Although biomass briquettes are clean and renewable energy sources, carbonized briquettes are charged the same excise duty as charcoal, which is a non- renewable source of energy. The Financial Act of 2016 mentions excise exemption for VAT & Custom Duty in RE equipment as well as materials. These include only 1% customs duty for a range of solar, biogas and wind energy equipment. This should be made more stringent and carbonized briquettes should be exempted from excise duty. Likewise, exemption should also be made for the case of plant and machinery.

vii. **Electricity tariff support:** Agriculture sector is receiving lower tariffs (as low as Rs 5/unit). Bio-briquette sector can be provided similar tariff. Alternatively, capacity cost part of electricity tariff relief could be provided.

viii. **Investment Subsidy:** The Renewable Energy Subsidy Policy 2016 has provision for a maximum subsidy amount of up to 40% of the total investment cost for energy conversion and processing equipment, hardware part of the enterprise and basic infrastructure required for the enterprise but not exceeding Rs. 100,000 for micro enterprises based on renewable energy. Likewise, maximum subsidy amount of up to 30% of the total investment cost for energy conversion and processing equipment, hardware part of the enterprise and basic infrastructure required for the enterprise but not exceeding Rs. 200,000 will be provided for small and medium enterprises based on renewable energy. Smoother co-ordination mechanisms between the respective institutions to make delivery smoother and bio-briquette more exclusive in these provisions should be done.

ix. **Accelerated depreciation:** Provision for accelerated depreciation on the total value of briquetting plant and machine for the first few years should be made. According to the Income Tax Act, accelerated depreciation of 1/3 of the value of the fixed assets investment is present for special industries and co- operatives registered under Co-operative Act 2048. Bio-briquette sector should be recognized as eligible for this accelerated depreciation.

x. **Concession loans:** The Renewable Energy Subsidy policy 2016 has provisions for soft loans and Interest subsidy for renewable energy. For Solar systems, the interest rate on credit will be maximum 5% if Government of Nepal (GoN) provides the fund for the loan and the interest rate on credit will be maximum 9% if banks use their own fund for loan. A 50% subsidy is also provided on bank interest for commercial solar installations. These concessions schemes should be expanded to encompass bio briquette sector as well.

xi. **Financing:** Bio briquetting sector has a high upfront financial investment cost. Financing mechanisms to help investors need to be explored. Easy financing via Central Renewable Energy Fund (CREF) can be an option. The immediate objective of the Central Renewable Energy Fund (CREF) Component is to institute the CREF as the core financial institution responsible for the effective delivery of subsidies and credit support to the renewable energy sector. This could also include seed funding for revolving investment funds, special credit facilities, and supporting lending institutions through both capacity building and underwriting. Apart from this, climate finance mechanisms such as Green Climate Fund (GCF) can also be mobilized. Bio-briquette sector can also be supported a Carbon-offset Project using carbon markets.

xii. **Certification and Standardization:** Industry standards, codes of practice and regulations are required for successful implementation. For this purpose representative groups from industry and both central and local government agencies should be charged with the task of developing standards and regulations compatible with good international and local practice. The Renewable Energy Testing Station (RETS) is well equipped to carry out testing of both the fuels as well as the stoves. Benchmarks are already available for improved cookstoves. Similar benchmarks can be developed for biomass briquettes. Likewise, a certification system can also be developed to certify those enterprises that meet with the quality standards. A technical committee can be constituted to propose standards and certification system to be developed together with AEPC, RETS and Nepalese Bureau of Standards and Metrology (NBSM).

xiii. **Capacity building:** The Energy Sector Plan (1999) has provision for technical Support for biomass energy, solar energy and mini-grid electrification to provide technical support for the development and implementation of renewable energy solutions. Policies for capacity building and community mobilization could help in sustainability of bio briquettes.

xiv. **Program Management and Monitoring:** There is a need to track the progress of the implementation of the renewable energy and energy efficiency program because, as experience builds in the early stages of implementation, it may be necessary to make modifications both at macro and micro levels. There should be provision for continuous monitoring and evaluation of the program to assess whether or not targets are met, and if any changes are required. A strong co-ordination mechanism for strategic and operational support is required.

xv. **Research and Development:** R&D needs to be undertaken in the field of boilers and cookstoves to make them more suitable for the use of briquettes. It has been found that some conventional systems do not work efficiently when using briquettes. Moreover, R&D dedicated towards dryer technology (used in removing moisture from raw materials) is required to improve efficiency and reduce costs. Research also should extend to assessment of quantification of potential raw materials and their quality assessment for briquetting. An information clearing house, such as Bio-Briquette Technology Support Facility as a Special Cell in AEPC, in cooperation with private sector for the entire biomass sector could be formed that identifies the technology needs for the entire sector. Likewise, Masters and PhD projects can also be undertaken with collaborative efforts of government, private sector and educational/ research institutions.

It is important that the government decreases incentives for specific technologies over time, in order to move them towards market competitiveness. On the other hand, it is also very important to provide a stable, predictable and transparent regulatory framework with a clear timeframe for the reduction and phase-out of support schemes so as to continue to attract investments in producing new technologies.

6. Implementation/institutional strategy

The institutional strategy must include working in close collaboration with all the relevant stakeholders. The role of AEPC as a facilitator is crucial to the success of implementing this policy framework. The key partners involved are:

1. **Briquette consumers:** These include the end users of bio- briquettes: industries, institutions and households that use bio briquettes. Their feedback provides valuable insight on demand- side needs and provides a platform for enterprises to work towards fulfilling consumer needs and expectations.
2. **Bioenergy Entrepreneurs Association of Nepal (BEAN):** This is an association of private enterprises that produce carbonized briquettes. The main goal of the association is to create enabling environment for charcoal enterprises.
3. **Private Enterprises:** Although BEAN exists as an association of bioenergy entrepreneurs, it does not give the full representation of all the enterprises that are involved in briquette manufacturing. Therefore, representation of the latter is also important to develop an effective and all- encompassing strategy.
4. **Research Institutions:** Research and Development is essential to progressively evolve the bio-briquette industry, especially in terms of locally adapting available technologies as well as fabricating them. The roles of National Academy of Science and Technology (NAST), Centre for Energy and Environment- Nepal (CEEN), RECAST (Research Centre for Applied Science and Technology) are crucial in advancing further research in this area.

6.1 Central Coordination Committee

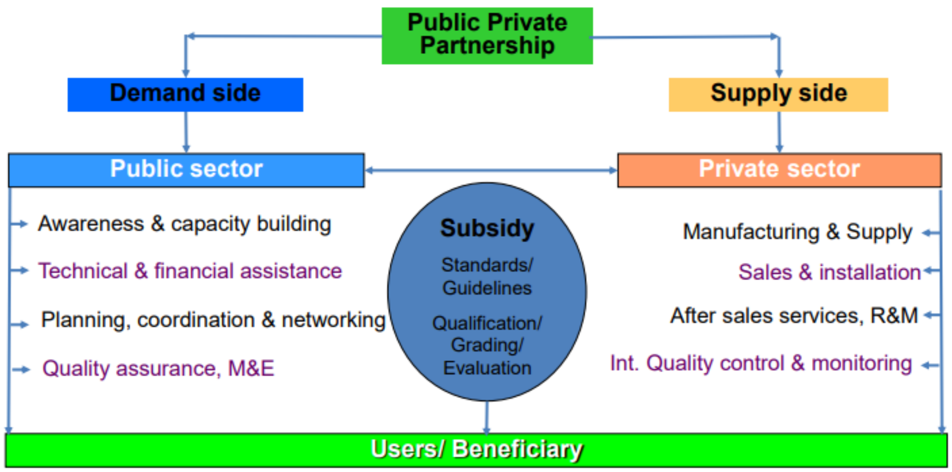
A Central Coordination Committee was formed for the implementation of the Biomass Energy Strategy. In order to coordinate among the relevant agencies associated with the promotion and development of biomass energy, the following Central Coordination Committee has been formed:

a) Secretary, Ministry of Population and Environment	Coordinator
b) Joint Secretary, Ministry of Agriculture Development	Member
c) Joint Secretary, Ministry of Federal Affairs and Local Development	Member
d) Joint Secretary, Ministry of Forest and Soil Conservation	Member
e) Joint Secretary, Ministry of Energy	Member
f) Joint Secretary, Water and Energy Commission Secretariat	Member
g) Joint Secretary, Ministry of Agriculture Development	Member
h) Executive Director, Alternative Energy Promotion Centre	Member
i) Executive Director, Solid Waste Management and Technical Support Centre	Member
j) Joint Secretary, Ministry of Population and Environment Member	Secretary

6.2 Proposed Approach

The proposed approach for implementation modality is based on Public- Private Partnership (PPP). PPP refers to the relationships between the private sector and public bodies often with the aim of introducing private sector expertise and/ or resources in order to help provide and deliver public sector assets and services. Common themes of PPPs are the sharing of risk and the development of innovative, long-term relationships between the public and private sectors.

AEPC's previous work has also been based on this modality:



In this model, the private sector builds, operates and owns the enterprise with the technical and financial support from government. The role of the government is further extended to creating a market stimulus as well as in managing risks via appropriate measures.

6.3 Operationalization of Way Forward

The following potential window has been identified for operationalizing the way forward described in 5.

S.N.	Action	Potential Window
1.	Special Protection for industry	Include bio- briquette industries in special industry category and the incentives of it, including priority loans.
2.	Certification and Standardization	AEPC could take the lead in convening the expert group to formulate standardization which could be enforced by the Nepal Bureau of Standards and Metrology. Awareness among users needs to be generated for purchasing certified briquettes and pellets.
3.	Concession Loans	Renewable Energy subsidy policy to be revised to specify concession loans for the bio- briquette industry.
4.	Accelerated Depreciation	VAT, Income tax/ corporate tax, excise duty tax and customs tax exemptions, direct capital subsidies and accelerated depreciation for existing as well as new bio briquette industries that manufacture energy efficient briquettes to be included in the Finance Act revision/ budget for 2019- 2020.
5.	Tax Reductions and Exemptions	
6.	Subsidies	
7	Financing	Determine the number of biomass briquette projects that could be eligible for funding via CREF.

8.	GESI	Identify measures to incorporate gender equality and social inclusion into briquette industries, and prioritize women led enterprises.
8.	Technical Support	An information clearing house in cooperation with private sector for the entire biomass sector could be formed that identifies the technology needs for the entire sector.
9.	Capacity Building	
10.	Industry Information and Education Campaigns	Prepare budgets for Pamphlets, brochures, TV advertisements and other information dissemination materials
11.	Program Management and Monitoring	AEPC to conduct monitoring every trimester and independent third party evaluation every year or in two years.
12.	Research and Development	Seed funding by the government for joint partnership between educational institution and private sector.

ANNEX 3(b) – A draft bio-briquette policy-prepared and submitted to the government of Nepal (an output of the project)

Bio-briquette Policy Draft

2018

Government of Nepal

Ministry of Energy, Water Resources and Irrigation

Singhadurbar, Kathmadnu

2018

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Bio-briquette Policy Draft, 2018

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Biomass energy is not yet being optimally tapped into, as the use of biomass energy is largely limited to traditional use (for household cooking). Biomass energy in Nepal has been considered as one of the important resources. However, its utilization and management had not been done in a proper and sustainable manner. Biomass densification can result in increased energy efficiency. At the same time, it can also provide a means for livelihood generation and reduce the dependence on unsustainable fossil fuels. As an agriculture based economy, Nepal has an abundance of raw materials for briquette production. This raw material base combined with forest residues provide a strong opportunity for bio briquette production. As a renewable fuel, biomass briquettes and pellets are suitable for household, commercial (army and police canteens, hospitals, schools and colleges, restaurants and hotels) as well as small to medium scale industries such as paper making industries, food processing, textile and clay products.

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- Collaboration with relevant partners on dissemination

3. Present Situation

About 74% of energy consumption of Nepal is supplied by traditional biomass energy, which includes firewood, cattle dung and agricultural residues. As per National Census 2011, nearly 4 million out of 5.4 million households in Nepal are still using traditional biomass energy including firewood for cooking. Reduction in the use of biomass energy has been a concern of all, as it results in the adverse effect on the human health and environment. According to the report published by World Health Organization (WHO) in 2012, indoor air pollution is the fourth major cause of the deaths amongst the poor and least developed countries. According to a study, about 7,500 people die in Nepal annually due to different diseases caused by the indoor air pollution. Studies have shown that women and children who spend their time in kitchen for long hours are most affected by this. On one hand, excessive consumption of timber results in depletion of forest resources whereas on the other hand, increased work load of woman for the collection of firewood. Moreover, use of traditional cook stoves consumes excessive firewood, emits excessive smoke and slow cooking has made women always busy. In order to get rid of such situation, the Government of Nepal through AEPC has been focusing on the promotion and expansion of use of clean energy technologies like improved cooking stoves (ICS), biogas, and solar-cooker/dryer.

According to the recent report of 'National Living Standards Survey', about 3 million households in Nepal have only access to ICS. Studies carried out by AEPC in 2009 and 2010 have revealed that the use of ICS resulted in the reduction of indoor air pollution by 62 %. Similarly, the consumption of firewood was reduced by 43% on an average together with the significant reduction in the time spent by the women in the kitchen by the use of ICS in rural area. So far, ICS have been installed in about 1.3 million households and biogas in about 365,000 households and solar cooker in about 600 households in Nepal and have been using renewable energy for cooking. The Government of Nepal with support from the development partners has been implementing the National Rural and Renewable Energy Programme as an integrated programme in renewable energy sector. For development and promotion of renewable energy, a subsidy has been provisioned through the mobilization of internal and external resource including carbon trade. For additional expansion of renewable energy technology, fulfilment of the United Nation's "Sustainable Energy for All" and "Sustainable Development Goals", a campaign called "clean cooking solutions for all" has been initiated to make all the households indoor air pollution free by providing clean cooking technologies. National action plan and investment prospectus are being formulated for enhancing access to clean and sustainable energy for all. Apart from this, a separate agroforestry policy is being formulated incorporating various aspects of agroforestry.

4. Major Problems and Challenges

Although Nepal is abundant in terms of biomass resources, their distribution across geographical regions vary. Forest degradation in areas where demand for forest based resources exceeds the supply, and inadequate proper utilization of biomass in areas where forest resources are surplus is challenge that needs to be addressed. This inability coupled with lack of coordination, integrated viewpoint and action plan among stakeholders of biomass energy sector further exacerbates the issue. There is a need of proper management of biomass energy resources due to its regional imbalance in availability while simultaneously addressing siloed approaches of agencies working on forestry, energy and agricultural sectors. Likewise, allocation of financial resources for biomass energy which contributes more than two thirds of the country's total energy demand is not proportional. Due to the social psychology towards the differences in types of energy used by the poor and rich class, the focus of the poorer communities has been concentrated into getting LPG connection rather than using the locally available biomass energy efficiently. This has majorly hindered the uptake of biomass briquettes in household level. It has been a challenge to increase awareness on effective use of biomass energy with utilization of appropriate modern technologies

5. Need for Policy

Biomass energy sector is still evolving in terms of appropriate policies. In order to sustainably develop bio-briquette sector, encourage households, industries and institutions to shift from traditional sources of energy to bio-briquettes, and to encourage private sector and financial institutions to invest in the sector, the need for a policy framework that solely addresses the issues in bio-briquette sector has been realized. This new policy focuses on creating enabling conditions to gradually increase the annual production as well as use of bio-briquettes in the country. It focuses on making bio-briquettes sustainable and easily accessible energy source that can contribute to energy efficiency and energy security.

6. Long term goal

To increase the access to affordable biomass briquettes and hence contributing to the environment conservation by replacing a portion of fossil- fuels and transforming traditional biomass energy use into modern, sustainable and clean energy.

7. Objectives

The objectives of strategy are mentioned as follows:

7.1. To contribute to energy supply and energy security by generating energy through management of agriculture forest residues and organic wastes from municipal urban and industrial areas.

7.2. To support employment and income generation through entrepreneurship development in bio-briquette sector.

8. Strategies

To achieve above mentioned objectives, the following strategic measures will be adopted:
8.1 To increase production of sustainable biomass briquettes by utilizing agricultural and forest residues and organic wastes.

8.2. To contribute to increased access to clean cooking technologies to all Nepalese households through the means of modern biomass briquettes.

8.3. To increase effectiveness and efficiency in the utilization and production of biomass briquettes.

9. Working Policies

For the implementation of aforementioned strategic measures, following working policies will be adopted:

9.1 Strategic Policies

9.1.1 An ambitious target of annual production of 20000 metric tonnes bio briquettes by 2030 is set by the Biomass Energy Strategies 2017. This target will be revised based on the results of monitoring and evaluation.

9.1.2 Bio-briquette industry to be included explicitly under 'national priority industries' category and be given all privileges accordingly, including priority sector loan (Industrial Enterprises Act 1992)

9.1.3 Public procurement and institutional use of briquette in government offices and other institutions through special programs in governmental organizations such as army, police, hospitals, prisons, orphanages and old age homes, etc.

9.1.4 Renewable Energy Portfolio for Selected type of industries (such as brick, dye, boiler-based industries) using fossil fuel to be made mandatory progressively to have 5% of input energy mix to be biomass-based by 2025.

9.1.5 Support for technology information, problems and assessments for (a) production of different types of bio-briquettes/pellets using different raw material (b) Stove/burners for different types of bio-briquette/pallets (c) quality assurance and standardization (d) public-private R&D support, testing and sharing (equipment, raw materials), information sharing (e) training for operators of technologies on ground (industry and commercial facilities) (f) technology demonstration and exhibition (g) enhance links between technical-experts and industry's real-life problems (h) regular newsletter/info provision

9.1.6 Creation of bio-briquette Technology Support Facility (BBTSF) under MoEWRI/AEPC with participation of stakeholders that is responsible for technology transfer, localizing technologies and training and capacity building of human resources.

9.1.7 To conduct industry and education campaigns to acquaint the public with the importance of bio-briquettes as well as, to incentivize industry and to keep industry informed of successful projects and emerging opportunities. This will be done through awareness programs and demonstration programs that focus on the use, handling and storage of briquettes as well as stoves.

9.2 Fiscal Policy

9.2.1 Tax Reduction and Exemption:

- Existing and new bio briquettes sector to be made explicitly eligible in the 'Hydro, solar and bioenergy operators that start generating by mid-April 2024 receive 100% corporate tax exemption for the first 10 years and 50% for five years after that' category.
- 1 % Custom Duty in briquetting equipment, machinery as well as raw materials
- To make bio briquette industries eligible to get 50% discount on land registration fees
- Include bio- briquettes industries under special industries and grant them 15% concession on applicable tax rate for Special Industries

- Extend electricity tariff support to bio- briquette industry through relief on capacity cost of electricity

9.2.2 Incentives for Productive End users:

- Provision for a maximum subsidy amount of up to 40% of the total investment cost for energy conversion and processing equipment, hardware part of the enterprise and basic infrastructure required for the enterprise but not exceeding Rs. 100,000 for micro enterprises based on biomass energy
- Maximum subsidy amount of up to 30% of the total investment cost for energy conversion and processing equipment, hardware part of the enterprise and basic infrastructure required for the enterprise but not exceeding Rs. 200,000 will be provided for small and medium enterprises based on biomass energy

9.2.3 Accelerated depreciation:

- Make bio briquetting sector eligible for an accelerated depreciation of 1/3 of the value of the fixed assets investment present for 'special industries' and co- operatives registered under Co-operative Act 2048.

9.2.4 Concession loans:

- Low interest rates on credits to be provided for bio-briquette industries at maximum 5% if Government of Nepal (GoN) provides the fund for the loan and maximum 9% if banks use their own fund for loan. 50% subsidy is also provided on bank interest

9.2.5 Financing:

- To explore financing mechanisms including easy financing via Central Renewable Energy Fund (CREF), Result Based Financing (RBF), seed funding for revolving investment funds, special credit facilities, and supporting lending institutions through both capacity building and underwriting
- To mobilize climate finance mechanisms such as Green Climate Fund (GCF) as well as support developing projects as carbon- offsetting projects using carbon market.

9.2.6 Standardization and Certification of bio-briquettes and devices

- Benchmarks and standards will be developed for biomass briquettes as well as, potentially the end-use devices in co- ordination with Nepalese Bureau of Standards and Metrology (NBSM), Renewable Energy Testing Station (RETS) and Alternative Energy Promotion Center (AEPC).
- Certification system to be developed to certify those enterprises/products that meet with the quality standards.
- Awareness generation of certified products to be carried out by Bio-briquette Technology Support Facility /Bio-Briquette Cell in MoEWRI/AEPC.

9.2.7 Capacity building:

- Provision for capacity building for development, facilitation and implementation of solutions for bio-briquettes and work on developing specific mechanisms will be carried out.

9.2.8 Research and Development (R&D):

- R&D will be carried out on briquetting machines, raw materials, end use devices, and assessment of quantification of potential raw materials and their quality assessment for briquetting will be carried out.
- Funding provisions for R&D in bio-briquetting sector to be made available in Financial Bill and revisions to be made as per M&E results.
- Provision of seed funding by the government for joint R&D partnership between educational institution and private sector.
- Provision of MoUs with educational institutions for supporting masters and PhD students working on biomass briquetting.

10. Implementation/institutional strategy

For implementation of this policy, the following institutional arrangement will be made:

13.1. At the Centre, AEPC will be responsible as the Centre of Excellence for providing technical assistance, and facilitating financial assistance to bio-briquette enterprises. Bio-briquette Technology Support Facility will work in close collaboration with research institutions and Renewable Energy Testing Station for quality assurance and technology research.

13.2. At the Centre, Central Renewable Energy Fund (CREF) is established for mobilization of subsidy amount. CREF will be managed by an "A class" commercial bank selected by GoN through competitive basis.

13.3. At the local level, the local bodies will be responsible for the promotion, demand collection, on-site monitoring and disbursement of the financial assistance.

Central Coordination Committee

A Central Coordination Committee was formed for the implementation of the Biomass Energy Strategy. In order to coordinate among the relevant agencies associated with the promotion and development of biomass energy, the following Central Coordination Committee has been formed:

a) Secretary, Ministry of Population and Environment	Coordinator
b) Joint Secretary, Ministry of Agriculture Development	Member
c) Joint Secretary, Ministry of Federal Affairs and Local Development	Member
d) Joint Secretary, Ministry of Forest and Soil Conservation	Member
e) Joint Secretary, Ministry of Energy	Member
f) Joint Secretary, Water and Energy Commission Secretariat	Member
g) Executive Director, Alternative Energy Promotion Centre	Member
h) Executive Director, Solid Waste Management and Technical Support Centre	Member
i) Joint Secretary, Ministry of Population and Environment Member	Secretary

11. Monitoring and Evaluation

AEPC will be responsible to conduct on-site monitoring of renewable energy systems and projects every trimester and annually while there will be third party independent monitoring and evaluation on the impact of subsidy, field verifications of installed RE systems or projects every two years or whenever necessary. At the local level too, local bodies will conduct on-site monitoring.

12. Power to Remove Difficulties

If any difficulty arises in connection with the implementation of this Act, Government of Nepal may issue orders to remove such difficulty by notification published in the Nepal Gazette.

ANNEX 4

Gender Mainstreaming in Biomass- briquettes Policy in Nepal

Submitted to:

Centre for Technology for Climate Network (CTCN)

Submitted by:

Energy Program

Department of Energy Environment and Climate Change

Asian Institute of Technology (AIT)

September 2018

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1. Women and Energy

Women are the primary energy producers in rural households, spending a lot of time gathering locally sourced biomass to fulfill their daily energy needs. This results in severe opportunity costs that prevent rural women from participating in other tasks, such as education (Habtezion S., 2003). The patterns of energy generation, distribution and utilization in rural areas therefore directly affect women's income generating opportunities; the lack of access to improved cooking fuel is a burden for women (UNDP Nepal, 2007). Studies show that when women are overburdened with lack of access to energy, they have increased tendencies to keep their daughters at home to assist with household chores. This further limit opportunities for girls to move forward through education, and increases the likelihood that their families will remain in poverty. Rural households are thus stuck in a vicious cycle of lack of energy security and poverty (Malla Mabona, 2001). Moreover, the health impact of indoor air pollution is disproportionately borne by rural women. The fuel-related burdens experienced by women in developing countries hinder social and economic progress throughout the community and have long-lasting impacts when personal and social development opportunities are lost. Increasing women's access to modern and efficient energy services can have significant positive impacts on their health as well as time use (Ryan, S. E.). This reinforces the need of increasing women's access to efficient energy technologies.

Energy is not gender neutral. The type, quantity and price of energy available have different effects on men and on women because they do different things with it. Men and women have different levels of access to different fuels, and energy shortage affects women more severely than it does men, especially in the context of rural households. Women have a disproportionately higher share of household work requiring the use of energy (cooking meals, obtaining water, etc.). Although both men and women tend to share the work equally in activities outside the home (working in the fields, processing of crops, etc.), the recent increasing trend of men being away from home overburdens women to single-handedly take on the responsibility of meeting energy needs within as well as outside of their households (ADB, 2018). Projects and programs are now starting to include gender mainstreaming into rural energy projects.

Several gender issues in the energy sector have been identified in different countries, and the gender disparity in rural households is much larger than in urban households. Some of the major gender issues in rural energy are listed below:

- Rural women are not well informed about the social, financial and material impacts of the efficient use of energy resources.
- Women are subject to indoor air pollution caused by burning of biomass, crop residues, untreated coal and other fossil fuels used for cooking.
- Women's energy consumption behavior directly affects the health, education and upbringing of children.
- In comparison with boys, the dropout rates among girl children in villages are mainly due to their unaccounted labor in the subsistence economy, particularly energy-related work at home and outside.
- When leaving their homes to seek biomass and other conventional energy-producing materials, rural women are subject to harassment and other security threats.
- The productivity of a male worker is equally affected, if he allots extra time for the household energy arrangements.
- Community behaviors involving the use of clean, renewable technologies significantly affect the socio-economic position of women in rural areas.

2. Gender Mainstreaming in Renewable Energy

Gender mainstreaming is defined as "including gender as one of the basic underlying factors that is taken into account in planning processes, i.e. recognizing gender differences in energy needs, use and priorities; developing programs responding specially to these needs; and incorporating meaningful roles for women in planning and implementing programs". Enabling women's involvement in renewable energy sources and technologies can create new livelihood opportunities thereby aiding in poverty reduction and promoting women's economic empowerment (Habtezion, S., 2013). Previous studies reveal that women are interested in reductions of the time and effort required for gathering fuel and performing household tasks, improvements in lighting and indoor air quality, and enhanced income opportunities. Gender mainstreaming in renewable energy projects can create an enabling environment to achieve this. Ryan, S. E (2014) proposes the following ways of gender mainstreaming into modern energy service projects:

- a deliberate gender strategy in project planning, implementation and institutions;
- a supportive policy and/or institutional environment for women's needs;
- a community-based organization with women's effective participation;
- gender relations that value women's labor; and/or
- industry objectives that coincide with women's interests

Some projects ensure women participation in projects by doing positive discrimination in favor of women enabling them to take up management and decision- making positions. Energy related projects including improved cookstoves, solar cookers, solar housing systems as well as biogas are often considered to be positively biased towards women. Alternatively, encouraging women entrepreneurship in rural renewable energy is another means of gender mainstreaming in these projects. Women are ideal candidates to become renewable energy entrepreneurs for household and small-scale industries. As they are users of these devices, they can be more sensitive to customers' desires; they are known to be good entrepreneurs with a good credit record and can more effectively market to women, since access to female clients is not hindered by social constraints (Clancy, J. & Dutta, S., 2005). Therefore, addressing women's basic subsistence needs and releasing their time and labor through technological interventions is a necessary first step in addressing gender mainstreaming concerns. The role for energy services in this context then becomes one of reducing the burden of women's workload, enabling them to have more flexible working hours and to participate in productive activities.

3. Case studies of Gender Mainstreaming in RETs

There are several rural renewable projects around the world that have mainstreamed gender issues in them.

1. In Char Montaz island of Bangladesh, PSL (Prakaushali Sangsad Ltd.) initiated a project called 'Opportunity for women in renewable energy technology utilization in Bangladesh'. The project has successfully engaged 35 rural women in the operation of a micro-enterprise for construction and sale of DC lamps, which can be used in combination with batteries in Solar Home Systems (SHS). These women have been trained in lamp construction, along with quality control, business development and marketing. The second phase of this project includes credit mechanism which enables access to a wider market for the women (Khan, 2003).

2. The Ndirande Nkhuni Biomass Briquette Programme in Malawi was initiated to empower women of Ndirande by enabling them to produce, use and market biomass briquettes. This program was initiated by an NGO called Nkhomano Development Centre. The women targeted by the program benefits them

by providing them access to modern efficient energy, income generation opportunities as well as reduced time and distance travelled to search fuel (Mabona, M., 2001).

3. The 'Lighting a Billion Lives initiative' in India, which features solar micro grids, solar lanterns, solar home lighting systems, and cookstoves provides opportunities for women's employment in sales, rentals, and repairs of solar lanterns. Access to solar lanterns leads to income-generating opportunities for women in areas such as midwifery, childcare, tutoring, homebased piecework, and food preparation for catering. Other opportunities include food processing and marketing based on improved refrigeration, as well as other small enterprises such as livestock breeding, IT, and residential accommodation (Baruah, 2015).

4. The Lighting Ethiopia program is directed to improve people's access to clean, affordable, quality off-grid lighting and energy products while promoting gender-sensitivity to meet this objective. The program encourages women's participation in the sector, thereby increasing their access to energy to improve their livelihoods. It also works with women's groups to help them access financing for energy products (International Finance Corporation, 2014; Chen and Kuriakose, 2015).

5. In Nepal, micro hydro plants are powering grain mills and reducing women's workload considerably (Mahat, 2004; IAEA and World Bank, 2015). Mini-grids offer women the opportunity to strengthen livelihoods and incomes by developing and expanding enterprises, as well as by being actively involved in their marketing, installation, and maintenance, as well as exploitation for productive uses (ESMAP, 2013a; World Bank, 2016).

6. Zimbabwe's Rural Sustainable Energy Project (RuSED) uses solar water pumping, which have supplied women with water for their crops and reduced the time spent collecting water by as much as 6 hours.

7. Gender mainstreaming in the "Liquid Biofuel Project" in Pakistan was done by involving women in project activities, discussions and decision-making processes. This project integrated gender mainstreaming from project initiation and provided training to women on home gardening as well as financial support to prepare land for cultivation. The women also possessed the flexibility of making decisions regarding the type of plants to grow, whether to have a mixed plantation, etc. As a result of the project, 56 women increased their monthly income by Rs. 2,500/= from home gardening.

8. Micro and pico hydro power plants in Nepal and Pakistan respectively are known to have been instrumental in bringing down women's workload considerably. In Nepal, prior to the hydropower plant, women used to spend at least two hours of manual labor for grain processing, which has now been reduced to approximately half an hour by using water mills for grain processing (Mahat, 2004). Similar benefits to women have also been observed in Pakistan from pico- hydro power projects, including monthly savings on kerosene usage.

9. Pakistan's Domestic Biogas Program (PDBP), facilitated and supported by ENERGIA, undertook gender mainstreaming and looked at opportunities to involve women in the supply side as owners or promoters of biogas construction companies, and in the demand side as trainers, community organizers, income generation facilitators, micro-finance lenders and integrators of biogas into other social and economic activities. As a result of this, women had more time for child care and social activities.

4. Bio- briquettes and Gender

Biomass briquetting is a process of densification of loose biomass to ensure effective and efficient use of loose biomass. Briquetting is known to have several socio- economic opportunities, including creation of job opportunities, reduction in poverty, as well as women empowerment (Ahmed S., et al., Njenga, M.,).

Clancy et al. (2002) illustrate how bio- briquettes can contribute to women's practical, productive and strategic needs:

Energy Form	Women's needs		
	Practical	**Productive**	**Strategic**
Improved biomass (supply and conversion technology)	-improved health through better stoves -less time and effort in gathering and carrying firewood	-more time for productive activities -lower cost of process heat for income generating activities	-control of natural forests in community forestry management frameworks

An economic analysis by Ahmed et al. (2008) revealed that biomass briquetting in Bangladesh helps indirectly for woman empowerment and ensuring their strong participation in the development of national economy by reduction of 70% to 80% fuel collection time. Another study by Njenga M. found that women in Kibera are increasingly engaging in bio- briquette manufacturing, either individually or as organized self-help groups. This has resulted in home use made savings of over 70%, while those who purchased them saved 30%.

In case of Nepal, UNDP (2007) reported that production of bio-briquettes contributed to women's income by adding as much as Rs. 6000 per month. This income helps them to pay their children's school fees and run the household. Gender mainstreaming in biomass briquettes in Nepal has come a long way since then. Gender equality issues have received significant attention in Nepal's legal and policy framework in recent years. Government policies that are focused on rural energy are much more gender sensitive, and recognize the need for bridging gender disparities and greater social inclusion. Many of the recent rural energy programs are guided by AEPC's Gender Equality and Social Inclusion (GESI) Mainstreaming plan, which paves way for supporting and benefitting women in rural communities (ADB, 2018).

UNDP Nepal's Micro Enterprise Development Programme (MEDEP) has provided entrepreneurship training to more than 200 people, mostly women. In Langhali Community Forest User Group (LCFUG) in Sunsari district, a 25 member women's group for briquette production was formed. This group is split into four small group of 5 to 6 members and each group operates the enterprise in its respective turn on rotation basis. This enterprise is providing employment, directly or indirectly to about 30 persons, mostly women. The community enterprise produces 100 to 150 briquettes a day and sells at Rs. 8 per briquette. The community is planning to further improve and expand enterprise since there is a growing demand for bio-briquette. The briquette enterprise has also designed and produced an appropriate briquette stove, made up of clay as well as metal, which are sold at Rs. 60 and Rs. 175 respectively (MEDEP, 2008). Thus the women of Langhali Community are venturing as entrepreneurs, making sustainable use of the locally available renewable resources.

On a larger scale, MEDEP works closely with Himalayan Naturals Pvt. Ltd., which is a pioneer bio briquette supplier in Nepal. It has created employment opportunities directly for over 375 community members from

5 community enterprises, of which 102 are females (ANSAB). Numerous women's groups have been formed under the Community Forest User Groups (CFUGs) that work with Himalayan Naturals and are engaged in making bio- briquettes as an enterprise. This gender sensitive collaborative approach has proved to work successfully for Himalayan Naturals.

Despite the notable potential welfare gains from increased access to energy, a lack of careful design considerations, targeting, and support services could mean that many in the margins are not always able to afford benefits from energy even when provided with access. Previous experience in Nepal has been mixed, ranging from practices that border on indifference or even ignorance to ones that show promise on how interventions can prove beneficial to women. It is important to recognize that energy should be seen not just as an efficiency or welfare element in development, but that it is also an indirect means for enhancing gender equity (Skutsch, 1998). Steps must be taken to explore opportunities for collaborating with women's groups such as mothers' groups, women's savings and credit groups, and women leaders in the community. Likewise, provision of training to women on technical, business, and leadership development skills must be developed so that they can secure direct employment in energy projects as well as maximize benefits from improved access to energy services and technologies. The latter can be achieved through collaboration and partnerships with local governments, civil society groups, private sector, and financial institutions (ADB, 2018).

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ANNEX 5

Stakeholder Consultation Workshop

on Promotion of Sustainable Use of Biomass Briquettes in Nepal

Submitted to:

Climate Technology Centre and Network (CTCN)

Submitted by:

Energy Program

Department of Energy Environment and Climate Change

Asian Institute of Technology

January 2018

Executive Summary

Nepal has an abundance of biomass residues that can be used for the commercial production of biomass briquettes, that make them attractive in terms of higher density, heating value and ease of transportation and storage. This opportunity needs to be harnessed by developing a sustainable business model and policy incentives for the stakeholders.

Asian Institute of Technology (AIT) and Alternative Energy Promotion Centre (AEPC) jointly organized a stakeholder consultation workshop on 22- 23 January at The Dining Park Restaurant and Lounge in Kathmandu, Nepal. The workshop was funded by Climate Technology Centre and Network (CTCN) and supported by Ministry of Population and Environment (MoPE). The overall objective of the workshop was to gain an overview of the key issues and challenges in bio briquette sector, and how to address them.

The first day of the workshop focused on technology framework and business model for briquette industries. On the technology front, the key issues include inadequate knowledge of value of biomass, lack of value addition to biomass, inability to make efficient use of biomass and lack of adequate facts on accessibility and characteristics of biomass in Nepal. Some other issues that were discussed upon include affordability of technologies, product diversification, drying of products and end user technologies. The business model session focused on possible business models in the context of Nepal, including cash at gate policy, product diversification, 3rd party financing and build- operate- transfer models. Feedback from participants shed light on business issues including lack of investment support, market segmentation and consumer identification, marketing mechanisms and networking, demand creation and stove designs. SWOT analysis of the proposed business models were also carried out.

The second day agenda was policy framework, where pertinent gaps in Nepalese policy scenario were identified and measures to bridge these gaps discussed. Some of the gaps include: Revenue rates for briquettes not fixed, lack of consumer awareness, high upfront costs, market barriers, technology support, tax and tariff reform and institutional development, quality control and standards, low- interest loans, grants and other financing mechanisms for briquette industries, investment support via low- interest loans, grants or subsidies for combustion (e.g. pellet industries). Measures to bridge these gaps include creation of an enabling environment, special protection for industry, fiscal incentives for market barriers, institutional development and risk management.

The AIT team also went for site visit to Centre for Energy and Environment- Nepal (CEE-N), Organic World Pvt. Ltd. And Himalayan Naturals Pvt. Ltd. to understand the issues faced in manufacturing process.

The stakeholder consultation workshop gave way to important aspects to be included for the policy framework and constructed the way forward for training program that will be held later in June 2018.

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1. Introduction

1.1 Background

According to the National Survey of Energy Consumption and Supply situation of Nepal (2011/ 2012), biomass comprises of approximately 80% of the fuel mix in Nepal (WECS, 2014). Such traditional fuel sources have low energy efficiency and the smoke emitted by these can result in health hazards. Biomass densification is a process that involves the conversion of loose biomass into densified briquettes (>25 mm) or pellets (<25 mm). This process helps alleviate several problems associated with loose biomass- low bulk density, low energy density, poor combustion characteristics, and issues with transportability and storability.

Nepal has an abundance of biomass residues that can be used for the commercial production of biomass briquettes. Fuel briquettes generated by the low-pressure compaction of paper, sawdust, agricultural or yard waste, etc. currently serve as an alternative to firewood, wood pellets and charcoal in developing countries in Africa, Asia and South America. Biomass briquettes are growing as an alternative bio mass energy source in Nepal due to abundance of biomass fuel in present scenario. Low-energy content feedstocks can be compacted, pressed and combusted to produce heat output commensurate with higher energy content fuels in the form of bio briquettes.

Biomass briquette offers several advantages over the traditional bio-fuel, including higher volumetric calorific value, easy collection, transportation, lower cost, accumulation, longer burning duration and cleanliness. Biomass densification can bring in several benefits for Nepal including tackling indoor air pollution, energy security, job creation, women empowerment, waste management, prevention of forest fires, and production of cheap and eco-friendly fuel.

1.2 Rationale

Enhanced use of renewable energy is required for sustainable growth in Nepal. However, financial and market barriers, technical barriers, institutional and regulatory barriers are present that obstruct the use of biomass energy at a large scale. A strong policy framework and innovative business models that remove and address these barriers are required to promote efficient utilization of biomass and to enhance national capacities. One key opportunity to harness the potential of biomass energy is to produce briquettes that make them attractive in terms of higher density, heating value and ease of transportation and storage. Currently, the full potential of biomass densification has not been realized in Nepal. Though biomass briquetting has opportunities, a financially sustainable business model is required to continually increase its production, market base, quality assurance and productive use. This model needs to be backed by strong policies that ensure sustainability of the business. Developing such a business model and policy framework needs feedback from various stakeholders including private enterprises involved in the business, end users that the business targets, technology experts who can improvise the technology to local context as well as policy experts who develop policy incentives for the whole sector.

2. Stakeholder Consultation Workshop on 'Promotion of Sustainable Use of Biomass Briquettes in Nepal'

2.1 Workshop Proceedings

The stakeholder consultation workshop was organized jointly by Asian Institute of Technology (AIT) and Alternative Energy Promotion Centre (AEPC), with funding by Climate Technology Center and Network (CTCN) and supported by Ministry of Population and Environment (MoPE). The workshop was conducted for one and half days, with the first day focusing on technology framework and business plan, and the second day focused on policy framework. The agenda of the workshop is given in Appendix 1.

2.2 Objectives of the workshop

The overall objective of the workshop was to gain an overview of the key issues and challenges in bio briquette sector, and how to address them. The specific objectives were:

- To develop a sustainable business model for bio briquette use and carry out its SWOT analysis
- To create a policy framework for promoting sustainable use of bio briquettes
- To discuss way forward for capacity building and knowledge sharing and dissemination workshop

The invitation was sent out to 27 stakeholders from various private enterprises, donor and research agencies, government organizations, and independent consultants (Appendix 2).

The workshop was conducted at Dining Park Restaurant and Lounge in Kathmandu, Nepal from 22- 23 January 2018. A total of 26 participants attended the workshop (Appendix 3).

2.3 Day 1:

2.3.1 Opening Remarks and Welcome:

The first day began with opening remarks from Dr. Shobhakar Dhakal (AIT), Ms. Shubha Laxmi Shrestha (AEPC) and Mr. Ram Hari Panthi (MoPE). Mr. Panthi gave an insight to the participants about how CTCN works, and its role in providing technical assistance to Nepal. All three speakers emphasized on the outcomes of the workshop, i.e. a business plan and policy framework for biomass briquetting in Nepal. AIT and AEPC will prepare these documents, which will be co-ordinated by MoPE and forwarded to CTCN.

After the opening remarks, there was a group photo session followed by tea break.

Objectives of the workshop: Dr. P. Abdul Salam (AIT) went through the objectives of the workshop as:

- To develop a business model
- To create a policy framework
- Capacity building and knowledge sharing and dissemination workshop

He also explained that the workshop was to discuss the findings of literature review that was carried out for the first two objectives, identify other challenges and issues (inputs provided by stakeholders) and the appropriate solutions to address these challenges.

2.3.2 Morning Session: Technology Overview by Dr. P. Abdul Salam/ Dr. Ramesh Man Singh/ Prof. Dr. Krishna Raj Shrestha

Presentation by Dr. P. Abdul Salam

Dr. Salam presented on technological overview for solid biomass densification, starting from technologies available globally, and moving on to the ones used and practiced in Nepal. Several innovations are present in the global technology for densification, including cold densification, mobile densification and torrefaction.

In the context of Nepal, throughout the 1980s and 1990s four types of technologies were introduced- screw extruder briquetting using charred rice husk, screw extruder briquetting using biomass, roller press briquetting and beehive briquetting. Piston press technology was introduced in the early 2000s. Nepal is endowed with a wide variety of available raw materials including (i) Forest based residues- invasive plants, pine needles and cones, pruning of trees at plantations, cleared biomass under power lines, leaves, twigs, sticks etc.; (ii) Agricultural crop residue- cereal and cash crops; (iii) Waste from wood-based industries- logging waste, saw-mill waste, veneering industry waste, plywood and particle board, furniture, handicraft, parquet and other industries; (iv) Herb processing waste- medicinal and aromatic herbs; (v) Municipal solid waste- combustible portion of urban waste. However, past and contemporary experience of briquetting in Nepal has shown a number issues.

He identified some of the key issues in developing countries as inadequate knowledge of value of biomass, lack of value addition to biomass and inability to make efficient use of biomass. The technical challenges for biomass in Nepal also includes the need to clearly assess the accessibility and characteristics of biomass resources. He also emphasized that there are issues other than technological/ technical that could hamper the promotion of biomass briquetting, such as technology selection, operators' knowledge, etc.

Presentation by Dr. Ramesh Man Singh

Dr. Singh presented on the experiences of National Academy of Science and Technology (NAST) and Centre for Energy and Environment- Nepal (CEEN) with bio-briquetting. NAST had/has been providing a lot of technological help in this domain. Historically, cost of machine was very high with screw wearing being the major problem, but now more affordable technologies are available from India and Bangladesh. There used to be no facility to analyze the end products and had to be sent to India. Biomass testing is now available at NAST. NAST was involved in JICA supported project for coal type (pillow) briquettes. However, cooking devices were not developed properly during this time. Although company registration grew in the early 1990s, only 6 survived till 1997.

CEEN has been working with AEPC in developing training manuals (focusing on entrepreneurship, beehive briquetting, etc.) as well as conducting studies on market demand and feasibility, policy recommendations and technical parameters for quality assurance of biomass briquetting. CEEN has also been working in R&D, and has produced improved beehive briquettes in the form of 'Sajilo mould', as well as produced Agnee stoves for bio briquettes, where the CO concentration drops once there is secondary air. CEEN also developed portable rice husk briquetting machine that could be powered by micro hydro projects, and produce rice husk briquettes. CEEN has also been involved in production of small pellet machine using saw dust and other raw materials. Dr. Singh also mentioned that a variety of bio briquette technologies are used in Nepal, except agglomeration technology (which is used in making charcoal balls).

Dr. Singh highlighted some of the opportunities for bio- briquettes, and stated that there are several market opportunities for bio briquettes, but these need policy incentives.
Some of the challenges faced by the industry include:

- Technical: Huge gap in technology, lack of R&D support, lack of expertise, lack of training, and qualified manpower
- Financial: Higher tax (more than liquor industry), no loan support for biomass, lack of incentives, inability to utilize technology funds in the sector of briquetting
- No market guarantee: lack of secure market
- Social and promotional support lacking
- Need to form specific policies

This presentation was followed by a roundtable discussion, moderated by Prof. Dr. Krishna Raj Shrestha, on technology issues and challenges, and viable solutions to these. The discussions focused on the main technology barriers in Nepal and the levels of intervention.

In the 80s and 90s, technology for briquetting itself was very expensive, and there were a lot of repair and maintenance issues. Hardfacing and welding of screws are now available in Nepal. However, Nepal still faces a number of technological barriers in this sector:

- Raw Materials: There are about 200 plywood industries in Nepal. 60% of sawdust comes as waste. This could be used as raw material for pellet industries especially in Jhapa, where 40 plywood industries are present.
- Affordability of technology: Although Japanese technology is very advanced and efficient in this sector, with very less wear and tear, it is expensive and not affordable in the context of Nepal.
- Product diversification: Technology mostly limited to rice husk and beehive briquettes. This needs to be diversified to charcoal, pellets, and other raw material use.
- Potential of briquettes as energy source has been only limited to pilot studies. Quantification of feedstock needs to be done, along with assessment of the overall production capacity and where the potential customers are located.
- Processing unit is one of the biggest issues in the industry. There is no network for technological support, and reliance on machine suppliers exists. This hampers the entire production line.
- Drying of products is also an issue. Feasibility of using Renewable Energy Technologies (RETs) as dryers for bio briquettes needs to be further looked into. Likewise, possibility of using waste heat during charring for drying could be a guide for technologies.
- Char production by pit method is inefficient, so using charring drums is recommended which can increase the amount of char produced. Coating the mild steel charring drums with coal tar can help avoid corrosion, thereby increasing the lifespan of the drum.

- There is a need to form a special unit (in either AEPC or MoPE) that is devoted towards assessments and R&D on briquettes for the long-term use of bio briquettes and can also provide preliminary information and suggestions to new entrants in the sector.
- Feasibility studies and financial analysis need to be specific, pertaining to specific raw materials.
- Projects thus far have been focused on research, and no support has been for technology.
- There needs to be emphasis on informing people about correct technologies and cost effectiveness of these
- How to adapt charring kilns (that are developed for flat lands with tractors and trolleys) in the context of Nepalese topography. Likewise localizing available technology in a solution oriented system is needed.
- End user technologies in the form of stove design and use is still lacking. Users used wrong technology and eventually lost interest. This led to reduction in production by private producers and resulted in briquets shortage. So, private producers have lost their way now. Consumers want features such as instant operation, temperature control etc. So, they seem to be disinterested. Consumer awareness on handling and boiler modifications is necessary.
- Assessment of the entire technology chain is needed: ignition of briquettes, stove/ heater technology, briquette making technology, controlled cooking technology as well as ventilation management.
- Competitiveness of technology must be assessed with respect to other available technologies, and further analysis on how to make bio briquette competitive in market is necessary. Assessing backward links as well as forward links is needed.

This discussion emphasized on the need to diversify production (both raw materials and products), improvise available technologies in the context of Nepal, awareness generation in terms of available technologies and their correct use (to both producers and consumers), and the need of a holistic approach to bio- briquettes as clean and efficient combustion fuels.

This discussion was followed by a lunch break, where participants further discussed on several factors with each other. After lunch, everyone reconvened for the afternoon session that was focused on business model for bio- briquettes.

2.3.3 Afternoon Session: Business Model Session by Dr. Shobhakar Dhakal/ Mr. Sushil Gyawali/ Mr. Vishwa B. Amatya

Presentation by Dr. Shobhakar Dhakal

The afternoon session began with a presentation by Dr. Shobhakar Dhakal (AIT) on business models for bio briquettes. He began with an overview on global markets for biomass briquettes. Wood pellets are popular worldwide, with huge markets in the US, UK, Japan, South Korea and China, and increasing markets in Asia. He then discussed on various business models present in the Renewable Energy sector, including:

- **Results Based Financing Approach:** This approach involves payment based on results and the relationship between payments and results is pre- defined. This is a performance based financing approach that has been used in ICS financing in Uganda.

- **Developing a Value Chain Model:** This model involves formation of the entire value chain, from supply to consumers by the enterprise. It is in practice in Africa by a company called Eco- fuel Africa.
- **Cash at gate policy:** In this model, carbonized agricultural waste is bought from people with a 'cash at gate' policy, allowing for enterprises to develop networking with a large number of people who provide a continuous supply of raw materials of multiple types.
- **3rd Party Financing/ Consumer Financing:** Consumers finance their access to technology by relying on 3rd party financing, such as the revolving funds set up by donors /micro-credit facilities/ rural banks to purchase technologies.

Literature review showed that carbonized briquette businesses in Nepal operate in collaboration with Community Forest User Groups (CFUGs), while uncarbonized briquette industries do not have any such collaborations. Therefore, different models are proposed for uncarbonized briquetting industries and carbonized industries in Nepal:

1. **Cash at gate policy with product diversification for uncarbonized briquettes**
   In this model, it is proposed that industries use a cash at gate policy to diversify their raw materials and decrease their cost of operation (by decreasing transportation costs and cost of raw materials), and simultaneously diversify their products (briquettes, pellets, pillow briquettes, stoves) in order to reach a diverse range of customers.
2. **3rd party financing for carbonized briquettes**
   Here, the private enterprise assists high potential community enterprises to further access motorized machinery by partnering with Micro Finance Institutions (MFIs) or rural banks, so that the enterprise can scale up and increase their production.
3. **Build- Operate- Transfer (B. O. T) Model for carbonized briquettes**
   In this model, the role of private enterprise decreases over time, as the community based enterprise takes ownership of the entire value chain.

The proposed models were open for discussion, where the stakeholders could put forward their views on their feasibility in the context of their own industries.

Presentation by Mr. Sushil Gyawali

Mr. Gyawali presented on the business model of his company 'Himalayan Naturals Pvt. Ltd' which produces carbonized briquettes and pellets. Himalayan Naturals is a community- private partnership organization formed in 2009 that works with 150 community based enterprises in 50 community forests from 7 districts. The chief issues faced by the enterprise are:

- Lack of support on enterprise development, R&D, promotion and market stimulation
- Economic challenges in accessing better technologies for pyrolysis and combustion technologies
- Contradicting forest policies that work against briquetting industries
- Lack of adequate recognition for renewable energy financing

This was followed by a roundtable discussion on business models for Nepal, which was moderated by Mr. Vishwa B. Amatya. The discussion revolved around market issues and challenges for upscaling the industry as a whole. The main points from the discussion were:

-

- Capacity building is required at rural level so as to build a strong supply chain.
- Mapping of both demand side and supply side is needed to make the industry sustainable.
- Banking sector is highly commercial in nature, and are skeptic about investment in this sector. Small loans are also not easily provided, and the interest rates are very high.
- Government support in development of business model is a must. Role of CFUGs must be taken into account while building business models as their role is imperative (CFs are autonomous bodies). But, extraction of feedstock from National Forest is very difficult. Forest sector policies could be hindering investments in this sector.
- There is a huge scope for LPG replacement but biomass technology is not yet fully matured and is capital intensive. User habit change is also needed. Consumers find it easier and more convenient to use gas than charcoal.
- Major issue for charred briquettes is high cost of raw material, while that for uncharred is access to the raw material itself. Carbonization is needed in extraction which increases cost. So, it can only compete where cost of fuel is high. This narrows the target customer base.
- Inefficient system of fuel use is present in the country, eg. Langtang area. Intervention of briquettes as fuel is required to before consumers shift from fuelwood to LPGs. This requires huge investments for stoves.
- Private producers are unable to supply if huge demand is present. Regular supply of biomass fuels becomes an issue.
- Industries need to look into how to tap into commercial and industrial sectors, because households might not be the ideal consumer base. There is a need to identify consumers group that need briquets rather than compete directly with consumers using LPGs.
- Businesses have to start developing efficient market mechanisms and networks to ensure constant demand.
- Differentiation of enterprises into social (CFUGs based) and industrial (for large scale production) scales, and market segmentation accordingly is required. Different kinds of customers have different needs, so it is important to identify the target customers.
- Need for demand creation exists. There is some demand, but only in niche markets, which will soon be saturated. So enterprises need to look for new markets (eg. Large restaurants).
- Need to look at support services also, such as transportation/ financing/ packaging/ labor cost, etc. as businesses are very price sensitive at present.
- Prices for stoves are relatively high at present. But they could go down drastically if a large number of stoves are procured.
- Linking briquettes with environmental standards, especially for brick kilns could be one method of demand creation. Using briquettes also helps to increase the quality of bricks in terms of color and texture. However, the price of briquettes are still too high to make this economically feasibile.
- Business models also need to look at end users' needs, including stove designs. Are there any stove designs available for higher efficiency and what specifications are required by different consumers must be a part of the business model.

After this, a short tea break was taken before moving on to SWOT (Strength/ Weakness/ Opportunity/ Threat) analysis of the business models. This was conducted as an open discussion carried out in two steps:

a) First, Mr. Amatya asked the participants to validate the list of factors he had compiled based on the discussions carried out in the earlier session.
b) The participants then further added factors to the list, explaining reasons for each factor to be placed in a category.

The results of the analysis are presented below:

Strength	**Weakness**
- Global availability of technology and technological capability, only need to customize the technology - Local capacity for technology services has improved - CFUGs availability and their positive outlook on briquette - Socio- environmental impact of the industry (prevent forest fire, reduce poverty, improve women empowerment) - Growing market and awareness - Possibility of using climate financing	- Price sensitivity of the industry - End use device shortage - Lack of competitiveness with other fuels - Misappropriation of cheap financing (good governance and transparency) - Lack of proper monitoring of stove quality and fuel quality - Lack of inter ministry co- ordination - Lack of risk minimization tools - Lack of political commitment and awareness - Lack of investors and large financing - Uneven play field (Other RETs have subsidies, briquettes don't) - Lack of industry support programs - Less preferred by policy
Opportunities	**Threat**
- Opportunities to use forest biomass - Briquette market exists (but needs segregation) - Opportunity to use resources such as forest biomass under high tension lines - Ease of collection of some biomass - Agricultural residue as a resource (husk, straw, bagasse, stalks) - Price of fossil fuel is increasing - Affordability of stoves when the industries scale up - Technology innovation for densification present in global scenario	- Competition from other kinds of fuels and sectors - Labor cost is high, and labor supply is low - Cost of spare parts (Foreign currency threat) - Political instability - Lack of financing - Provincial laws have not yet been fixed - Price of oil and coal could reduce - Nepal could find natural gas - Conflicting policies between energy and forestry sectors - Competition from other sectors' investments

Day 1 ended with concluding remarks on technology framework and business plan. Everyone agreed that business models should be based on demand, and technologies for end users should be developed simultaneously.

2.4 Day 2:

Day 2 began with summary by Dr. Salam about the previous day. He also mentioned that if further clarifications were required, Skype meetings could be arranged with the participants in the future.

2.4.1 Policy Framework by Dr. Shobhakar Dhakal/ Ms. Shubha Laxmi Shrestha/ Mr. Nawa Raj Dhakal

Presentation by Dr. Shobhakar Dhakal

Dr. Dhakal's presentation gave an overview of biomass briquetting policies in global context. International standards as well as certification systems are present for pellets and briquettes as well as stoves. He emphasized that the quality of briquettes and pellets needs further discussion in the context of Nepal. Apart from these, different countries have policy incentives for bio-briquettes. The increasing inclination towards policy formulation for biomass energy has stemmed from the global commitment in increasing their share of renewable energy sources to curb climate change.

Policies for biomass briquetting are prevalent in Asia as well. China has a renewable energy law from which specific policy instruments stem. China has a comprehensive framework with extensive planning present for biomass briquetting. It has a target of 50 million tons of solid biomass fuel production by 2020. China also has provisions for low interest loans at maximum 3% interest rate for 1-3 years. India's policy incentives for bio briquettes include accelerated depreciation, exemption from sales tax and excise duty, 5-year income tax holiday, low interest loans for briquette industries, and 25- 30% subsidies on total investment and briquette press.

Nepal has a target of producing 20,000 metric tonnes of briquettes and pellets by 2030. The Finance Act states VAT waiver for briquettes and pellets, customs tax exemption for machinery and its components and chemicals for bioenergy production, and income tax exemption for industries that produce bioenergy from forest produce. Likewise, there is also provision for upto 40% subsidy for small businesses based on renewable energy.

Dr. Dhakal also identified some of the gaps that need to be addressed in the policy front in Nepal, including:

- Revenue rates for briquettes not fixed
- Lack of consumer awareness
- High upfront costs
- Market barriers
- Technology support, tax and tariff reform and institutional development
- Quality control and standards
- Low- interest loans, grants and other financing mechanisms for briquette industries
- Investment support via low- interest loans, grants or subsidies for combustion (e.g. pellet industries)

Presentation by Ms. Shubha Laxmi Shrestha

Ms. Shrestha presented on the policy overview in Nepal including various policies that are in favor of briquetting industry and the prevailing gaps:

- Forest Policy does not have provision to promote RE usage.
- RE Subsidy Policy does not have any explicit or special provision for briquettes and a clear-cut idea on how to provide subsidy to bio briquettes is also not present.
- Current capacity of Nepali producers is 7,000 metric tons and the target is 20,000 metric tons by 2030.
- Those producers issuing VAT invoices seem to be unaware about act 44.01 and 44.02 about VAT exemption.
- Royalty obtained by forests: Rs 15/kg of charcoal. Ways to grant concession on this need to be explored.
- Even though tax exemption request letter is issued by AEPC, customs office is making things difficult while getting tax exemptions. (e.g. in case of importing chemicals, particularly starch).
- bioenergy.org.np has information about resource mapping and prioritization (for charred as well as uncharred) for about 16 districts done on scientific basis which mostly focuses on forest residues.
- There is an absence of a clear picture about resource availability and how to access it (charred or uncharred). A comprehensive assessment of resource availability, quantity and access needs to be done. Resource assessment on scientifically harvesting resources and their regeneration potential is lacking.
- Bio- briquette quality and standard testing can be conducted at the Renewable Energy Test Station (RETS).
- Tax exemption for briquettes which is included as a provision in Finance Act, must be implemented.

This gave way to the policy framework roundtable discussion which was moderated by Mr. Nawa Raj Dhakal (AEPC). The session began with the notion that policies are guiding documents, while acts are binding. Therefore, there is a need to explore formulation institutional acts and sectoral acts for biomass briquetting. The session progressed with addressing the policy gaps:

- Need for enabling environment: The government must be involved for forming the enabling environment for fuel use and end use devices as well as for standards testing and certification. This also requires government to enable technology dissemination and financing.
- Stringent budget separation is required for R&D for bio briquettes.
- Need to identify underlying gaps to build capacity for production of 20,000 metric tonnes
- Conditional grants for alternate energy needs to be tapped. Possibility of tapping into financing exists here, but there is no concrete design yet.
- AEPC's role to be supporting: in terms of training, resource mobilization, assessment, database. AEPC should be involved in preparing model policies and guidelines, but the implementation should be done by the local governments.
- Energy governance and the role and responsibilities in new federal structure needs to be clarified. At the same time, lessons learnt from other countries should be also analysed.

- Formation of national level database, national level standards, testing and certification, technology specifications, capacity building, carbon financing and institutional coordination need to be addressed.
- Policy incentives are needed for improving access to raw materials under high tension lines, use of diverse types of resources and facilitation of suitable technologies
- Fiscal incentives for market barriers, soft loans, market diversification need to be present. VAT and custom duty exemption are already present. This information needs to be disseminated among the industry stakeholders. Capital subsidies for bio briquetting and pelletizing machines should be developed.
- Target customer base needs to be identified: Firewood using population that are shifting to LPGs.
- Need to fix the scope of industry: whether it is going to target household level, commercial level, institutional level or industrial level.
- Capacity building for resource mobilization needs to be done. Electricity prices for briquette business to be fixed.
- R&D support policy needs to be developed, including technologies for stoves and cooking solutions at high altitude tourism areas. Technology financing in the form of "Technology Development Fund"
- Special protection for industry: policies to push institutional use of briquette in government offices and agencies. Include this in special industry and eligibility for priority sector loan. Electricity tariff rate reduction (provision of subsidy) and link with environmental pollution
- Industries need to be made more aware of the prevalent customs and VAT exemptions. Accelerated depreciation on machinery needs to be provided.
- Occupational health and safety is also an issue, for which minimum parameters and safeguarding principles need to be fixed.
- Policies for awareness at user level, pilot demonstration needs to be developed. Users are aware only about carbonized briquettes and not about uncarbonized ones.
- Mentoring for companies need to be done for marketing and branding for the industry.
- Provision of institutional development that acts as a one stop service for bio briquette.
- The development of provincial laws can also affect biomass related policies. The role of AEPC in facilitating this is imperative.

2.4.2 Concluding Remarks

Dr. Salam gave the concluding remarks of the workshop and thanked all the organizers as well as the participants for their contribution. He also mentioned the way forward for training program in June where the findings of this workshop, with further refinement would be disseminated to policy makers.

2.5 Field Visit

On 24th Jan 2018, the team from AIT visited three sites (CEE-N, Organic World Pvt. Ltd. and Himalayan Naturals Pvt. Ltd.) to gain hands- on knowledge about the issues faced in bio briquetting sector. While CEE-N is involved in production of both carbonized and uncarbonized briquettes (from various raw materials), fabrication of production and end- use technology and R&D, the latter two enterprises are involved in production of carbonized briquettes from forest residues. Some of the issues faced by these companies include irregular supply of raw materials, high transportation cost, stove design improvement, drying of products, high ash content and choice of binders. Affordable options for drying of products is a pressing issue prevalent in all enterprises.

3. APPENDICES

3.1 APPENDIX 1: Workshop Agenda

STAKEHOLDER CONSULTATION WORKSHOP ON

PROMOTION OF SUSTAINABLE USE OF BIOMASS BRIQUETTES IN NEPAL

Date: 22nd Jan- 23rd Jan, 2018

Venue: Dining Park Restaurant and Lounge Bar
Mid Baneshwor, Kathmandu

Organized by:
Asian Institute of Technology (AIT), Thailand and Alternative Energy Promotion Centre (AEPC), Nepal

Funded by:
Climate Technology Center and Network (CTCN)

Supported by:
Ministry of Population and Environment (MoPE)

Day 1: Jan 22, 2018

9:00- 9: 30	Registration/ Tea
9:30- 9:50	Welcome/ Opening remarks
	Welcome by Dr. Shobhakar Dhakal (AIT)
	Welcome by Mr. Ram Prasad Dhital (AEPC)
	Opening remarks by Mr. Ram Hari Pantha (MoPE)
9:50- 10:00	Objectives of the workshop- Dr. P. Abdul Salam
10:00- 10: 20	Technology Overview- Dr. P. Abdul Salam
	(Overview of existing technologies in the global context, and those applicable to Nepalese context)
10:20- 10:40	Presentation by participants
	Dr. Ramesh Man Singh (CEEN)
10:40- 10:50	Tea Break
10:50- 11:00	Guidance on discussion- Dr. Shobhakar Dhakal
	(Guidance on discussion and expected outcomes)
11:00- 12:30	Roundtable discussion on technology framework by Prof. Dr. Krishna Raj Shrestha
	(Discussion on existing scenario in Nepal and identify problems. Propose solutions to technology barriers. Get feedback on the solutions.)

12:30- 13:30 Lunch break

13:30- 13:50 Business Plan Overview- Dr. Shobhakar Dhakal

(Overview of existing business models in the global context, and those applicable to Nepalese context)

13:50- 14:10 Presentation by participants

Mr. Sushil Gyawali (Himalayan Naturals)

14:10- 15:30 Roundtable discussion on Business Models, including SWOT analysis by Mr. Vishwa B. Amatya

(Existing business models vs. proposed business models, Strength/ Weakness/ Opportunities/ Threats for proposed models)

15:30- 15:50 Tea Break

15:50- 16:30 Continued discussion on technology framework and business model

Day 2: Jan 23, 2018

9:00- 9: 30 Registration

9:30- 9:40 Welcome Remarks and Summary of day 1

By Dr. P. Abdul Salam (AIT)

9:40- 10: 20 Policy Overview- Dr. Shobhakar Dhakal (AIT)

(Overview of existing bio- briquette related policies in Nepal, South Asia and global context)

10:20- 10:45 AEPC presentation- Ms. Shubha Laxmi Shrestha

(Government policy/ support for biomass energy and bio briquette production)

10:45- 11:15 Roundtable discussion on policy framework by Mr. Nawa Raj Dhakal

(Discussion on policy gaps in Nepal and how to address them)

11:15- 11:30 Tea break

11:30- 12:20 Roundtable discussion on policy framework by Mr. Nawa Raj Dhakal

(Discussion on feasibility of policy implementation in Nepal)

12:20- 12:30 Closing Remarks

12:30- 13:30 Lunch

3.2 APPENDIX 2: List of Invitees

S.N.	Contact Person	Contact address	Organization
1.	Mr. Ram Prasad Dhital	ram.dhital@aepc.gov.np	AEPC
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4.	Ms. Shubha Laxmi Shrestha	shubha.shrestha@aepc.gov.np	AEPC
5.	Mr. Prakash Bhandari	prakash.bhandari@aepc.gov.np	AEPC
6.	Mr. Prajwal Raj Shakya	prajwalrajshakya@gmail.com	AEPC
7.	Prof. Dr. Krishna Raj Shrestha	shresthakr1@hotmail.com	CEEN
8.	Mr. Ram Hari Pantha	rhpantha@hotmail.com	MoPE
9.	Dr. Rabindra Dhakal	dhakalrabindra3@gmail.com	NAST
10.	Dr. Ramesh Man Singh	rameshmsingh@hotmail.com	CEEN
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13.	Mr. Sushil Gyawali	sushilgyawali@gmail.com	Himalayan Naturals Pvt. Ltd
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22.	Mr. Kanhaiya Bhagat	kanhaiya.bhagat@yahoo.com	Universal Biomass Briquette Industry
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26.	Mr. Deepesh Sharma	dpesh7@gmail.com	CEEN
27.	Vishwa B. Amatya	vbamatya@gmail.com	Independent Consultant

3.3 APPENDIX 3: List of participants

S.N.	Contact Person	Contact address	Organization
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2.	Mr. Nawa Raj Dhakal	nawa.dhakal@aepc.gov.np	AEPC
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3.3 APPENDIX 3:Photo Gallery

Fig: Group Photo of participants in the workshop

Fig: Opening Remarks by Mr. Ram Hari Panthi (NDE)

Fig: Roundtable Discussion on Policy Framework

Fig: Roundtable Discussion Session

Fig: Presentation by Dr. Shobhakar Dhakal

Fig: Presentation by Dr. Ramesh Man Singh

Fig: Technology Session Moderation by Prof. Dr. Krishna Raj Shrestha

Fig: Policy Overview in Nepal by Ms. Shubha Laxmi Shrestha

Fig: Policy Overview in Nepal by Ms. Shubha Laxmi Shrestha

Fig: Pellets production in Himalayan Naturals Pvt. Ltd.

Fig: Burning of pellets produced inorganic World Pt. Ltd.

Fig: Stove fabricated at CEE-N

Fig: Briquetting Machine at CEE-N

Fig: Drying of uncarbonized briquettes at CEEN

ANNEX 6

Report on "Stakeholder Dissemination Workshop and Training on Promotion of Sustainable Use of Biomass Briquettes in Nepal"

Submitted to
Climate Technology Centre and Network (CTCN)

Submitted by
Energy Program
Department of Energy, Environment and Climate Change
Asian Institute of Technology (AIT)

July 2018

Executive Summary

Nepal has an abundance of biomass residues that can be used for the commercial production of biomass briquettes, that make them attractive in terms of higher density, heating value and ease of transportation and storage. This opportunity needs to be harnessed by developing a sustainable business model and policy incentives for the stakeholders.

Asian Institute of Technology (AIT) and Alternative Energy Promotion Centre (AEPC) jointly organized a stakeholder dissemination workshop and training on 20- 21 June at The Dining Park Restaurant and Lounge and a High level Stakeholder Dissemination Workshop on 22nd June at the Ministry of Forest and Environment in Kathmandu. The workshop was funded by Climate Technology Centre and Network (CTCN) and supported by Ministry of Forest and Environment (MoFE) and Ministry of Energy, Water Resources and Irrigation (MoEWRI). The overall objective of the workshop cum training was to disseminate the key findings on business model and policy framework in bio briquette sector, and to train the stakeholders on how to address the key technological issues prevalent in the sector in Nepal.

The first day of the workshop focused on business model and policy framework for briquette industries. The business model session focused on business models in the context of Nepal, including cash at gate policy, product diversification, third party financing and build- operate- transfer models. Way forward session shed light on how the government could intervene in the business model and facilitate demand creation and supply security. The policy framework session focused on several policy recommendations that could be operationalized in Nepal including financing, tax exemptions, accelerated depreciation, prioritizing bio briquette sector, focusing on research and development, creating consumer awareness and setting national standards and certification schemes. The second day was a training on how to address technology issues faced in Nepal, including selection of raw materials, binder choice, use of technology, etc.

The third day agenda was high level stakeholder dissemination, where the business model and policy framework were disseminated to the high level stakeholders. Measures on how the government could facilitate the operationalization of business model were decided. This requires a holistic approach that encompasses the entire supply chain, from assessment of biomass potential raw material to demand creation. On the policy front, there was general agreement that bio briquette sector should be a national priority sector and receive its full benefits. Policies need to be revised to recognize ‘briquette’ and ‘pellets’ explicitly. It was also decided that accelerated depreciation and decreased electricity tariffs for bio briquettes would be immediately looked into.

The stakeholder dissemination workshop and training gave way to important aspects to be included for the policy framework and constructed the way forward for the policy framework that would be presented to the MoEWRI for operationalization. The dissemination workshop and training program is an activity under the project “Promotion of Sustainable Use of Biomass Briquettes in Nepal” funded by CTCN and carried out by AIT.

Table of Contents

1. Introduction

According to the National Survey of Energy Consumption and Supply situation of Nepal (2011/ 2012), biomass comprises of approximately 80% of the fuel mix in Nepal (WECS, 2014). Such traditional fuel sources have low energy efficiency and the smoke emitted by these can result in health hazards. Biomass densification is a process that involves the conversion of loose biomass into densified briquettes (>25 mm) or pellets (<25 mm). This process helps alleviate several problems associated with loose biomass- low bulk density, low energy density, poor combustion characteristics, and issues with transportability and storability.

Nepal has an abundance of biomass residues that can be used for the commercial production of biomass briquettes. Fuel briquettes generated by the low-pressure compaction of paper, sawdust, agricultural or yard waste, etc. currently serve as an alternative to firewood, wood pellets and charcoal in developing countries in Africa, Asia and South America (McDougal et al., 2010, Yazdani & Ali). Biomass briquettes are growing as an alternative bio mass energy source in Nepal due to abundance of biomass fuel in present scenario. Low-energy content feedstocks can be compacted, pressed and combusted to produce heat output commensurate with higher energy content fuels in the form of bio briquettes.

Biomass briquette offers several advantages over the traditional bio-fuel, including higher volumetric calorific value, easy collection, transportation, lower cost, accumulation, longer burning duration and cleanliness (Ahiduzzaman, 2007). Biomass densification can bring in several benefits for Nepal including tackling indoor air pollution, energy security, job creation, women empowerment, waste management, prevention of forest fires, and production of cheap and eco- friendly fuel (AEPC, 2017).

Enhanced use of renewable energy is required for sustainable growth in Nepal. However, financial and market barriers, technical barriers, institutional and regulatory barriers are present that obstruct the use of biomass energy at a large scale. A strong policy framework and innovative business models that remove and address these barriers are required to promote efficient utilization of biomass and to enhance national capacities. One key opportunity to harness the potential of biomass energy is to produce briquettes that make them attractive in terms of higher density, heating value and ease of transportation and storage. Currently, the full potential of biomass densification has not been realized in Nepal. Though biomass briquetting has opportunities, a financially sustainable business model is required to continually increase its production, market base, quality assurance and productive use. This model needs to be backed by strong policies that ensure sustainability of the business. Developing such a business model and policy framework needs feedback from various stakeholders including private enterprises involved in the business, end users that the business targets, technology experts who can adapt the technology to local context, development partners that can support financing as well as policy experts who develop integrated policies for the whole sector.

A stakeholder dissemination workshop and training was organized jointly by Asian Institute of Technology (AIT) and Alternative Energy Promotion Centre (AEPC), with funding by Climate Technology Center and Network (CTCN) and supported by Ministry of Forest and Environment (MoFE) and Ministry of Energy, Water Resources and Irrigation (MoEWRI). The workshop was conducted for two and half days, with the first day focusing on business model and policy framework, the second day on technology training and the third day on high level stakeholder dissemination.

2. Stakeholder Dissemination Workshop and Training on 'Promotion of Sustainable Use of Biomass Briquettes in Nepal'

2.1 Objectives of the workshop

The overall objective of the workshop was to gain an overview of the key issues and challenges in bio briquette sector, and how to address them. The specific objectives were:

- To disseminate the proposed business model and policy framework for
- To provide solutions to technology issues faced by private enterprises
- To finalize way forward for operationalizing the proposed business model and policy framework

The agenda of the workshop is given in Appendix 1.

The invitation was sent out to 39 stakeholders from various private enterprises, donor and research agencies, government organizations, and independent consultants.

The stakeholder dissemination workshop cum training was conducted at Dining Park Restaurant and Lounge in Kathmandu, Nepal from 20- 21 June, 2018. The high level stakeholder dissemination workshop was held at the MoFE in Kathmandu on 22nd June 2018. A total of 49 participants attended the program (Appendix 2).

2.2 Day 1: 20th June 2018

2.2.1 Welcome: Dr. P. Abdul Salam opened the workshop by welcoming all the participants and briefly reviewing the agenda of the entire workshop cum training. He then requested all the participants to introduce themselves.

2.2.2 Welcome and Objectives: Ms. Shubha Laxmi Shrestha, Senior Officer (AEPC), welcomed all the participants on behalf of AEPC and described the objectives of the workshop. The workshop is the final output dissemination program based on the consultation workshop that was held earlier in June. The major objective of this workshop is to finalize the three reports produced as a result of the previous workshop: Technology framework, Business Model and Policy framework repots. The first day is aimed at finalizing the aspects of business model and policy framework that need to be presented on the third day at the High Level Stakeholder Dissemination Workshop. The second day would focus on the technological challenges faced by biomass briquetting industries and how to address these issues. The third day would comprise of the Central Coordination Committee members development partners and experts in the industry to come up with concrete policies that can be materialized immediately.

2.2.3 Presentation by Dr. Shobhakar Dhakal:

The first presentation of the day was on business action plan for sustainable biomass briquettes in Nepal. Dr. Dhakal began the presentation stating that equal representation of carbonized and uncarbonized briquette industries is expected for the third day. He briefly reviewed the findings of the previous workshop including the international market for biomass briquettes as well as different business models available worldwide in biomass sector. The models discussed were: developing value chain, cash at gate policy, lease or hire model, third party financing and Results based Financing. He also gave a brief overview of the SWOT analysis that was the outcome of June workshop.

Two business models were proposed for Nepal; one each for charred briquettes and uncharred briquettes. He emphasized on product diversification, raw material diversification and addressing the entire value chain with financing from RBF for the uncharred briquette enterprises. For charred briquette enterprises, he proposed that community based enterprises model should be strengthened, and the role of private sector is important in marketing of products. The presentation is given in Appendix 3.

Overall, some of the key points to be considered or business model in Nepal are:

i. Strengthening of supply chain and demand creation for both types of briquettes
ii. Networking with end users
iii. Phased approach for target setting on quantity of briquettes

iv. Comprehensive approach towards Research and Development

2.2.4 Feedback and Way Forward

The feedback session built on the presentation. Following were the key points discussed:

A. Policy

- Standardization of briquettes and pellets is important, in order for them to be compatible with stoves
- Government's role in business model has to be identified; chiefly in rolling out the business action plan
- More research and capacity building is required on what different raw materials can be used and what are the appropriate raw material and binder combinations and ratios
- African models might not be the best suited for replication in Nepal, as the socio- economic and cultural contexts vary
- Protection of briquetting sector is important, along with technical and financial support
- Public procurement of briquettes can be one avenue for market creation: in institutional cooking and office space heating
- Value chain needs to be shortened so that direct linkages between private sector and end users can be formed. The roles of end users, private enterprises, government agencies and other relevant bodies should be explicitly recognized for this
- Targets for carbonized and uncarbonized briquettes have to be set.
- Transportation costs for briquettes are high
- How the federal/ provincial/ local government laws will affect bio briquetting sector must be addressed. The role of AEPC will be largely to facilitate ad build capacity needed for this
- The value chain model by Bioenergy program was very successful and could be replicated with expansion in the coverage area
- Efforts are required for quality assurance and standards. Differentiated standards for different producers should be developed
- Enabling environment creation by government includes: policy formulation, financing, capacity building, human resources as well as industries support
- It is cumbersome to implement the subsidies for end users. How can producers be supported instead to lower their costs as they are relatively easier to administer and can be beneficial to the industries
- Policy and actions should be recommended on the basis of BEST strategies
-

B. Research and Development

- R&D is primarily focused on industrial consumption only. It has to be done or domestic stoves as well.
- Carbonized briquettes are still used for slow heating. How can R&D support this?
- Information gaps are present between R&D and manufacturing companies. A lot of misinformation is present. Coherent links and networks between R&D institutions and private enterprises need to be established
- Biomass energy is multi sectoral and multi- dimensional, and cannot be driven by a single institution. Identification of raw materials that can be used as feedstock to increase energy efficient use of biomass and replace imported energy is needed.
- VAT exemption should be available for raw materials
- Monitoring and Implementation unit in each ministry should work to streamline information across all agencies

- Effective communication about equipment/ raw materials that need to be imported for briquette should be explicitly recognized for VAT and customs waivers.
- Need to emphasize operationalization of strategy 3.1 of BEST for R&D
- How can the roles and responsibilities be explicitly recognized for R&D, technical matching, awareness, government entry points for Day 3
- Knowledge center for knowledge transfer to disseminate awareness on briquettes (from production to consumption)

C. Consumers

- Consumers lack awareness, because o which commercialization is difficult
- Large scale industries can be potential consumers of briquettes, provided proper marketing and support are available
- How can rural consumers be targeted as main users of biomass fuels?
- Sustainability of briquette business: how can briquettes be sold where they are manufactured? This can reduce the transportation costs and thus reduce price of briquettes
- End users should be incentivized when they opt for cleaner fuels
- Awareness among end users that briquettes comprise of pellets and uncharred briquettes as well needs to be intensively promoted

D. Technology

- End users technology is still lacking. Compatibility of end use devices is a major issue
- Stove modernization needs to be addressed
- Demonstrations should be more intensive and the approach should be diversified to target students, women groups, industries and households
- Designated testing centres should be present

LUNCH BREAK

2.2.5 Presentation by Dr. Shobhakar Dhakal:

The afternoon session commenced with Dr. Dhakal's presentation on policy framework in Nepal. He emphasized on the need to include bio briquettes sectors in Special industries so that they can benefit from all the benefits given to special industries. Policy focus should be directed towards imparting special protection to briquetting sector, including R&D, concession loans and low interest rates, awareness generation and demonstration, explicit mention of briquettes in acts, instrument for technology facilitation to suppliers and end users, and a co- ordination committee for bio briquettes. The presentation is given in Appendix 4.

2.2.6 Feedback and Way Forward

The feedback session was based on the presentation, and following key points were discussed:

A. Fiscal Policies

- Inclusivity of both carbonized and non- carbonized briquettes must be done in policies and acts for the specific businesses.
- Royalty on char should be revised as it is a renewable energy.
- Incentives for products, if made available, could encourage industries to shift towards using briquettes
- Bank interest rates are currently at 14%. Provision should be made for low interest loan
- Cost of electricity used in the industries is high. Provisions for lowering this cost should be made
- Bio briquettes should be made eligible for deprived sector lending

- Public procurement for institutional use of briquettes should be done to create demand of briquettes
- Provisions for fund allocation for R&D in bio briquettes should be done

B. Other Policies

- Standards and certification of briquettes must be done in order to create quality assurance and consumer satisfaction
- An appropriate institutional mechanism should be formed that will work in Nepal' current government frame
- Government's role in forming market linkage is required, from ensuing supply security to demand creation
- Renewable energy portfolio for industries can be established, determining a fixed % of energy input in industries as renewable

The day ended with general agreement that more concrete and specific recommendations must be made on the High Level Stakeholder Workshop.

2.3 Day 2: June 21, 2018

2.3.1 Opening Remarks by Ms. Shubha Laxmi Shrestha

Ms. Shrestha opened the training by welcoming everyone and stating that the aim of this training was to address the technical and technological issues present in Nepal. New participants introduced themselves before moving on to Dr. Salam's presentation.

2.3.2 Presentation by Dr. P. Abdul Salam

The first presentation of the day was on the general outlook on briquetting technologies. The presentation covered various aspects of briquetting, including different types of technologies available worldwide, cogeneration, binder options, raw material selection and torrefaction. Dr. Salam emphasized that it is important to check the end use of briquettes in order to assess market availability for densified fuels. In addition to this, enterprises should also assess if it is more beneficial to use cow dung as a binder or to use it for biogas generation. Current research is focused on reducing the energy input for briquetting, particularly particle size vs. energy input. He also mentioned that in sugar industries, bagasse is used for co-generation, and molasses for ethanol generation. Similar practices could be done in Nepal as well. The presentation is given in Appendix 5.

2.3.3 Discussion and Feedback:

- Feasibility study for mobile pelletizer should be carried out as it could be more suited to the topography of Nepal
- Health impacts of charred briquettes vs. non charred briquettes
- Pellets are more convenient for households and they are more energy efficient
- Gasifier stoves for charred pellets can minimize pollution
- Forced draft stoves for charred pellets can be more energy intensive
- Water circulation system with pellets can be used for hot water

2.3.4 Presentation by Ms. Shubha Laxmi Shrestha and Mr. Prajwal Raj Shakya

In order to give a more precise overview of the issues and problems in Nepalese briquetting sector, this presentation (Appendix 6) emphasized on the work done previously be AEPC and the major issues faced in Nepal. AEPC has conducted several trainings and is likely to work on resource mapping by using GIS. AEPC could collaborate with Renewable Energy Testing Station (RETS) for fuel and stoves testing. A biomass testing centre could be established at NAST, especially the breaking strength of briquettes as the equipment are already available there. One of the problems for resource mapping of forest resources is that government so far only has a comprehensive timber based mapping guideline. However, Bioenergy Project prepared a Resource mapping guideline that can be used as the base by AEPC.

The key issues and challenges face in Nepal include:

- Technical issues: These issues range from lack of proper information on appropriate technologies to issues in repair and maintenance of machinery. A technology support facility is needed that can address all these issues.
- Financial issues: The capital investment is very high with high upfront costs. Lack of soft loans is a pressing issue.
- Market issues: Market linkages and effective networks are missing, particularly for community based enterprises because of which they are unable to operate properly
- Quality issues: Quality assurance is difficult as national standards and certification schemes are lacking
- Raw material issue: Sustainability and availability of raw materials is not ensured which affects supply security

This was followed by a brief feedback session to cover any other issues that the stakeholders deemed important. The additional issues were:

- Lack of awareness among consumers: End users are unware about handling and storage of briquettes. Therefore, exhibitions and demonstrations are necessary to create mass awareness. The location of such exhibitions can play a key role in determining the number of end users reached.
- Renewable Energy Book by AEPC (data book) could be used to address the information gaps and help bring clarity to the real case scenario as a knowledge product for dissemination.

LUNCH BREAK

2.3.5 Presentation by Dr. P. Abdul Salam

After the feedback session, lunch was served which was followed by Dr. Salam's presentation (Appendix 7) on possible solutions and real case examples relevant for Nepal. Dr. Salam stated that it is important to calculate the technical potential, theoretical potential and economic potential of biomass resources and they should be collected near the source itself in order to reduce transportation costs. Also, heat waste should be utilized and volatiles from charcoal briquettes should be recovered and used in order to increase the energy efficiency. Retort kilns for charcoal making can increase volatile substance recovery. However, these are not compatible for shrubs as the volatiles are difficult to capture. Torrefaction could be a better option here. Co- densification could be a potential technology in Nepal as it does not make use of any binder. Dr. Salam also talked about possible dryer technologies that can be used in Nepal, ranging from solar tunnel drying to more advanced options.

After the presentation, there was a brief coffee break which was followed by a feedback and discussion session. The key points of the discussion included:

- Use of mass media such as a mini series or telefilm for reaching a larger mass
- Drying technologies for carbonized briquettes for large capacity briquette enterprises can be based on hybrid systems that are started out as pilot plants
- Standard methods for pellets testing to ensure they do not break during transportation and/ r storage

2.4.6 CLOSING REMARKS

The discussion session was followed by closing remarks:

Mr. Prachin Lal Shrestha thanked everyone for their participation and inputs.

Mr. Chatur Shrestha (from MoEWRI) stated that the Ministry would take further steps in Alternative Energy sector and emphazised AEPC's role in communicating with the Ministry.

Dr. Dhakal thanked the MoEWRI and MoFE as well as CTCN for their support in organizing the workshop cum training program. He emphasized that operationalization of BEST needs pushing from stakeholders and the gaps identified in the two days would be put forward to the high level stakeholders to find appropriate measures to address them. Issues in terms of business models, technology and policy from supply to demand need to be addressed in a holistic manner in order to ensure that biomass briquette is a sustainable sector for the enterprises involved.

2.5 Day 3: 22nd June, 2018

2.5.1 Welcome Remarks

The third day of the workshop was a High Level Stakeholder Dissemination Workshop that was targeted at relevant policy makers, donor agencies and experts. The half day workshop began with welcome remarks by Mr. Ram Prasad Lamsal, who welcomed all the participants and stated that it is imperative to focus on the way forward from the workshop. It was followed by a brief introduction of all the participants.

Mr. Ram Hari Pantha then laid out the agenda of the workshop. He explained how the CTCN project came to be and AIT's role in the project. H also emphasized on the role of AEPC to operationalize the policy framework.

2.5.2 Presentation on Business Models

The first presentation of the day was on business models for bio briquette industry in Nepal. Dr. Dhakal began with the business models in international context and narrowed it down to Nepalese context. He gave a brief overview of the SWOT analysis that had been conducted earlier in January workshop and went on to identify the government's role in financing, demand creation, technology facilitation, end user utilization and resource identification. Government and development partners' role are present in the entire value chain. He also suggested the creation of a Biobriquette Technology Support Facility (BBTSF) that would be the primary technology facilitation and support centre for bio briquette in terms of technology, standards, etc.

2.5.3 Feedback and Discussion

The presentation was followed by a feedback session, where Mr. Ram Hari Pantha asked for feedback on stoves, community forestry and agriculture.

Clean Cooking Stoves could be related with bio briquettes in order to fulfil the Sustainable Energy for All (SE4All) targets. Although previous studies have been carried out and bio briquettes have been a priority for over 20 years, implementation is the real challenge impeding the sector. BEST targets have been set in accordance with the SE4All targets. Conducive environment for fostering renewable energy is necessary and this requires coordination among the relevant government bodies.

Community Forestry is an important source of raw material for briquette industry in Nepal. But the business models should not see community forest user groups (CFUGs) only as raw material suppliers, but recognize and extend their involvement along the value chain. Larger CFUGs in the past have failed because of inadequate market linkages. Therefore, CFUGs must be linked with private enterprises in terms of marketing to foster sustainability. Policies must be revisited to encourage bio- briquetting. The Forest Management Plan must recognize forest residues as a source of bioenergy and the royalty on char must be set accordingly. Likewise, local government royalties when crossing borders must also be determined. MoFE's role in providing technical support for such divisional set ups and the local government's support in raw material collection is significant.

Agriculture sector is another chief sector from which raw material is derived for bio briquette industry. The subsidies that are given in chemical fertilizers could be redirected towards financing bio briquetting.

Solid Waste Management is a pertinent problem in the nation, and is a challenge for all the local governments. Policies could incorporate use of Municipal Solid Waste (MSW) as raw material for bio-briquetting.

Another aspect to consider is mechanizing of the entire process of briquetting/ pelletizing, particularly raw material collection and treatment. Quantification of the raw material potential needs to be done to ensure supply security. It is also very important to assess the commercial/ economic viability of the business models.

2.5.4 Presentation on Policy Framework

The discussions were followed by Dr. Dhakal's presentation on policy framework. This presentation addressed the policy gaps in Nepal and how these gaps could be bridged. A holistic policy framework is required to capture the entire value chain, especially at the grassroot level. This calls for a multi – agency coordination and implementation mechanism. A strategic policy support is required to further push the target of bio briquette production for demand creation, provide special protection for the industry in the form of national priority industry and public procurement of briquettes for institutional use, and creation of a renewable energy portfolio standards for selected industries. Technology support is required to address the practical problems faced in this sector, for which Biobriquette Technology Support Facility is proposed. Fiscal Policy support in the form of tax exemption, electricity tariff support, investment subsidy and accelerated depreciation were also recommended. Likewise, policies for standardization and certification ad R&D are also needed. Further work on how these can be integrated in the working modality of MoEWRI is needed.

2.5.6 Feedback and Discussion

Forestry and Agriculture sectors in Nepal are not considered to be energy providers, which is a huge set- back for briquetting sector. Data is lacking on which sector provides how much raw material. Policy should integrate energy data form biomass. There are conflicting policies (such as permaculture vs. bioenergy use) and this has to be addressed. Briquetting industry is a volume based industry, so working capital subsidy for feedstock collection could help in reducing the investment burden. The industrial Enterprise Act of 2017 has prioritized renewable energy on a national level. This can be used in the favor of briquetting industry. Local government should be made aware on how they can utilize their renewable energy budget for briquettes. Likewise, it is necessary to identify the privileges provided to other fuels and how this affects briquettes.

2.5.7 Closing Remarks

Mr. Ram Prasad Dhital (AEPC) stated that the policy framework should address the entire supply chain. AEPC's role will be to act as a centre of excellence, and it can work with Nepalese Bureau of Standards and Metrology (NBSM) and RETS to ensure quality standards and certification. AEPC can also facilitate the development of renewable energy portfolio development with local governments and develop a technical pool of human resources for monitoring of projects.

Accelerated depreciation for bio briquettes and briquette sector's eligibility for deprived sector electricity tariffs will be immediately checked and acted upon.

Mr. Chatur Shrestha 9MoEWRI) stated that it is important to identify who will own the hurdles in briquette industry and implement the necessary policies. A comprehensive stakeholder analysis is lacking in this matter, especially in terms of sensitivity and the impact it will have are not addressed. White Paper released by the MoEWRI emphasizes on Renewable Energy and this should be included in further review, and regarded as a guiding document.

Lunch was served after this, which ended the two and half day Stakeholder dissemination and training workshop on promotion of sustainable use of bio- briquettes in Nepal.

A few photos from the workshop and training are given in Appendix 8.

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APPENDICES

APPENDIX 1: Workshop Agenda

STAKEHOLDER DISSEMINATION WORKSHOP AND TRAINING ON PROMOTION OF SUSTAINABLE USE OF BIOMASS BRIQUETTES IN NEPAL

Organized by:
Asian Institute of Technology (AIT), Thailand
Alternative Energy Promotion Centre (AEPC), Nepal

Funded by:
Climate Technology Center and Network (CTCN)

Supported by:
Ministry of Forests and Environment (MoFE)/Ministry of Energy, Water Resources and Irrigation (MoEWRI)

Day I (20 June 2018): STAKEHOLDER DISSEMINATION WORKSHOP
Venue: Dining Park Restaurant and Lounge, Mid Baneshwar, Kathmandu

Attended by: Private sectors, Industries, Academicians, Non-government Organizations, policy makers

Schedule:

10:00- 10:30 Registration/ Tea & Introduction of Participants

10:30- 10:40 Welcome/opening remarks

AIT (3 mins) - Welcome
AEPC (3 mins) - Welcome
NDE (3 mins) - Opening remarks

10: 40- 10: 45 Objective of the workshop (Dr. P. Abdul Salam)

10:45- 11:15 Sharing of business action plan for promotion of sustainable biomass briquette use in Nepal (Dr. Shobhakar Dhakal)

11:15- 12: 15 Discussion and Feedback on business model

12:15- 12: 30 Coffee Break

12: 30- 13: 00 Conclude and finalize business model

13:00- 14:00 Lunch

14:00- 14: 30 Sharing of Policy Framework for Promotion of Sustainable Biomass Briquette Use in Nepal (Dr. Shobhakar Dhakal)

14:30- 15: 30 Discussion and Feedback on policy framework

15:30- 15:45 Coffee Break

15:45- 16:15 Conclude and finalize policy framework

16:15- 16:30 Way forward

STAKEHOLDER DISSEMINATION WORKSHOP AND TRAINING ON PROMOTION OF SUSTAINABLE USE OF BIOMASS BRIQUETTES IN NEPAL

Organized by:
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Supported by:
Ministry of Forests and Environment (MoFE)/Ministry of Energy, Water Resources and Irrigation (MoEWRI)

Day 2 (21 June 2018): TRAINING ON BIOMASS BRIQUETTING TECHNOLOGY: Issues, Challenges, Opportunities in and Prospective Solutions for Nepal
Venue: Dining Park Restaurant and Lounge, Mid Baneshwar, Kathmandu

Attended by: Academicians, Municipalities, Non-government Organisations, Private Sectors, Industries, and Women's groups

Schedule:

10:00- 10: 30	Registration/ Tea
10:30- 10:35	Welcome/ Introduction of new participants
10:35 - 11:30	Biomass Densification Technology: The Prospective Solution for Efficient Biomass Resources Utilization (Including successful examples) (Dr. P. Abdul Salam)
11:30- 11:45	Discussion
11:45- 12: 00	Coffee Break
12:00- 12: 30	Biomass Briquetting in Nepal: Current status, issues, challenges and opportunities (Mr. Prajwal Raj Shakya)
12: 30- 13: 00	Discussion
13:00- 14:00	Lunch
14:00- 15: 30	Biomass Briquetting in Nepal: Possible Solutions and Examples (including feedstock preparation, quality control and quality assurance, health and safety measures, and best practices) (Dr. P. Abdul Salam)
15:30- 15:45	Coffee Break
15:45- 16:15	Discussion and conclude technical issues and solutions
16:15- 16:30	Concluding Remarks

APPENDIX 2: List of participants

S.N	Contact Person	Contact address	Organization
1.	Mr. Chatur Bahadur Shrestha		MoEWRI
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22.	Mr. Avadesh Barai	abdeshbarai123@gmail.com	Majgaon Briquette Udyog
23.	Mr. Bishnu Chalise	blc_dc@yahoo.com	Green City Briquette Industry
24.	Ms. Anantaa Pandey	anantaa.pandey@gggi.org	Global Green Growth Institute
25.	Mr. Aditya Parajuli	parajulitea@yahoo.com	Parajuli Tea Industries (P) Ltd.
26.	Mr. Prajwal Raj Shakya	prajwalrajshakya@gmail.com	Expert of the sector
27.	Mr. Shekhar Sharma	ssharma20@worldbank.org	World Bank
28.	Mr. Vishwa Bhusan Amatya	vbamatya@gmail.com	Independent Consultant
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APPENDIX 3: Photo Gallery

Fig 1: Stakeholder Dissemination Workshop Day 1

Fig 2: High level Dissemination Workshop Day 3

Fig 3: High level Dissemination Workshop Day 3