THE BIOMASS BRIQUETTING PROCESS

A Guideline Report

October 2016
Authors

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Foreword


In order to reach these targets, we must support and monitor all stages of biomass production, ensuring first and foremost that the harvesting of biomass from forestry residues or from agricultural residues is done in a sustainable manner. It is also important to note that harvesting of biomass from forestry residues has the added benefits of reducing fire risks and creating rural employment, and harvesting of biomass from agricultural residues may increase revenues for farmers. We must make sure that the technologies that are set up to transform these residues are up to the required technical and environmental specifications.

The Ministry of Energy and Water is committed to focus not only on electricity production from bioenergy, but also on heating as well in order to increase our energy security and provide affordable and sustainable heating options for rural communities. At this stage, and thanks to the pilot projects implemented by the UNDP CEDRO, the country is gathering pace and momentum towards achieving a more sustainable energy system. We are moving forward to understand better the national and natural resources, which may be used to satisfy our growing energy needs.

Arthur Nazarian
Minister of Energy and Water
Foreword

The strategy of the Ministry of Agriculture for the years 2015–2019 included the objective of improving the good governance and sustainable use of natural resources through:

1) Adopting good governance and promoting sustainable use of forests, and;

2) Implementing Lebanon’s forest fire management Strategy and rationalizing the harvest and investment of wood and non-wood forest products.

In addition to establishing an area of forests and rangelands on which a plan for sustainable management was foreseen.

Lebanon’s National Strategy for forest fire management (Decision No. 52) comprised a strategic objective on modifying fire risk through a number of means (e.g., encouragement of sustainable fuel wood collection coupled with incentives for farmers/herders not to burn crop residue and pastures). Also, it addressed the need to develop preventive silviculture and fuel management aiming at reducing the highly flammable biomass and management of the forests to increase their resistance to fires (or reduce their susceptibility to fires). This includes but is not limited to grubbing and pruning, tree thinning, brushwood crushing, prescribed burning, controlled grazing and species selection.

Lebanon’s National Forest Program (2015-2025) operational objective 5 highlighted the importance of developing an action plan to support small entrepreneurs and small forest enterprises through the development of value chains in wood (Activity 5.1) in addition to putting in place a sustainable management plan for the development of the socio-economic values of wood (Activity 5.3).

To this end, I hope that this publication will serve the purpose of further promoting the sustainable harvest and use of biomass from forestry and agricultural residues such that our forests are further protected from risks of fires and in order to increase local sources of employment and revenue.

Akram Chehayeb
Minister of Agriculture
Foreword

The European Union gladly contributed to this innovative project, which looked into biomass briquetting from forest residues in Lebanon. The project provided framework for both analysis and experimentation on this renewable energy source – which is still rarely used in the country. The strong leadership of the CEDRO IV project team and the Ministry of Energy and Water in this pilot operation has led to interesting and promising conclusions that are described in this report.

In the European Union we did similar exercises some years ago, and it was widely acknowledged that increasing the use of biomass in the EU could not only help diversify Europe’s energy supply, but could also create substantial growth and jobs while lowering greenhouse gas emissions. We look forward to witnessing a sustainable development of this promising source of energy in Lebanon, and its direct and indirect positive effects on Lebanon’s socio-economic situation.

Ambassador Christina Lassen
Head of the Delegation of the European Union to Lebanon
Foreword

The present set of reports on the potential use of bioenergy in Lebanon was prepared by the “Community Efficiency and Renewable Energy Demonstration” (CEDRO) project, which supports the country’s efforts towards a national sustainable energy strategy. CEDRO, active in Lebanon since 2007, is funded by the European Union and implemented by UNDP.

Bioenergy which originates from forest and agricultural residues can be fabricated into various forms such as briquettes or logs, and has the potential to be a viable resource for household heating and cooking. Using bioenergy reduces dependence on highly polluting fossil fuels and also plays a vital role in reducing illegal logging. With the increasing risks of forest fires posed by climate change, establishing a value chain for the sustainable harvesting of forest residues for briquette production also serves to reduce this risk. Finally, the production of bioenergy provides sources of rural income to local communities and generates employment opportunities since manufacturing includes labour intensive tasks such as pruning of trees and collection of biomaterial.

Biomass briquette production has a significant growth potential both in residential and industrial markets. Its environmental benefits include sustainable forest management, neutral carbon dioxide emissions balance, and low sulphur emissions. Its other advantages include a high calorific fraction, significant moisture content, and lower ash content. In general, briquettes are an ideal fuel for low consumptions where the higher cost of the fuel is balanced out by the lower investment cost of the simplified heating technologies.

The reports are based on practical knowledge gained by the CEDRO project during the implementation of two pilot projects that introduced systems for briquette production. They provide real-life tools and guidelines on how to manage forest resources in the Lebanese context, how to design and construct briquetting machines, and how to manage the systems. UNDP hopes that these publications can support in expanding the use of such environmentally-friendly technologies and promoting the uptake of sustainable energy resources in Lebanon.

Philippe Lazzarini
UNDP Resident Representative
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1. Introduction to the energy use of wood and agricultural wastes

World population growth and, as a result, its increase in energy demand, together with growing global consciousness about the scarcity of the earth’s natural resources, has turned energy into a precious good - so precious that nowadays international geopolitics are largely associated with access to and control of energy sources. Traditional energy sources are characterized as exhaustible and some of them, especially fossil fuels, have substantial impacts on the natural environment and are the main culprit of climate change. As a global solution, renewable energies play a key and unique role, since they are obtained from natural, regenerative sources that do not deplete; and they also cause minimal to no environmental problems, such as climate change, radioactive waste, acid rain and air pollution.

The sources of renewable energy that have reached full commercial maturity are: solar, wind, tides and waves, rivers, geothermal energy, organic waste and energy stored in vegetation and forests (biomass).

What is biomass? The European Technical Specification CEN/TS 14588 defines “biomass” as “any biological origin material excluding those that have been embodied in geological formations undergoing a process of mineralization.”

Biomass energy use is obtained by converting organic chemical energy into fuels for transportation, heat and/or electricity. World bioenergy supply has gradually increased over recent years (Figure 1). In 2010, the total estimated bioenergy supply was over 50 EJ, corresponding to about ten percent of the total world primary energy supply (IRENA, 2014). A large majority of biomass consumption takes place in residential and commercial premises (such as cooking and heating fuel).

Figure 1. Biomass consumption in the world during the period 1990 to 2010 (source: IRENA).
Through five basic processes: combustion, anaerobic digestion, fermentation, gasification and pyrolysis, biomass can be converted into heat or electricity. This report will focus on the combustion process, specifically on solid biofuel briquette combustion.

**Solid biofuels:** Products derived from solid biomass that can be used in direct energy conversion processes, obtained from biomass by generally physical transformations, such as chipping, grinding or drying, as well as densification in the case of briquettes and pellets.

Biomass consumption worldwide has two clear patterns; on the one hand, it is nowadays the only source of energy for nearly 2.5 billion people worldwide, mainly living in rural areas of developing countries in Asia, Africa and Latin America. Approximately 70% of biomass energy is consumed in developing countries for traditional uses with very low efficiencies (10%-20%). On the other hand, in industrialized countries, bioenergy is mostly untapped and forgotten. Modern uses of biomass for heat and power generation include mainly high-efficiency, direct biomass combustion, co-firing with coal and biomass gasification. These modern uses are rapidly increasing all over the world.

Biomass consumption in industrialized countries is expected to continue growing, since its use compared to other traditional energy sources (especially when used for heating) is less damaging to the environment, while also offering economic savings under certain conditions.

The advantages of biomass consumption make it a great candidate to be chosen as a sustainable energy source in homes and businesses. The use of biomass energy has significant economic and environmental benefits, from saving money on fuel, to enhancing the local economy, to cutting down on pollution attributed to fossil fuels and enhancing forest management through the reduction of fire risks and severity.

In the particular context of Lebanon, where recurrent energy supply challenges need to give way to a substantial promotion of clean energy (the country officially committed to having 12% of its energy consumption from renewable sources by 2020), biomass remains a largely untapped resource.

1.1 Briquettes and other commercial solid biofuels

**Briquettes** - Briquettes are generally 50-80 mm diameter and 150 mm length sawdust cylinders compressed at a high temperature, with a moisture content ranging between 10 to 20%. Other shapes, rectangular or prismatic, are also frequent, depending on the manufacturer. In some cases, they have holes in order to improve their combustion. Briquettes may be composed of crushed and densified wood or composed of crushed, dried and molded charcoal, under high pressure.

*Source: CTFC*
Pellet - It is a type of elongated pelletized fuel, smaller than briquettes, which is manufactured through sawdust pressing, where lignin serves as a binding agent for granules; therefore there is no need to use any other substance than the wood itself to obtain this product. The pressing process gives the pellets a shiny appearance and makes them denser.

Source: CTFC

Charcoal - Solid residue derived from wood carbonization, distillation, pyrolysis and torrefaction (trunks and branches of trees) and from wood by-products, resulting in a solid, fragile and porous fuel with higher calorific value when compared to wood. Its use by mankind goes back to ancient times, practically associated with the use of fire itself.

Source: CTFC

Firewood - Product resulting from forest intervention and the use of small-sized wood or wood that has features that makes it unsuitable for the timber industry. Additionally, firewood may be obtained from agricultural crops such as almonds, hazelnuts, vineyard strains, etc. It is generally used to make simple fires in stoves, fireplaces, and boilers. It is one of the simplest forms of biomass and is mostly used for heating and cooking.

Source: CTFC

Chip - Chip is shredded wood without any additives. To produce chip, a machine that transforms wood splinters into chip is required. The wood that should be chipped comes from trees with poor characteristics that cannot be used by the lumber industry. Another typical source of chips comes from treated wood waste subproducts such as pallets.

Source: CTFC

Almond shells, hazelnut, pine nuts

These biofuels are produced as a by-product from the industrial use of almonds, hazelnuts and pine nuts.

Source: www.briquettesplant.com/almond-shells.html

Other solid biofuels - There are many organic products that have the potential to become solid biofuels. Given the current commercial expansion of biofuels, it is very likely that new products such as biofuels from corn cones, pruning, olive pits etc., the use of which is already being studied, will appear.
1.2 Biomass sources for the production of biofuels

Forests - Forest management and harvesting, both for protection and timber commercialization purposes, are the primary sources of solid biomass fuels, typically as a result of cleaning, pruning and tree felling operations. The drawbacks and/or concerns associated with professional forest exploitation are: dispersion, difficult accessibility, variety of tree sizes and composition, competition in terms of using these sources for other purposes (wood-based panels, industry or paper mills), the presence of impurities (stones, sand, metals) and high moisture content. These factors have slowed down the widespread use of these products as solid biofuels.

Source: CTFC (GAFIB)

Agriculture - Pruning olive trees, vineyards and fruit trees are the main sources of solid biomass from agriculture. The main drawbacks to their use, in addition to its seasonality, are collection optimization and their transportation. Herbaceous agricultural residues are obtained from the harvest of some crops, such as cereals (straw) or corn (stover). Again, source availability depends on its seasonality and variation of agricultural production.

Source: Chambre d’agriculture de Picardie (France)

Forest and agricultural industries’ residues - Chips, bark or sawdust from primary and secondary industries processing wood, fruit stones, shells and other food industry residues (olive oil, pomace, canning, nuts...) form a significant share of many industrial solid biofuels. In these cases, their seasonality is due to variations in industrial activity.

It must be noted that certain residues or by-products should be treated carefully because they may contain other undesirable materials or substances, such as paint, adhesives, inorganic materials (nails, screws, etc.) which affect the quality and safety of the product obtained and the integrity of the process.

Source: CTFC

Energy crops - Energy crops are crops specifically formulated for energy use (typically, fast growing species). There are many experiences related to field experimentation projects, the results of which require some more time to be conclusively assessed. Among the various agricultural herbaceous species likely to become energy crops are thistle, sorghum and Ethiopian canola, and among tree species, poplars, eucalyptus and paulownia, the latter two species having lower water demands than poplars.

Source: CTFC
## 2 Local and international context for briquette use

### 2.1 Briquette definition

According to the international ISO 17225 STANDARD, solid biofuels, fuel specifications and classes, a briquette is a “densified biofuel made with or without additives, having a cubic, prismatic or cylindrical shape, with a 25 mm diameter, produced from woody biomass compression or crushed herb.”

### 2.2 Composition material

Briquettes are made of combustible material obtained from agricultural, forestry waste, or coal dust (Table I). Briquettes are produced by the densification of these raw materials. The densification process is mainly composed of two parts:

- Compaction (reduction of raw material volume)
- Sealing (ensuring that the product remains in a stable, compacted state)

Current regulations (for example ISO 17225), allow the use of specific additives to enhance and maintain briquettes’ compaction. These additives contain starch (rice flour, cassava flour, mashed sweet potato), or molasses and Arabic gum to give greater consistency to the resulting product.

Table I. Most common materials used for briquette production

<table>
<thead>
<tr>
<th>Origin</th>
<th>Raw materials that can be used</th>
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<tbody>
<tr>
<td>Agricultural wastes</td>
<td>Cassava stalk, coconut frond, cotton stalks, corn stalks, straw, millet, oat straw, frond palm oil, rice straw, rye straw, sorghum straw, soybean straw, sugar reed leaves, wheat straw</td>
</tr>
<tr>
<td>Industrial processing residues from agriculture</td>
<td>Cocoa beans, coconut shells, coffee husks, cotton seed hulls, peanut shells, cobs and wrap corns, oil palm stalks, waste from olive pressing, rice ball, sugar cane bagasse</td>
</tr>
<tr>
<td>Forestry development</td>
<td>Leaves, branches and twisted trunks.</td>
</tr>
<tr>
<td>Plantation and forestry residues</td>
<td>Leaves, branches, stumps, roots, etc.</td>
</tr>
<tr>
<td>Wood industry wastes</td>
<td>Sawdust</td>
</tr>
<tr>
<td>Bioenergy crops</td>
<td>Acacia spp, Cunninghahmia lanceolata, Eucalyptus spp, Pinus spp., Populus spp., Platanus spp., Robinia pseudoacacia y Salix spp.</td>
</tr>
</tbody>
</table>

Source: FAO, 2014
2.3  Briquette market

Since the mid-nineteenth century, industrial briquetting methods have been reported. Briquette use has been linked to periods of fuel shortages and times of crisis. During World War II, briquette production from waste wood and other residues greatly expanded in Europe and America. After the War, briquettes lost ground in the market due to cheaper hydrocarbon alternatives.

During periods of high energy prices, such as the 1970s and early 1980s, the use of briquettes was revitalized, mainly in Scandinavian countries, the USA and Canada (D. Aguilà, 2013).

Finally, due to movements combating climate change and global promotion of renewable and clean energies, the use of briquettes is spreading worldwide, steadily growing from 2000 until today.

2.3.1 Domestic (informal) market

Typically, the production and sales of domestic briquettes takes place in local markets, not far from biomass sources (forests, agricultural sites or agro-processing facilities) and the customer’s premises.

These markets are very often the cheapest (and even the only) energy supply option (compared to fossil fuel derived products), and involve many productive stakeholders and dealers who sell to captive customers.

In some developing countries, large manufacturers operating on a regional or even national scale, with centralized production and distribution service and sales points, often produce domestic briquettes.

2.3.2 Industrial market

The market for industrially manufactured briquettes comprises the public sector, private facilities with mid to large consumption rates (above 5 kW thermal), medium-sized commercial and services premises and industries with small and medium energy demands.

Industrially made briquettes have higher energy requirements per customer than residential ones. Although non-densified biomass fuels (e.g. wood chips, or almond shells) are cheaper than both types of briquettes, the latter are less restrictive in terms of space availability, leading to a higher energy value per volume of storage for briquettes compared to non-densified residues. Additionally, it should be noted that distance between selling points and customer facilities is a key factor for the preference of briquettes on non-densified biomass, since the transportation cost (per energy value) of briquettes is lower than non-densified fuels.

An advantage of industrial briquettes over domestic ones is the quality of its properties, especially physical stability and calorific value, which are essential to medium-low energy-requiring facilities. The development of this market is crucial for future innovation, modernization and automation of briquette production and consumption.
2.4 Briquette competitiveness

In Lebanon, biomass briquette production and consumption has a significant growth potential for medium and small installations, both in residential and industrial markets. Furthermore, it would create new employment opportunities and income generation, especially in rural areas. Most crucial of all, collecting biomass for briquettes from forestry residues in particular, if done in a sustainable manner (as is highly recommended – see UNDP-CEDRO biomass inventory and harvesting report), can contribute to improved forest management by reducing the risk of forest fires.

The competitiveness of briquettes in the biofuel market is linked to several parameters, namely, the development of renewable energy in the global market and specifically of biomass compared to fossil fuels. Their advantages are described below:

2.4.1 Environmental benefits

- Using renewable energies can contribute to sustainable forest management.
- Neutral CO₂ emissions balance
- Low sulfur emissions (which usually causes acid rain).
- If it has a forest origin under a proper management scheme, it contributes to forest regeneration and prevention of forest fires.
- If it is sourced from agricultural or industrial waste, it enables a residue with a second life.
- Ash from briquettes burning can be used as fertilizer.

2.4.2 Social benefits

- Creates jobs throughout the supply chain, especially in rural areas, thus preventing rural migration to urban areas.
- If it has a forest origin, it will promote its sustainable management, improving the state of forests:
  - With direct incidence to the decreased risk of fire and the corresponding damages to human health and properties.
  - With indirect incidence in perception of the forest as a source of jobs and wealth creation (e.g. tourism).
- It promotes confidence in renewable energy at local and rural levels.

2.4.3 Economic benefits

- Positive life cycle economic balance, cost €/kWh lower than fossil fuels.
- Decreases the dependence on energy imports, thus favoring greater energy price stability by not depending on international markets volatility.
- Local added value, fostering local or regional businesses along the supply chain (forest operators, transportation and warehousing, briquette manufacturers, dealers, installers and maintenance services providers, etc.).
- Enables the valorization of sub-products and even waste.

b) The ability of briquettes’ competitiveness compared to other solid biofuels with similar characteristics:
2.4.4 Advantages

- High calorific fraction
- Moisture content, density and constant and homogeneous granulometry
- Lower ash content
- International marketing with standardized composition

2.4.5 Disadvantages

- Potentially higher price conditioned by the manufacturing (compaction) process and the availability of other cheaper biofuels closer to the customer premises
3 Technical description

3.1 Briquetting process

Briquettes are essentially manufactured by compressing and compacting forestry, agricultural or industrial origin raw material. Natural compaction of the raw material is achieved by compressing at high pressure, which produces an increase in temperatures leading to a Bakelized surface, which gives a glossy appearance and consistency to the briquettes.

The typical briquette production process includes the following stages: a) milling, b) drying, and c) pressing (or briquetting).

In the following pictures (figure 3), very similar models of machinery are presented with differing specifications such as the channeling in the output of the pressing stage.

Figure 2. Typical stages in briquette manufacturing
Source: http://www.pelletproductionline.es/briquette-press.html

Figure 3. Examples of briquette production lines
Source: http://www.pelletproductionline.es/briquette-press.html
When lignocellulosic materials are used, high temperatures obtained during the compressing stage produce a softening of the lignin, which acts as a binding substance once it cools down and solidifies (figures 4 and 5), thus not requiring any other compacting additives (D. Aguilà, 2013). Still, in case that the obtained briquette lacks consistency and breaks apart, natural (standard) additives can be used.

![Figure 4. Final product](Source: www.jordisegusl.es)

![Figure 5. Compacted material issued from softening, cooling and solidifying of lignin due to high temperature.](Source: http://www.pelletproductionline.es/briquette-press.html)

Depending on the outlet of the briquetting machines, briquettes can have different geometries, but the most typical ones are cylindrical, or prismatic.

![Figure 6. Different geometries of briquettes](Source: http://www.pelletproductionline.es/briquette-press.html)
Briquettes made of charcoal acquire a darker color (figure 7), which can be bleached using lime or other components.

![Figure 7. Briquettes made from wood (left) and charcoal (right)
Source: http://carboneros.org/products/2008-12-22-10-52-09/esp/](image)

### 3.1.1 Storage

One of the key steps of the briquette-making process is the provision and storage of the raw material. It is very important to adequately size the storage capacity in order to compensate eventual problems or seasonal changes in raw material supply, whether planned or not.

Furthermore, it is essential to take advantage of the storage time in order to allow natural drying, thus minimizing the need to dry the raw material to reach the minimum moisture content required for the compressing process.

The storage area must be covered and with sufficient capacity to enable the continuous operation of the installation during the periods of lower supply of raw material (CDI & CRA, 1993).

![Figure 8. Storage in heaps covered by sheds and geotextiles
Source: GAFIB CTFC](image)

Covering the piles of raw material with a geotextile (figure 8) is also a possibility, often cheaper than building sheds. It is also important to store the raw material on cemented floors, especially outdoors, to prevent the mixing of sand, stones or other impurities that can both affect the briquetting machinery as well as the quality of briquettes.

In order to ensure that the moisture content of the raw material is reduced to the required levels for compressing, drying machines are often considered to complement the natural drying achieved during the storage period.
At this point, it is imperative to take into account the type of biomass to create a density suitable for briquette production:

### 3.1.1.1 Forest wood, sliver, wood sawdust
Forest wood and sliver can be stored in pieces (bulk), or chipped, or crushed as sawdust. It must be noted that within wood chips or sawdust heaps moisture content can vary due to physical, chemical, and biological processes. To minimize this variation, trunk storage is recommended for 4-6 months, prior to subsequently proceeding to crushing just before briquetting.

It would be convenient to use sawdust from the timber industry, to minimize the energy used in the production of briquettes process; in principle, this sawdust should have a low moisture content.

### 3.1.1.2 Agricultural waste
Agricultural waste (aka agrowaste) is typically stored in similar ways to forest wood. Depending on the moisture content of agrowaste, in certain cases it may be appropriate to pre-dry or even pyrolyze it before the process of briquetting in order to increase its calorific value. Fluctuations in the supply chains may be more frequent than forest wood, thus making it advisable to consider an oversized storage area whenever possible.

### 3.1.2 Crushing
Crushing is a set of processes that allows the reduction of particle sizes to the needs required by the final energy conversion technology. According to the size of the product, crushed biomass is classified as chopped (50-250 mm), chipped (8-50 mm) or grinded (< 8 mm) (D. Aguilà, 2013).

- **Wood chips**: Biomass in the form of parts with a definite shape produced by a mechanical treatment with razor-sharp tools (CEN/TS 14588).
- **Hog fuel**: Biomass in the form of pieces of variable sizes and shapes produced by crushing tools, blunt roller, hammers and chains (CEN/TS 14588).

The **precrusher** process (optional) is done in robust mechanical machines, not by cutting but by actually pressing. They are used to crush the biomass to sizes that are coarse, and they can contain sieving systems to extract hard materials or impurities (nails, stones).

**Crushers** are machines designed to reduce the size of biomass by moving metallic tools (typically hammers or teeth). The crushers are mounted on the periphery of a rotating cylinder that works at a high speed in order to take advantage of the centrifugal force to enable a more effective impact of the hammer on the material to shred.

**Chippers** are designed to process soft materials, usually tree trunks, wood and wood products not containing hard elements that can reduce solid wood particles through a mechanism of cutting blades. The blades are mounted on a rotating element with high speed.
3.1.3 Drying

In warm climates, it is beneficial to link the storage with natural drying, as aforementioned, with the purpose of reducing the level of moisture content of biomass before the forced drying phase.

**Natural drying**

Natural drying is based on exposing the biomass to favorable environmental conditions to reduce the moisture contents in the biomass without supplying any heat externally. It is achieved by means of a controlled exposure of the biomass to solar radiation, wind and other natural processes such as the thermogenesis.

A traditional way to dry a pile or heap of biomass is based on the utilization of the “chimney effect” (figure 9); such effect is achieved by facilitating the creation of a central, vertical channel inside the heap through which external (dry) air is dragged by natural convection to pass through the biomass and finally come out from the top, like a chimney. While flowing through the moist biomass, the air warms up and drags part of the moisture, thus drying the biomass.

Due to moisture reduction, during storage in piles there is a loss of biomass volume that generally tends to be a 0.5% - 1% per month in cold and temperate climates and 0.75% - 3% per month in warm and humid climates.

Practical recommendations to achieve natural drying with minimum dry matter losses are:

- Make piles not exceeding a volume of 40 to 50 m³.
- Avoid the presence of fine materials that prevent air from entering the pile.
- Check the temperature at the center of the heap or pile and mix the material with shovel when temperatures higher than 60°C are detected.

![Figure 9. The chimney effect – natural drying of a biomass heap.](source)

**Source:** Luis Ortiz, Alejandro Tejada Aprovechamientos de la Biomasa forestal producida por la cadena Monte-industria – Use of forestry biomass from the supply chain Forest-Industry
To initiate the densification process, acceptable moisture content levels should be between 5% and 15% of the biomass weight. Since this moisture content is not achieved through natural drying in temperate or Mediterranean climates, it will have to be completed by forced drying.

**Forced drying**

Forced drying is the industrial process that reduces the moisture content of biomass fuel down to a specified range (5% to 15%) suitable to start densification.

The capacity of a drying system is rated in moisture (water) mass per hour (typically kg/h) that such a system can evaporate.

The design of a drying unit should be determined by taking into account the maximum moisture content of incoming raw material in the process of briquetting and also from the briquetting capacity of the facility. It is important that the design of the drying unit does not create a bottleneck in the briquetting process.

### 3.1.3.1 Direct driers (pneumatic)

In direct driers (figure 10 and 11), biomass is circulated throughout an externally heated tunnel, and is dried by hot and dry air in direct contact with wood. The drying process can be adjusted to the moisture contents and volumes per hour to be dried.

*Figure 10. Schema of a direct dryer*

Source: SPIRAX SARCO, [http://www.spiraxsarco.com](http://www.spiraxsarco.com)

3.1.3.2 Indirect driers (rotary drum or trommel)
In cases of high moisture content (more than 50%), direct driers may not be effective enough. In this case, indirect driers are required that enable a higher retention time and that also enable mixing biomass. Spinning the biomass in a heated, rotating cylinder, typically performs this task. Here, the biomass is dried by contact with the hot internal surface of the cylinder. Regulating the internal slope and the rotational speed controls material movement.

3.1.4 Compacting
The most widely used briquetting technologies are described in the following sections (Aguilà, 2013):
- Impact densification (figure 12) – Piston Briquetting: A piston driven by a flywheel pushes the crushed biomass throughout a cylinder mould. Achieved densities are generally in the range 1,000 to 1,200 kg/m$^3$. 

*Figure 11. Direct dryer
Source: Henan Kingman M&E Complete Plant Co., Ltd. (KMEC)*

*Figure 12. Schema of a piston pressing briquetting machine
Source: BIOMAX Indústria de Máquinas Ltda,
www.biomaxind.com.br/site/en/briquetting/compacting.html*
• Extrusion densification (figures 13 and 14) – Screw Briquetting: This system is based on the pressure of a special screw that pushes raw material within a chamber that becomes progressively narrower. This technology enables the creation of inner holes in the briquettes thus favoring its later combustion.

![Figure 13. Schema of a screw pressing briquetting machine](https://energypedia.info/wiki/File:Figure_7a_screw_presses.jpg)

This system can achieve higher briquette densities, ranging between 1,300 to 1,400 kg/m³. However, this process requires more energy consumption and more maintenance.

• Hydraulic or pneumatic briquetting

Through hydraulic briquetting (figure 15), the pressure is exerted by a cylinder operated by a hydraulic or pneumatic system. This process is commonly used when the raw material has poor quality, such as a high moisture content (above 30%) or when a very detailed definition (clearly cut and shaped) of the briquette form is not required.

Hydraulic briquetting is energy efficient equipment with low maintenance costs. The briquettes density produced by this technology will have a density between 700 and 1,000 kg/m³.
3.2 Briquette consumption equipment

Briquettes can be used as fuel for several types of heat producing devices:

3.2.1 Stoves

Stoves can range from 5 to 30kW of thermal output, and are usually wood, pellet or briquette powered. Such (small) power capacity is suitable for space heating of a single room, or several nearby rooms by using channeled exits. Apart from supplying heat, these stoves can also have a decorative use (figure 16a).

Locally produced stoves are available in the Lebanese market (figure 16b). Biomass briquettes can fuel these stoves.

Figure 15. Schema of a hydraulic pressing briquetting machine

Figure 16a. Wood or briquettes stove
Source: http://www.itrisa.com/

Figure 16b. Wood or briquettes stove
3.2.2 Boilers

- **Low power boilers (figure 17):** Boilers are used to generate heat that can then be transferred to a working fluid (typically water, in domestic premises) to supply space heating circuits and/or domestic hot water circuits. Low power boilers range from 6-60 kW and are recommended for single-family houses or small buildings. The main benefit of these boilers is their reduced size, high efficiency and low cost.

- **Medium power boilers:** Medium power boilers range from 60-150 kW thermal output and are designed to supply heat to residential buildings (apartment blocks) or office buildings.

- **High power boilers:** High power boilers range from 200-800 kW thermal output and are designed to supply heat demands of industrial processes.

- **Thermal power stations:** Thermal power stations have capacities of 1 MW or above, and they are built to produce and supply heat to several nearby facilities or district heating networks.

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**Competitive use range of briquettes**

Medium to high power boilers (above 60 kW thermal output) are optimized machines with the objective of achieving a maximum efficiency, and thus typically require wood chips, which come at no extra manufacturing cost as opposed to the briquettes.

Therefore, briquettes are an ideal fuel for low consumptions where the higher cost of the fuel is balanced out by the lower investment cost of the (simplified) heating technologies.
3.2.3 Sizing

3.2.3.1 Space heating needs
The determination of heating needs of a given space or building is critical to avoid undersizing or oversizing the heating system.

Key parameters for the determination of the space heating demand profile include specific climatic conditions at the site, eventual seasonality, indoor (desired) temperature ranges, the surface areas and volumes of the spaces to be heated, the type of building insulation, and the heat transfer losses within the building envelope.


It is advisable to assess potential measures to reduce the heating demands, such as improving the building walls’ insulation or installing double glazed windows. Any reduction in the heating demand will facilitate the use of smaller (and cheaper) boilers, as well as fuel use.

3.2.3.2 Boiler capacity
Once the heating demand is clear, the following aspects need to be considered when assessing a suitable boiler:

• Efficiency: Commercial boilers are robust and mature products, with a typical efficiency between 80% - 95%. Condensing boilers (commercially mature for natural gas fuel) can achieve an even greater efficiency, and the first commercial models based on wood pellets have been recently released in European markets.

• Peak heating demand: In addition to the average demand, peak heating demand is a key factor when determining the capacity of a convenient boiler.

Certain boiler installation companies offer simple tools to determine the convenient boiler to cover customer needs. One of these tools is presented below:

First, the climatic conditions of the site must be determined (table II):

Table II. Localization for a boiler following climatic conditions

<table>
<thead>
<tr>
<th>MILD CLIMATE</th>
<th>COLD WEATHER</th>
<th>VERY COLD WEATHER</th>
<th>EXTRA COLD WEATHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coastal populations and about 50 km inland</td>
<td>Populations between 50 and 150 km from the coast not exceeding a 500 m altitude.</td>
<td>Populations living 150 km from the coast or located within an 800 m altitude.</td>
<td>Interior and elevations higher than 800 m populations.</td>
</tr>
</tbody>
</table>

Source: adaptation from http://grupobiosan.com/calculamos-tu-potencia
Once the site is identified with the climate it is located in, the next step is to establish the watts per square meter of surface depending on certain parameters of the housing/space that need to be heated. The thermal insulation of the housing/space needs to be considered, whether it is good, medium or non-existent. Furthermore, if the apartment/room is oriented toward the south or the north, it is also an important factor to consider. Other factors that need to be considered are whether the facility is an apartment in an urban area or a detached house in a rural area and whether the house is on the ground or the top floor or if it is in between floors.

From these parameters we can extract a coefficient (table III):

Table III. Heating capacity needs conversion coefficients (W/m²) - Good or medium insulation spaces

<table>
<thead>
<tr>
<th>ORIENTATION</th>
<th>SOUTH</th>
<th>NORTH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat in urban area</td>
<td>Between floors</td>
<td>Ground floor</td>
</tr>
<tr>
<td>Detached house in rural area</td>
<td>----</td>
<td>Between floors</td>
</tr>
<tr>
<td>Mild climate</td>
<td>66</td>
<td>68</td>
</tr>
<tr>
<td>Cold climate</td>
<td>69</td>
<td>71</td>
</tr>
<tr>
<td>Very cold climate</td>
<td>75</td>
<td>77</td>
</tr>
<tr>
<td>Extra cold climate</td>
<td>82</td>
<td>85</td>
</tr>
</tbody>
</table>

Source: http://grupobiosan.com/calculamos-tu-potencia

Table IV. Heating capacity needs conversion coefficients (W/m²) - Without Insulation

<table>
<thead>
<tr>
<th>ORIENTATION</th>
<th>SOUTH</th>
<th>NORTH</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Flat in urban area</td>
<td>Between floors</td>
<td>Ground floor</td>
</tr>
<tr>
<td>Detached house in rural area</td>
<td>----</td>
<td>Between floors</td>
</tr>
<tr>
<td>Mild climate</td>
<td>78</td>
<td>80</td>
</tr>
<tr>
<td>Cold climate</td>
<td>81</td>
<td>83</td>
</tr>
<tr>
<td>Very cold climate</td>
<td>87</td>
<td>89</td>
</tr>
<tr>
<td>Extra cold climate</td>
<td>97</td>
<td>100</td>
</tr>
</tbody>
</table>

Source: http://grupobiosan.com/calculamos-tu-potencia

The coefficients in the tables above (tables III and IV) need to be multiplied by the surface area (in square meters) of the area to be heated to obtain an indicative figure of the necessary boiler power capacity (in Watts) required.
4 Specifications and standards required

4.1 General concepts and terminology

There are several concepts in the supply and demand chain of solid biofuels that need to be known by the producer, transformer, or consumer of solid biofuels and briquettes.

The first of these concepts are weight and volume of the briquettes:

- **Weight**: Weight units used for biofuels are kilograms and the metric ton which, according to the international system of units, are abbreviated (kg) and (t) respectively.

- **Volume**: The main units of measurement of volume of biofuels are:

  - **Solid cubic meter (m³)** is used in reference to the volume occupied only by wood. This unit of measurement is typically used for industrial wood.

  - **Stere** (apparent m³) which refers to the amount of wood contained in a cubic meter of wood and air, whereas the empty space is occupied. It is used for firewood.

  - **Cubic meter stack (stack m³)** is the unit of measure used for perfectly stacked trunks.

  - **Apparent cubic meter (apparent m³)** is the unit of measurement used for trunks and, in general, for chips.

The volume of woodfuels, densified or not, varies with the shape, the size and the arrangement of its parts (table V).

Table V. Weight and volume measurement units used in the marketing of biofuels

<table>
<thead>
<tr>
<th>Unit</th>
<th>Trunks</th>
<th>Woodchips</th>
<th>Pellets</th>
<th>Briquette</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ton (t)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Kilogram (kg)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
</tr>
<tr>
<td>Stere</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>apparent m³ (map)</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>stack m³</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

*Source: Own from Wood fuels Handbook (Biomass Trade Centre 2)*

- **Weight/Volume (specific weight)**: The specific weight is a dimensionless value that arises from the weight/volume ratio. In the case of wood both its moisture influences weight and volume and, therefore, to obtain comparable values, it is necessary to specify moisture content conditions to which measurements are made.

Specific weight anhydrous: $\phi_0 = \text{Anhydrous weight} / \text{anhydrous volume}$

Damp specific weight: $\phi_h = \text{Weight (h\% moisture content)} / \text{Volume (h\% moisture content)}$
Wood moisture: Moisture is the most important parameter from the point of view of energy. The drier the biofuel, the higher its calorific value. The moisture content is also very important when it comes to transportation and storage, given that the more humid the biofuel is, the greater its volume (losing therefore efficiency).

The moisture content of a biomass sample (i.e. the difference between the weight of the wet sample and the weight of the same sample once dried) can be indicated measured in the following ways:

a) Moisture content on a dry basis: It expresses the weight of the water present in the biomass, in relation to the weight of the dry sample ($P_o$):

$$h (\%) = \left(\frac{P_h - P_o}{P_o}\right) \times 100$$

“$P_h$” corresponds to the weight of the biofuel moisture (h), and “$P_o$” is the weight of the same biofuel dried using a stove at 103 °C ± 2 °C until it has lost its moisture (weight stable).

b) Moisture content on a wet basis: It expresses the weight of water in relation to the weight of the biomass sample (Ph).

$$H (\%) = \left(\frac{P_h - P_o}{P_h}\right) \times 100$$

Both moisture content ratios can be obtained from one another, with the following expressions:

$$h = (100 \times H / 100 - H)$$

$$H = (100 \times h / 100 + h)$$

Finally, an equivalence table such as the one presented in Table IV is very useful to quickly relate both ratios.

<table>
<thead>
<tr>
<th>H%</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>30</th>
<th>35</th>
<th>40</th>
<th>45</th>
<th>50</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>h%</td>
<td>18</td>
<td>25</td>
<td>33</td>
<td>43</td>
<td>54</td>
<td>67</td>
<td>82</td>
<td>100</td>
<td>150</td>
</tr>
</tbody>
</table>

For example, a sample of freshly cut wood containing half of its weight in water would have a wet basis (H) moisture content of 50%, and a dry basis moisture content of 100%.

$$T_{yrf} = T_{yrf} + Tyrf \times (M_{ci} \times \frac{1 - M_{cf}}{1 - M_{ci}} - M_{ci})$$

Where,

- $M_{ci}$: Initial moisture content (%)
- $M_{cf}$: Final moisture content (%)
- $T_{yrf}$: Required annual tonnage of residues at $M_{ci}$
- $T_{yrf}$: Final annual tonnage of processed residues at $M_{ci}$
- **Calorific value**: The calorific value is the amount of thermal energy in the combustion of one kilogram of fuel. Calorific value can be given as Lower Calorific Value or Lower Heating Value (LHV) or as Higher Calorific Value or High Heating Value (HHV).

The HHV refers to the overall amount of heat released during biomass combustion; however, a part of this heat will be used in vaporizing the water molecules contained in the biomass (water latent heat). The HHV calculation is performed in the laboratory, by testing with a bomb calorimeter. For this reason the moisture content has such a critical influence in the calorific value of biomass fuel (see Annex II for reference LHV of several biomass types).

The LHV is typically used since it is easier to obtain and it refers to the gross usable energy in the dry biomass (that is, once the moisture has been completely released).

Therefore, HHV is always higher than LHV and both are usually expressed in the following units:

- \( \text{kcal (kilocalories) per Kg} \)
- \( \text{kJ (Kilojoules) per Kg} \)
- \( \text{kWh (Kilowatt hour) per tone} \)

In order to convert units in MJ to kWh and vice versa, a factor of 3.6 is used.

### USEFUL CONVERSIONS AND EQUIVALENCES

<table>
<thead>
<tr>
<th>Units</th>
<th>Conversion Factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 MJ</td>
<td>3.6 = 0.28 kWh</td>
</tr>
<tr>
<td>1 kWh x 3.6</td>
<td>= 3.6 MJ</td>
</tr>
<tr>
<td>1 kcal</td>
<td>= 4.187 kJ</td>
</tr>
<tr>
<td>1 kWh/kg</td>
<td>= 1 kWh/t</td>
</tr>
</tbody>
</table>

**4.2 Concepts related to combustion and heating supply systems**

**4.2.1 Thermal energy**

In the context of solid biomass use, thermal energy is the energy released in the form of usable heat by means of a thermo-chemical process (combustion, pyrolysis or gasification).

The international system of units (SI) includes the Joule (J) and the Watt-hour (Wh) as the thermal energy units.

Other units are frequently used, such as Equivalent petroleum tons (tep), which correspond to the amount of energy released during the combustion of one ton of crude oil.

Units of thermal energy conversion factors (table VII):

#### Table VII. Conversion factors of the most frequent energy units:

<table>
<thead>
<tr>
<th>Units</th>
<th>KJ</th>
<th>Kcal</th>
<th>kWh</th>
<th>tep</th>
</tr>
</thead>
<tbody>
<tr>
<td>KJ</td>
<td>1</td>
<td>0.239</td>
<td>0.278 x 10^3</td>
<td>23.88 x 10^9</td>
</tr>
<tr>
<td>Kcal</td>
<td>4.1868</td>
<td>1</td>
<td>1.163 x 10^3</td>
<td>0.1 x 10^6</td>
</tr>
<tr>
<td>kWh</td>
<td>3,600</td>
<td>860</td>
<td>1</td>
<td>86 x 10^6</td>
</tr>
<tr>
<td>tep</td>
<td>41.87 x 10^6</td>
<td>10 x 10^6</td>
<td>11.63 x 10^3</td>
<td>1</td>
</tr>
</tbody>
</table>
Other common energy conversions are:

- Cal = 1 kcal = 1,000 cal = 4.187 KJ
- 1 J = 0.239 cal
- 1 kWh = 3.6 MJ

### 4.2.2 Power

Thermal power (Q) is the rate of thermal energy supply per time unit. It is expressed in Watts:

$$1 \text{ Watt} = 1 \text{ Joule} / \text{ Second}$$

When considering biomass combustion (in a given stove or boiler), it is useful to distinguish between several power capacities:

- **Rated thermal power (QN):** is the maximum amount of thermal energy per unit of time that can be produced steadily during combustion.
- **Gross power (QB):** refers to the power released by the fuel in the combustion chamber.
- **Performance of the stove or boiler (η):** expresses the ratio between the useful thermal power (QN) and the gross power (QB).

### 4.2.3 Environmental impact

The resulting solid particles after biomass burning can be classified into three main types (table VIII): organic carbon, soot and inorganic ash.

<table>
<thead>
<tr>
<th>Particles</th>
<th>Origin</th>
<th>Particle size</th>
<th>Solubility</th>
<th>Chemical composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organic carbon</td>
<td>Combustion air gap</td>
<td>50-600 nm</td>
<td>It depends on aging</td>
<td>Organic compounds such as hydrocarbons</td>
</tr>
<tr>
<td>Soot</td>
<td>Flaming combustion</td>
<td>20-50 nm</td>
<td>Insoluble</td>
<td>Condensable compounds and elemental carbon</td>
</tr>
<tr>
<td>Inorganic ash</td>
<td>Complete combustion</td>
<td>50-125 nm</td>
<td>Soluble</td>
<td>Alkaline salts, KCl, K2SO4, metals</td>
</tr>
</tbody>
</table>

*Source: Kocback, 2008*

When burning biomass, ash is obtained as a solid by-product. Ash toxicity can be of concern in case of waste wood burning (e.g. painted wood, or wood from building demolition), where the presence of elements like lead or cadmium can lead to water or soil pollution. Ash control and treatment is necessary.

Cleaning systems can significantly reduce the particle emission from biomass-fuelled facilities (table IX); cyclons are the standard equipment used to extract particles from fumes and exhaust gases after combustion. Cyclones can achieve up to a 50% reduction of particle emissions, and the use of several cyclones in series (aka multicyclone) gives a 75% reduction of particle emissions. More complex systems, like electrostatic precipitators can reach an emission reduction above 90%.
However, these systems have a high cost, and therefore cyclones are normally included in mid to large capacity boilers.

Table IX. Reductions in the emission of particles resulting from combustion for different systems of control processes

<table>
<thead>
<tr>
<th>Reductions Rates Achievable with Emissions Control Devices</th>
<th>PM10</th>
<th>PM 2.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Cyclone</td>
<td>50%</td>
<td>5%</td>
</tr>
<tr>
<td>Multi-Cyclone</td>
<td>75%</td>
<td>10%</td>
</tr>
<tr>
<td>Core Separator</td>
<td>29-56%</td>
<td>72-94%</td>
</tr>
<tr>
<td>Fabric Filter (Baghouse) with Cyclone</td>
<td>99%</td>
<td>99%</td>
</tr>
<tr>
<td>Electrostatic Precipitator (ESP)</td>
<td>95%</td>
<td>90%</td>
</tr>
</tbody>
</table>

Source: BERC biomass energy research center - USA, 2011

In terms of atmospheric emissions (table X), agricultural and forestry biomass burning is considered neutral since the emitted carbon dioxide is absorbed by the equivalent mass of growing vegetation.

Table X. Comparison of primary energy contents and CO\textsubscript{2} emission factors of several fuels. - (Source: IDAE, 2011).

<table>
<thead>
<tr>
<th>Fuels</th>
<th>Direct energy consumption</th>
<th>Primary energy</th>
<th>Emission factor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy source</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ttep</td>
<td>Specific weight or volume</td>
<td>tep</td>
</tr>
<tr>
<td>Coal</td>
<td>1</td>
<td>2.01 t</td>
<td>1.14</td>
</tr>
<tr>
<td>Black lignite</td>
<td>1</td>
<td>3.14 t</td>
<td>1.14</td>
</tr>
<tr>
<td>Coking coal</td>
<td>1</td>
<td>1.45 t</td>
<td>1.14</td>
</tr>
<tr>
<td>Agricultural biomass</td>
<td>1</td>
<td>3.34 t</td>
<td>1.25</td>
</tr>
<tr>
<td>Forestry biomass</td>
<td>1</td>
<td>2.87 t</td>
<td>1.25</td>
</tr>
<tr>
<td>Petroleum coke</td>
<td>1</td>
<td>1.29 t</td>
<td>1.42</td>
</tr>
<tr>
<td>Coke oven gas</td>
<td>1</td>
<td>1.08 t</td>
<td>1.14</td>
</tr>
<tr>
<td>Diesel oil C</td>
<td>1</td>
<td>1.092 l</td>
<td>1.12</td>
</tr>
<tr>
<td>Fuel oil</td>
<td>1</td>
<td>1.126 l</td>
<td>1.11</td>
</tr>
<tr>
<td>Natural gas</td>
<td>1</td>
<td>910 Nm\textsuperscript{3}</td>
<td>1.07</td>
</tr>
<tr>
<td>Liquefied Petroleum Gases (LPG)</td>
<td>1</td>
<td>1.763 l</td>
<td>1.05</td>
</tr>
<tr>
<td>Butane</td>
<td>1</td>
<td>1.679 l</td>
<td>1.05</td>
</tr>
<tr>
<td>Propane</td>
<td>1</td>
<td>1.748 l</td>
<td>1.05</td>
</tr>
<tr>
<td>Refinery gas</td>
<td>1</td>
<td>0.85 t</td>
<td>1.12</td>
</tr>
</tbody>
</table>
Solid biomass combustion emits minimum (or no) quantities of sulfur oxides (that have the potential to become sulfuric acid and contribute to the acid rain phenomenon).

Regarding nitrogen oxides, they are through oxidation of the nitrogen content in the biomass and the air. Since biomass is usually burned at lower temperatures than fossil fuels, the formation of nitrogen oxides is also lower. Still however, controlling the biomass combustion process reduces the amount of nitrogen oxides that are released (both the temperature and the air percentage in the combustion chamber).

Incomplete combustion of biomass can lead to the release of small quantities of carcinogenic compounds such as benzopyrene or aromatic polycyclic hydrocarbons. Certified stoves and boilers comply with regulations on carcinogenic compounds’ emissions; however, proper adjustment and manufacturer’s recommendations on maintenance of the burning systems must be observed to minimize these emissions.

**Box 3 - Forest Management: the key to fire (and emission) prevention in Lebanon**

Sustainable forest management is important in order to reduce emissions. Forestry biomass is a local resource, that comes directly from the natural environment and therefore its use must be planned under a proper management plan.

A central aspect of this plan is the improvement of the forest structure, reducing the accumulated biomass and therefore contributing to the prevention of forest fires.

In a wildfire, uncontrolled combustion involves unwanted emissions into the atmosphere, while controlled combustion of the same amount of biomass is a net reduction of emitted particles. According to studies by the United States Environmental Protection Agency (1995), the emission factor of a wildfire is 8.5 g of particles (PM1, PM2.5 and others) per kilogram of dry biomass burned. Moreover, according to Janhäll et al. (2011), the emission factor of a wildfire can be between 5 g and 17 g of particles per kilo of biomass burned. Adopting an intermediate value of these securities, 10 g / kg of biomass burned, considering that in 2007 4,000 ha burned in Lebanon, and taking an average stock of 50,000 kg / ha, one can conclude that in 2007, 200,000 t of biomass were burned that were out of control, emitting 2,000 tons of particles.

### 4.3 Standards

The International Organization for Standardization (ISO) is the agency responsible for promoting the development of international standards of manufacture (both products and services), trade and communication for all industrial branches. Its main function is to seek the standardization of products and safety standards for companies or organizations (public or private) at the international level.

Although ISO is a network of national standards institutes from 163 countries, the standards developed by ISO are not enforceable per se. The International Organization for Standardization is a nongovernmental organization and it does not depend on any other international organization; therefore, it does not have the authority to impose its standards on any country.

The preparation of international standards is usually done through ISO technical committees. ISO standards’ contents are copyrighted, and national certification bodies typically adopt ISO standards into their national standards and regulations.

An ISO regulation that is directly related to biomass briquettes is Regulation ISO 17225.
REGULATION ISO 17225, Solid biofuels. Specifications and types of fuels (Committee responsible for ISO/TC 238, solid biofuels).

It aims to provide clear and unambiguous classification principles for solid biofuels, as a tool to enable efficient trading of biofuels, transparency between selling and buying parties, and to facilitate communication with equipment manufacturers.

4.3.1 Classification of wood briquettes

ISO standard 17225 includes a classification scheme for briquettes made from wood (table XI).

Table XI. Classification of briquettes made from wooden materials - (ISO 17225)

<table>
<thead>
<tr>
<th>Origin and source</th>
<th>A1</th>
<th>A2</th>
<th>B</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (M)</td>
<td>M 12 ≤ 12</td>
<td>M 15 ≤ 15</td>
<td>M 15 ≤ 15</td>
<td>% (m/m) As received</td>
</tr>
<tr>
<td>Ash (A)</td>
<td>A 1.0 ≤ 1.0</td>
<td>A1.5 ≤ 1.5</td>
<td>A3.0 ≤ 3.0</td>
<td>% (m/m) Dry basis</td>
</tr>
<tr>
<td>Density of particle (DE)</td>
<td>DE 1.0 ≥ 1.0</td>
<td>DE 0.9 ≥ 0.9</td>
<td>DE 0.9 ≥ 0.9</td>
<td>g/cm³ As received</td>
</tr>
<tr>
<td>Net calorific value (Q)</td>
<td>Q 15.5 ≥ 15.5</td>
<td>Q 15.3 ≥ 15.3</td>
<td>Q 14.9 ≥ 14.9</td>
<td>MJ/kg kWh/kg As received</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>N 0.3 ≤ 0.3</td>
<td>N 0.5 ≤ 0.5</td>
<td>N 1.0 ≤ 1.0</td>
<td>% (m/m) Dry basis</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>S 0.04 ≤ 0.04</td>
<td>S 0.04 ≤ 0.04</td>
<td>S 0.05 ≤ 0.05</td>
<td>% (m/m) Dry basis</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>Cl 0.02 ≤ 0.02</td>
<td>Cl 0.02 ≤ 0.02</td>
<td>Cl 0.03 ≤ 0.03</td>
<td>% (m/m) Dry basis</td>
</tr>
</tbody>
</table>

The values in columns A1 and A2 refer to fresh wood and waste wood not chemically treated. The A1 class refers to fuels with lower content in ash and nitrogen than A2.

Class B allows the use of processing sub-products and industrial waste from chemically-treated lumber.
4.3.2 Classification of non-wood briquettes

ISO standard 17225 includes a classification scheme for briquettes made from non-wood materials (table XII).

Table XII. Classification of briquettes made from non-wood materials - (ISO 17225)

<table>
<thead>
<tr>
<th>Origin and source</th>
<th>Herbaceous biomass</th>
<th>Fruit biomass</th>
<th>Aquatic biomass</th>
<th>Mixtures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moisture content (M)</td>
<td>M 12 ≤ 12</td>
<td>M 15 ≤ 15</td>
<td>% (m/m)</td>
<td>As received</td>
</tr>
<tr>
<td>Ash (A)</td>
<td>A 6.0 ≤ 6.0</td>
<td>A10.0 ≤ 10.0</td>
<td>% (m/m)</td>
<td>Dry basis</td>
</tr>
<tr>
<td>Density of particle (DE)</td>
<td>DE 0.9 ≥ 0.9</td>
<td>DE 0.6 ≥ 0.6</td>
<td>g/cm³</td>
<td>As received</td>
</tr>
<tr>
<td>Net calorific value (Q)</td>
<td>Q 14.5 ≥ 14.5, Q 4.0 ≥ 4.0</td>
<td>Q 14.5 ≥ 14.5, Q 4.0 ≥ 4.0</td>
<td>MJ/kg, kWh/kg</td>
<td>As received</td>
</tr>
<tr>
<td>Nitrogen (N)</td>
<td>N 1.5 ≤ 1.5</td>
<td>N 2.0 ≤ 2.0</td>
<td>% (m/m)</td>
<td>Dry basis</td>
</tr>
<tr>
<td>Sulfur (S)</td>
<td>S 0.20 ≤ 0.20</td>
<td>S 0.30 ≤ 0.30</td>
<td>% (m/m)</td>
<td>Dry basis</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
<td>Cl 0.10 ≤ 0.10</td>
<td>Cl 0.30 ≤ 0.30</td>
<td>% (m/m)</td>
<td>Dry basis</td>
</tr>
</tbody>
</table>

There are only two kinds of non-wood briquettes (A, B). Both class A and class B have similar net calorific values; however, they differ in terms of moisture, ash, nitrogen, sulfur and chlorine content levels.

The use of additives to enhance the cohesion and stability of the briquettes is permitted, provided that these additives are clearly indicated. They could be used to improve the quality of the fuel, for example, combustion properties, in order to reduce emissions or to make production more efficient.

The use of non-wood briquettes in residential buildings, small commercial buildings and public buildings is not frequent, since applications in this kind of buildings require a fuel of higher quality for the following reasons:

- Small-scale heating systems usually do not have advanced controls and cleaning of the combustion gases.
- Generally, professional technicians do not operate combustion
- They are often in residential and populated zones.
4.3.3 Classification of briquettes by size and shape

Another characteristic of briquettes is their size and shape, whether cylindrical, cubic, or prismatic.

**Cylindrical:** D- Diameter (=L3- Height) L1- Length

![Cylindrical shaped briquettes](image1)

*Figure 18. Characteristic dimensions of cylindrical shaped briquettes*

**Cubic:** L1- Length L2- Width L3- Height

![Cubic shaped briquettes](image2)

*Figure 19. Characteristic dimensions of cubic shaped briquettes*

**Prismatic:** D- Diameter L1- Length L2- Width L3- Height

![Prismatic shaped briquettes](image3)

*Figure 20. Characteristic dimensions of prismatic shaped briquettes*

4.4 Data base of commercial systems suppliers

There are continuous changes in companies engaged in briquettes’ production and/or sale or machinery for their production. A short list of Lebanese and global companies is presented in table XIII.
Table XIII. Data base of briquetting systems suppliers

<table>
<thead>
<tr>
<th>Company</th>
<th>Area of work</th>
<th>Country (headquarters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kfarfakoud Briquette Center</td>
<td>Sale of briquettes</td>
<td>Lebanon</td>
</tr>
<tr>
<td>SOLARNET</td>
<td>Sale of briquettes/ Equipment for briquett</td>
<td>Lebanon</td>
</tr>
<tr>
<td>SEEGER ENGINEERING</td>
<td>Engineering projects with renewable energy</td>
<td>Germany (USA, Spain)</td>
</tr>
<tr>
<td>BARDI</td>
<td>Equipment for briquetting</td>
<td>Italy</td>
</tr>
<tr>
<td>BUGNOT SAS</td>
<td>Equipment for briquetting</td>
<td>France</td>
</tr>
<tr>
<td>EQUIPE JEAN PAIN</td>
<td>Equipment for briquetting</td>
<td>France</td>
</tr>
<tr>
<td>HANTSCH</td>
<td>Equipment for briquetting</td>
<td>France</td>
</tr>
<tr>
<td>NICOLAS INDUSTRIE</td>
<td>Equipment for briquetting</td>
<td>France</td>
</tr>
<tr>
<td>RABAUD SAS</td>
<td>Equipment for briquetting</td>
<td>France</td>
</tr>
<tr>
<td>Baxi</td>
<td>Pellet furnaces and boilers</td>
<td>Sweden</td>
</tr>
<tr>
<td>HERZ Enegietechnic</td>
<td>Manufacture or sale of stoves / boilers</td>
<td>Germany</td>
</tr>
<tr>
<td>WEIMA</td>
<td>Equipment for briquetting</td>
<td>Germany</td>
</tr>
<tr>
<td>UNTHA Shredding Technology</td>
<td>Equipment for briquetting (wood shredders)</td>
<td>Austria</td>
</tr>
<tr>
<td>CUÑAT, S.L.</td>
<td>Equipment for briquetting</td>
<td>Spain</td>
</tr>
<tr>
<td>C.F. Nielsen</td>
<td>Equipment for briquetting</td>
<td>Denmark</td>
</tr>
<tr>
<td>WEKOTOR Torun</td>
<td>Equipment for briquetting</td>
<td>Poland</td>
</tr>
<tr>
<td>SIGMA THERMAL</td>
<td>Engineering projects with renewable energy</td>
<td>(USA/India)</td>
</tr>
<tr>
<td>FEECO international</td>
<td>Equipment for briquetting</td>
<td>(USA/Australia)</td>
</tr>
<tr>
<td>Sherwood Industries</td>
<td>Manufacture or sale of stoves / boilers</td>
<td>USA</td>
</tr>
<tr>
<td>K.R. Komarek Inc.</td>
<td>Equipment for briquetting</td>
<td>USA</td>
</tr>
<tr>
<td>LIPPEL</td>
<td>Equipment for briquetting</td>
<td>Brazil</td>
</tr>
<tr>
<td>PANDA</td>
<td>Equipment for briquetting</td>
<td>China</td>
</tr>
<tr>
<td>SD Group</td>
<td>Equipment for briquetting</td>
<td>China</td>
</tr>
<tr>
<td>Lehra Fuel-Tech Pvt. Ltd.</td>
<td>Equipment for briquetting</td>
<td>India</td>
</tr>
<tr>
<td>HARSHAD ENGINEERING</td>
<td>Equipment for briquetting</td>
<td>India</td>
</tr>
<tr>
<td>NovinFirewood</td>
<td>Sale of briquettes</td>
<td>Iran</td>
</tr>
</tbody>
</table>
5 Operation and maintenance requirements

5.1 Components of the briquette production facilities

In order to discuss the key operation and maintenance aspects in briquette production, the production processes shown in Figure 21 below will be used as a reference:

![Figure 21. Typical production processes of wood briquettes (top) and charcoal briquettes (bottom) from agricultural and forestry waste (right-side figure)](http://www.woodbriquetteplant.com/)

5.1.1 Moisture control prior to biomass processing

As discussed in Section 3.1.3, controlling moisture content is a critical aspect to determine the dryness of the biomass and its readiness to be processed into briquettes. Moisture meters can be either fixed or mobile.

Fixed moisture meters are typically located in laboratories or test rooms; samples of the stored biomass stocks are then taken to the meters for a moisture content check. Typically, fixed meters also provide information about bulk density and dry weight (tons/m³), and most models are prepared for automated data recording and communication with computers and/or printers. Some models are even prepared to print a small report.

![Figure 22. Fixed moisture meter](http://www.humimeter.com/es/bioenergia/humimeter-bma/)
Mobile moisture meters can be brought to the biomass storage areas, thus enabling a quicker check of moisture contents “in situ.” Spear type sensors are typically used to facilitate the measurement of moisture inside a biomass heap or stockpile, and at different depths. Mobile meters can also incorporate data logging, and are prepared for communication with computers and printers.

The maintenance required by the mobile moisture meter is higher than the fixed ones. The spear sensor is the most sensitive part, therefore this component should not be hit hard, cleaned after every use and should be kept without resin or any other substance that could stick to the spear and mask the moisture content measurement.

5.1.2 Milling

Biomass milling is done by crushers or chippers, depending on the desired size of the resulting material (refer to section 3.1.2).

The main components of crushing machines (figure 24) are: the grinding chamber, the rotor hammers (crushing elements), the grate (that can be perforated to sieve the crushed bits in different sizes), and the ventilator that sucks the crushed biomass out of the crushing chamber.

With respect to chippers, the main components are: the feeding roller and platform, the chipping chamber, the cutting blade, the sieve grate and the recovery platform.
In terms of maintenance, the main components subject to severe wear are the grinding elements (hammers, blades); despite being built with highly resistant materials (typically steel), a frequent check up on their condition is important (and replacement in case of low performance), together with the prevention of metallic elements or stones from entering into the crushing and chipping chambers. The grates and sieves must also be inspected regularly to ensure that there are no obstructions to the crushed or chipped biomass outlet, which affects the output of the process as well as potentially damaging the grate or sieve.

5.1.3 Drying

As discussed in Section 3.1.3, there are two main types of driers: direct and indirect.

5.1.3.1 Direct driers (pneumatic)

The main components of driers are:

- **Hot air source** – The hot air flow that will dry the biomass needs to be produced, either on purpose (through a boiler run on part of the pre-dried biomass), or by using waste heat coming from a cogeneration unit or another nearby heat source if available.

- **Drying channel** – The dimensions (diameter or height, length) of the space where the biomass will be dried need to be adequate to ensure that the moisture content will be reduced to the specified levels for briquetting. Typically, biomass is conveyed by means of moving belts or platforms.

- **Cyclone separator** – The air flow used to dry the biomass will drag solid particles that need to be extracted and collected via cyclones.
5.1.3.2 Rotator drum (trommel) or indirect driers

In case of high moisture contents (over 50%), rotator driers are used. The particular characteristic of these units is that the drying channel is cylindrical and can rotate at variable speeds, enabling biomass mixing and a prolonged contact with the hot air flow.

Some trommels can have a fire prevention system, typically based on water spraying.

Driers (both direct and indirect) are automated units, which typically require professional and specific maintenance. The main potential problems are related to a backlog of feeding biomass to the feeding hoppers (inlet to the drying chamber) or problems related to the hot air sourcing.

5.1.4 Briquetting

Briquetting technologies have been presented in Section 3.1.4. The most important components, following the chosen technology are:

5.1.4.1 Piston briquetting

The major components of briquetting piston units (figures 12 and 26) are:

- Biomass hopper: where the crushed biomass is stored, ready to be compacted into briquettes. Automated valves control the amount of biomass to be dispensed into the compacting cylinder to manufacture briquettes in batches.

- Pressing cylinder, piston and matrix: the chamber where the densification of the briquette takes place by the pressing action of a piston. At the end of the cylinder, a matrix with the desired shape of the briquettes is fixed.

- Flywheel: the rotating element that drives the piston movement. The flywheel is used to store kinetic energy to support continuous and stable operation.

Figure 26. Piston briquetting units in series in a Brazilian briquette factory

Source: LIPPEL  http://www.lippel.com.br
In terms of maintenance, it is important to periodically inspect that no remains of biomass are left in the cylinder, which could affect proper compacting of the briquettes being produced. Moving elements will also require periodic lubrication and checking up of the rotating mechanisms.

5.1.4.2 Densification by extrusion - Screw briquetting machine.

The major components of the screw type briquetting (figure 27) units are:

- Hopper, which collects the crushed biomass prior to densification.
- Extrusion screw (figure 28), which is the element responsible for moving and compacting the biomass.
- Extrusion matrix (figure 29). It is the area where the densification of the briquette is produced; its shape determines the form of the briquette.
- Briquette cutter, cuts the briquettes in a fixed length.
- Control panel hosts the electrical circuits and protects the machine that powers the moving parts of the unit, as well as the electronics that govern the whole system.
The main maintenance concerns of screw briquetting machines are to (1) ensure that there are no traces of adhering resin on the screw and matrix, and (2) to check the condition of the cutter’s edge, making sure it maintains its sharpness and cleanliness in order to neatly cut the briquettes. Moving elements will also require periodic lubrication and checking up their rotating mechanisms.

5.1.4.2 Densification by extrusion - Screw briquetting machine.

The components of hydraulic briquetting systems (figure 30) are very similar to the other types of briquetting units discussed above (hopper, control panel, matrix) with the exception that with this technology a hydraulic or pneumatic system moves the piston.

The advantages of this type of briquetting machine are its low energy consumption, and the fact that it accepts thicker and more heterogeneous biomass, or biomass with a higher moisture content. The result is a less dense briquette and with an unstable shape compared to other densifier technologies.

Another advantage is the relative lower maintenance required, basically limited to the checking up of eventual material adhesions in the cylinders and matrix.

5.1.5 Packaging

5.1.5.1 Briquettes packing with thermosealing

A frequent semi-automatic technology is the packing of briquettes in plastic bags and then sealing them by applying heat to melt and close the plastic (figure 31) bags.
The only maintenance required here is the regular checkup of the bag’s sealer condition and cleaning loose pieces of plastic.

Fully automated briquette packaging technology (figure 32), which usually wraps the briquettes in plastic or cardboard boxes is available on the market. The transfer of briquette bags unto pallets is done manually.

This type of equipment does not require significant maintenance.

5.1.5.2 Pallet wrapping machine

A pallet wrapping machine gives the briquettes a standard form to facilitate storage and subsequent distribution to end users. This machine wraps the contents of the pallet with a plastic layer (figure 33 and 34).

The main components of this machine are:

• The turntable deposition pellet. When operated, it rolls around itself.
• The arm containing the carriage roll plastic, and in the case of automated models, the sensor that detects the end of the packaging, and the dashboard.

The pallet wrapping machines require no maintenance except ensuring the replacement of the plastic rolls.
5.2 Briquette consumption equipment components

5.2.1 Stoves

The main components in most non-automated stoves are (figure 35):

- Combustion chamber: where combustion takes place; it must be well insulated to avoid thermal loss.
- Ash collection container: at the bottom of the stove, it collects the ashes that fall as a result of gravity and it must be emptied regularly.
- Fumes pipe or chimney: extracts the smoke to an outdoor area; it can be used as a heating pipe.
Additionally, in stoves with some kind of automation, other typical features are:

- **Biomass feeding system:** It consists of a briquette storage space (or hopper) and dispensing mechanism, which progressively releases the briquettes into the combustion chamber. It must be noted that for an automatic feeding system to be effective, briquettes must have uniform dimensions.

- **Front and rear air outlet,** where usually the hot air outlet is produced by the front and top part of the stove but the back part has one or two outputs that can be channeled to other parts through fans (depending on the temperature required of the stove and the temperature of the space to be heated, fans can operate at higher or lower speeds).

- **The control panel,** usually located at the top of the stove.

In terms of maintenance, non-automated stoves require the removal of ashes and cleaning the fumes pipe. Since briquettes have lower moisture content than wood logs, cleaning the fumes pipe or chimneys will be less recurrent in briquette stoves compared to traditional fire places.

In the case of automatic stoves, since their operation is more optimized, cleaning fumes pipes will even be less recurrent than in non-automated ones. It is important not to leave remnants of briquettes or too much dust in the hopper, which could obstruct the briquette feeding into the combustion chamber.

### 5.2.2 Boilers

The principal components of briquette boilers (figure 36) are very similar to the systems described for automated stoves (Briquette feeding system (figure 37), combustion chamber (figure 38), control panel, ash collection container).

*Figure 36. Boiler main components*
*Source:* http://www.todoencalefaccion.com/
Specific components of boiler-based systems are (figure 36):

- Heat exchanger: It is the device that enables the heat transfer at high efficiencies between the fumes from briquette combustion and a working fluid (typically water) that is then used to run a heating system. Tubular exchangers are the most widespread, although there are several other types of heat exchangers in boilers.

- Hot water storage tank: It is a thermally insulated water tank, connected directly to the boiler return via a special pump. This entails that the stored water in the tank is heated up in the boiler and then circulated within the heating system. Having a storage tank allows the boiler to operate at rated capacity (and high efficiency), avoiding interruptions due to insufficient demand for energy in the heating system and acting as an energy buffer to balance an eventual depletion of briquette input in the boiler. The high thermal inertia of the storage tank enables a longer heating capacity, even with the boiler off (e.g. early morning).

A precondition to optimize the operation and maintenance of boilers is the correct choice of the boiler power capacity. Proper sizing enables operation under the most efficient conditions, reduces the need for ash management and boiler cleaning. Users can perform the basic maintenance tasks (such as emptying the ash collector trays). Authorized maintenance technicians conduct more specific tasks (e.g. adjustment of the feeding system, checkup of the heat exchanger).

Table XIV below shows the main preventive maintenance tasks for briquette boilers.
<table>
<thead>
<tr>
<th>OPERATION</th>
<th>PERIODICITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boiler stamped data revision</td>
<td>t t</td>
</tr>
<tr>
<td>PH measurement of the boiler water</td>
<td>t t</td>
</tr>
<tr>
<td>Verification of the safety valve</td>
<td>t t</td>
</tr>
<tr>
<td>Review of the expansion vessel</td>
<td>t t</td>
</tr>
<tr>
<td>Review of water treatment systems (if applicable)</td>
<td>t t</td>
</tr>
<tr>
<td>Checking the refractory material (if applicable)</td>
<td>2t t</td>
</tr>
<tr>
<td>Checking water pressure in the circuits and the boiler</td>
<td>t m</td>
</tr>
<tr>
<td>Leak test in circuit piping and household</td>
<td>-- t</td>
</tr>
<tr>
<td>Inspection and cleaning heat recovery equipment</td>
<td>t t</td>
</tr>
<tr>
<td>Inspection and cleaning of air impulsion and return units</td>
<td>t t</td>
</tr>
<tr>
<td>Status check, availability and stamping of fire prevention elements</td>
<td>t t</td>
</tr>
<tr>
<td>Review of the thermal insulation status</td>
<td>t t</td>
</tr>
<tr>
<td>Revision of the automatic on and off control system</td>
<td>t 2t</td>
</tr>
<tr>
<td>Checking the status of the solid fuel storage (by user)</td>
<td>w m</td>
</tr>
<tr>
<td>Opening and closing of the foldable container in solid fuel installations (by user)</td>
<td>t t</td>
</tr>
<tr>
<td>Cleaning and removal of ashes in solid fuel installations (by user). Visual inspection of the biomass boiler (by user)</td>
<td>w m</td>
</tr>
<tr>
<td>Checking and cleaning, if necessary, of the combustion chamber, flues and chimneys in biomass boilers</td>
<td>t 2t</td>
</tr>
<tr>
<td>Checking the work thermostat adjustment and action</td>
<td>t t</td>
</tr>
<tr>
<td>Checking the temperature security adjustment and action</td>
<td>t m</td>
</tr>
<tr>
<td>Checking the ignition system of biofuel</td>
<td>t t</td>
</tr>
<tr>
<td>Verification of the combustion gas extractor</td>
<td>t t</td>
</tr>
<tr>
<td>Verification of performance of safety circuits and interlocking</td>
<td>t t</td>
</tr>
<tr>
<td>Cleaning of the afterburning dome</td>
<td>t m</td>
</tr>
<tr>
<td>Control of wearing parts (if applicable) or by manufacturer indications</td>
<td>t m</td>
</tr>
<tr>
<td>Control of runner plates (where applicable)</td>
<td>t m</td>
</tr>
<tr>
<td>Check safety installations against combustion retreat (where applicable)</td>
<td>t m</td>
</tr>
<tr>
<td>Control the cleaning of the combustion remnants</td>
<td>t m</td>
</tr>
<tr>
<td>Cleaning and inspection of the safety cap against combustion retreat</td>
<td>t m</td>
</tr>
<tr>
<td>Lubricate all bearings and chains</td>
<td>t m</td>
</tr>
<tr>
<td>Measurement of flue gas and creation of a measurement record (from 01.10.2006)</td>
<td>t m</td>
</tr>
<tr>
<td>Cleaning and checking the sealing of the door</td>
<td>t m</td>
</tr>
<tr>
<td>Cleaning and checking the biofuel feeding auger (not briquettes) and ash removal</td>
<td>t m</td>
</tr>
<tr>
<td>Cleaning and checking the wiring and sensors condition</td>
<td>t m</td>
</tr>
<tr>
<td>Electrical connections verification and tightening</td>
<td>t t</td>
</tr>
<tr>
<td>Verification and adjustment of the ventilation motor thermal protection</td>
<td>t t</td>
</tr>
<tr>
<td>Checking grounding boiler connections and electrical systems for transport biofuel</td>
<td>t t</td>
</tr>
<tr>
<td>Checking warning lights and replacement if necessary</td>
<td>t t</td>
</tr>
<tr>
<td>Checking switches, contactors, relays and electrical protection</td>
<td>t t</td>
</tr>
<tr>
<td>Checking the status and operation of the boiler room ventilation</td>
<td>t t</td>
</tr>
</tbody>
</table>
Key:
w: once a week; m: once a month, the first at the beginning of the season
t: once a season (year); 2t: twice a season (year), one at the beginning of it, and the other at a half of the period of use, provided that there is a minimum difference of two months between both.

Unlike natural gas and diesel, biomass combustion generates ashes. Therefore, a device for removing them is necessary (figure 39). Wood ashes are not dangerous and are often used as fertilizer. In urban environments, they can be discarded in trash. In any case, local regulations must be applied.

5.3 Health and safety

Health and safety (H&S) regulations apply both to briquette production and briquette consumption.

5.3.1 Health and safety measures in briquette production

The main protection elements to be used during briquette production are listed below:

- Reflective vests: to facilitate staff visibility within biomass transport and manipulation operations, which often involve the use of vehicles or bulldozers.
- Safety boots: to prevent injuries to legs and feet caused by heavy objects that may fall, such as a pallet of briquettes.
- Technical gloves: to prevent hand injuries due to contact with biomass splinters, mechanical parts or hot parts in the machinery.
5.3.2 **Health and safety measures in briquette consumption installations**

In stoves and boilers it is advised to use the following protective elements:

- **Technical Gloves**: It is recommended to wear protective gloves due to the high temperatures that may be present around the combustion chamber and the ash collection trays.

- **Hearing protection**: Stoves and domestic range boilers typically include internal noise reduction systems, making them quieter than diesel and, in general, have no problems related to noise level. However, large capacity boilers (industrial range) can cause problems with vibrations transmitted to the building structure (equipment on the floor, or vibration transmission through pipes). In any case, hearing protection is advisable for staff exposed to vibrations for long periods of time.
6 Potential in Lebanon.

6.1 Resource availability

After conducting a generic description of Lebanon’s forests, there are mainly oak and pine forests. In addition, there is the presence of other forests, namely broadleaf and other conifers, including juniper and cedar.

Lebanon’s land occupation map, which was conducted in 2001 (LEDO project), indicates that oak represents 55% of forest cover, followed by pine (12%), juniper (9%) and cedar (1%). Mixed forests account for 19% and the rest accounts for 4%.

Going into more detail, the document “State of the Lebanon’s forests,” which was put together by the Association for the Development and Conservation of Forests in 2007, shows that:

Lebanese mountains are characterized by the presence of a considerable number of species, which may be regarded as relics of past humid vegetation and are still growing sporadically in the remaining forest patches.

In Lebanon, as in most Mediterranean countries, wood does not constitute a major forest product due to the present structure, cover and distribution of forests. No value is given to the commercial growing stock since timber harvesting is currently forbidden in Lebanon. However, some Lebanese tree species, like cedars, junipers and some oaks, have a potential of producing very good quality wood.

Major wood production in Lebanon uses oaks and to a lesser extent pines. In Lebanon, there are around 62,000 ha of oak forests. Every 100 m$^2$ of oak trees generally produces two tons of oak wood. The current price of oak wood is at US$ 150 / ton, and therefore the estimated economic value of oak wood in Lebanon is 1.86 billion US dollars.

Furthermore, every ton of oak wood can produce approximately 250 kilograms of charcoal. At the current price, the economic value of oak in Lebanon, if used for the production of charcoal, is US$ 2,067,700,000 (3,100,000,000,000 L.L.).

On the other hand, annual pine wood production is approximately 4,000 tons with a value of US$5/kilogram. This rate values yearly pine wood production at US$ 20 million. The MoA has recently revised the laws related to wood production. As a result, the ban on the production of charcoal has been cancelled to allow controlled exploitation.

Charcoal production, in addition to its contribution to the reduction of highly flammable biomass, is expected to contribute to poverty alleviation, if managed in an environmentally sustainable way. Lebanon’s forests are subject to different types of threats that are rapidly leading to their decline. This decline is represented by the fact that more than 35% of the initial forest cover in Lebanon has deteriorated over the past 40 years.

In 1999, Lebanon’s wood expenditure was estimated at 140 thousand tons and coal consumption at 1,560 tons (MOE / GEF / UNDP 2002). Nothing suggests that this data has decreased; in contrast, it may have increased. Given that four tons of wood are equivalent to one ton of carbon (FAO, 2010), then the total amount of wood consumed is estimated at 146,200 t or 52 KTEP (1996 IPCC). In addition, we should add 90 TEP of biomass that was used as fuel for heating and cooking from agricultural products and manure.
Broadleaf species exploitation is authorized in Lebanon; however, conifers cannot be exploited (FAO, 2010). According to official estimates published by the Ministry of Agriculture, based on the operating permits granted, the amount of wood for heating amounted to 11,000 tons, assuming a margin of 60% for illegal exploitations (FAO, 2010).

Therefore, the 2010 MOA figure (11,000 tons) is clearly below the figure adopted in 1999 by the MOE and the difference cannot be compensated by the fruit trees uprooted, which indicates that illegal logging is much larger than presumed.

This illegal activity involves environmental problems resulting from uncontrolled tree pruning, including conifers. Also, when the combustion of biomass is conducted in conventional stoves in confined spaces, particularly when the biomass has not been properly dried, it poses a serious health hazard. In terms of agriculture, Lebanon has a very favorable situation for the expansion of agriculture, because of its water availability and fertile land. In fact, Lebanon has one of the biggest proportions of arable land among all the Arab countries.

Nevertheless, its agricultural sector is not developed; it only employs about 12% of the total Lebanese workforce. In relation to GDP, it only contributes 11.7%, which places agriculture at the bottom of the economic sectors. (Bilan energetique du Liban 2008, AIE)

As a result, we can deduce that the forestry and agricultural sectors (and associated processing industries) have potential growth. And in turn, the increase in biomass is potentially usable for obtaining heat.

### 6.2 Local market status

According to data from the Lebanon’s Energy Inventory, conducted by the IEA in 2008, Lebanon is a poor country in energy resources since it imports about 97% of its energy needs. Its primary energy supply largely depends on liquid hydrocarbons.

Energy availability depends on access to affordable energy. Energy availability has an impact regarding the natural environment, which is abused during times of crisis. For example, in 2008, in order to cope with the rising price of oil, a large number of people, mainly in rural areas, stocked up on firewood from nearby forests or even their own yards to keep their homes warm.

Lebanese laws related to energy, energy efficiency and renewable energy are practically non-existent. For many years, Lebanon has neither had laws, nor a national action plan for energy efficiency and renewable energy. But in recent years (2005-2010), the country has made significant progress in terms of energy efficiency and development of renewable energy by developing pilot projects, which have had a positive impact on the country. Lebanon has developed a national action plan (The National Energy Efficiency Action Plan (NEEAP)) as a strategic document to mark the way forward when it comes to energy efficiency, promoting renewable energies and attaining the 2020 target where 12% of the country’s total energy will be renewable energy. Although this action plan is considered a breakthrough, we must bear in mind that there is room for progress since this document does not address the use of biomass as a source and form of energy.
The laws listed below have been identified as the most important:

Law 92/2010, which prohibits any use of burnt land to prevent purposeful hazardous acts that cause forest fires to take advantage of the wood or divert the use of the land.

Decree 8803/2002 and its amendments related to the quarries sector in Lebanon. Its purpose is to control quarries because the quarry sector is chaotic and it is devastating to environmental resources and landscapes.

Law 132/2010 regarding exploration activities for oil and gas in Lebanese territorial waters.

CEDRO project, which started in 2007 in order to promote energy efficiency and renewable energy in Lebanon, through market incentives that promote the installation of efficient and renewable energy sources and it assisted in drafting a national strategy for bioenergy (National Bioenergy Strategy for Lebanon, 2012).

Lebanon is in a deep crisis in terms of energy availability (table XV) to the extent that it is indisputable that chronic shortages in this regard affect the country’s economic development. Quotidian electricity outages, that are often prolonged, are the result of an insufficient energy production capacity.

The growing concern about carbon footprints and recent international agreements concerning greenhouse gas emissions have had an effect on the way the country faces issues relating to its future energy supply.

Table XV. Main sources of primary energy in Lebanon in 2008 - (Source: Table made from data of the Lebanon energy inventory)

<table>
<thead>
<tr>
<th>Energy source</th>
<th>Origin</th>
<th>% primary energy input (2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquid fuels</td>
<td>Importation</td>
<td>95</td>
</tr>
<tr>
<td>Gas fuels</td>
<td>Importation</td>
<td>95</td>
</tr>
<tr>
<td>Electricity</td>
<td>Importation</td>
<td>1.2</td>
</tr>
<tr>
<td>Hydroelectric energy</td>
<td>Local</td>
<td>0.6</td>
</tr>
<tr>
<td>Biomass</td>
<td>Local</td>
<td>2.1</td>
</tr>
<tr>
<td>Alternative energies</td>
<td>Local</td>
<td>1</td>
</tr>
</tbody>
</table>

Among these sources of energy, only biomass and alternative energies have the advantage where they can be stored for a period of time, while the rest have to be used immediately.
Contrary to a common perception, both globally and in Lebanon, the main energy consumers are buildings (table XVI). And in Lebanon, it is assumed that buildings are responsible for 0% of the CO₂ released nationwide.

Over 90% of these buildings are located within a 500 m altitude, and the country has a 2% annual rate of new construction (CDR-NLUMP, 2004). The buildings are characterized as being poorly insulated and by having generally ineffective heating and cooling equipment.

In 2007, approximately 56% of households were using hydrocarbons for heating and 18% used biomass (firewood and charcoal).

It is virtually impossible to separate Lebanon’s socio-economic development from the impact that energy consumption will exert on the environment, based on three patterns:

- A progressive transfer to cleaner energy sources including renewables is required.
- Development of energy efficiency in key sectors of the economy (tertiary sector, transportation, industry and agriculture).
- Adoption of sustainable patterns of life.

The climate change conference in Copenhagen, where Lebanon officially committed to cover 12% of its energy consumption by renewable energies before 2020 supports these approaches.

This commitment implies that renewable energy must be developed significantly, since considering the annual growth in energy demand would have to provide around 2,400 GWh per year, or the equivalent of 206 kTEP.

Therefore, it is expected that local markets, both wood and briquettes, will become more important in the coming years. Data reveals that biomass (wood and coal) in 2008 provided 18% of energy consumed in buildings (main demand), biomass from both personal production and local markets with small volumes of activity. It is assumed that before long, briquettes could gain ground over firewood especially when briquette advantages become widespread knowledge. Firewood is a traditional source of heating and energy and it has an established market, mainly in rural areas.

Table XVI. Where energy is consumed - (Source: Table made from data of the Lebanon energy inventory)

<table>
<thead>
<tr>
<th>Source of consumption</th>
<th>% of primary energy consumption (2008)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Buildings</td>
<td>50.50</td>
</tr>
<tr>
<td>Transportation</td>
<td>28.80</td>
</tr>
<tr>
<td>Industry</td>
<td>19.50</td>
</tr>
<tr>
<td>Other</td>
<td>1.20</td>
</tr>
</tbody>
</table>
6.3 Barriers and corrective measures

Throughout this document there has been talk of conditions conducive to solid biofuels’ development in Lebanon and its growth. At this point, the obstacles that may arise and possible corrective actions that need to address these obstacles will be discussed.

6.3.1 Development of other renewable energies

It is possible that other renewable energies such as solar or wind power are prioritized over the use of biomass. This order of priorities can happen, but the development of these energies is linked to large projects and large investments accordingly. Their development should not affect the use of biomass, because they are smaller projects and they are smaller investments that are more easily developed by private territory agents.

6.3.2 Pellet dominance over briquettes

It could happen that at the level of densified biofuels, pellet production comes at the expense of briquettes. This prevalence is caused by a more rapid spread of pellet plants, where sellers and installers can have more types of stoves and boilers. Regardless, pellet production may be contrasted by the fact that the briquettes can be consumed in traditional stoves and wood burners and their adaptation to pellet consumption is complex and in some cases impossible.

6.3.3 Difficulties in obtaining biomass from forest

Lebanon is a country that has witnessed a reduction in its forest area in recent years for various reasons (forest fires, altering land use and unplanned and unsustainable exploitation of land for firewood). There may not be much room to extract biomass from forests for the briquettes’ production, but some figures from the National Bioenergy Strategy for Lebanon show that the potential exists and is not as negligible when it comes to biomass (Above-ground biomass). All living biomass above the soil, including stem, stump, branches, bark seeds, and foliage of all the main forest tree species, represents 2.79 million tons. There is an additional 0.32 million tons in other forests (other wooded lands). Together they represent around 1.9-2.5 TJ of primary energy potential (primary energy potential) from woody biomass from fellings and 1.3-1.7 TJ of energy from residues from fellings.

The development of briquettes should come from wood from forests that are sustainably managed and would, therefore, condition the forest to have a lower risk of major fires. In addition, part of the wood dedicated to briquette production reduces firewood consumption, therefore preventing further deforestation.

At this point, the country’s ban on felling conifers should be kept in mind. This law could be mitigated allowing the use of broadleaf trees.

In addition, the briquettes may be composed of tree crops or agricultural residues, therefore, it must be easy and simple to obtain the raw material for briquette production.

6.3.4 Lack of equipment manufacturers and installers

For there to be a consecration in briquette production, it is vital to expand the use of facilities and automated boilers and stoves. If this expansion does not occur, equipment manufacturers and installers will remain undeveloped. Expansion and development in the industry is key for people to
access them easily. Nevertheless, it is expected that in the near future consumers will be attracted to replace their non-automated (traditional) stoves by more modern, efficient and reliable ones. Nevertheless, these are minor obstacles compared to the many advantages of using biofuels and briquettes.

6.4 Case studies

Lebanon carried out a pilot experience.\[1\]

The Kfarfakoud Briquette Center, Kfarfakoud (Lebanon)

There is a small facility where briquettes are produced by mixing olive residues (pomace) and woodchips (pruning of stone pines, olive trees, vineyards, apple orchards, and oak forests) near Kfarfakoud village.

The average mixture is 60% pomace (with a 50% moisture content) and 40% woodchips (with less than 50% moisture). The oil presses in the area deliver it to the facility, while the woodchips are made with material from pruning or clearing and, therefore, provide the pomace.

The old Kfarfakoud briquette factory is located at an altitude of 569 meters, whereas the new location is located at an altitude of 608 meters. The area of activity of the briquetting plant covers at least 100,000 ha. The new Kfarfakoud Briquette Center will be in a different building that is larger and better located. Production processes will be improved as well as the design of the plant, which will continue to produce briquettes from olive pomace and sawdust. It is anticipated that the improvements in the supply of raw material, pre-treatment, mixing, manufacturing, drying, storage and sale will encourage many consumers to stop using fuel oil. These briquettes will be much cheaper to use per unit of heat generated.

Equipment for the new center:

- Concrete storage areas for olive pomace, sawdust and the mixture of both
- Hoppers or silos
- Micro-sprinkler system to humidify the mixture
- Briquette machines
- Drying facility consisting of a stove fuelled by its own briquettes and the use of fans
- Metal structures for drying the briquettes
- Briquettes moving equipment including a loader and conveyor belts
- Bobcat for moving briquettes on pallets in the storage area
- Weighing scale and packaging bags
- Tractor with shovels and chippers
- Saw mill
- Roll-off truck carrying pallets
- Mobile pyrolytic furnace
- Offices, exhibition room and services

\[1\] Annex 1 contains more references on international projects with different profiles and sizes, which could be adapted to Lebanon.
• The new building consists of two blocks, one for production and another one for storage, sale and distribution.

Briquettes manufacturing
• Products to be used are olive pomace and woodchips.
• These products are stored outdoors separately on a concrete slab. Storing outdoors on concrete facilitates handling and loading the material and avoids mixing the pomace and woodchips with impurities by keeping them off the ground.
• The production plant has been designed to consist of a feed hopper that pours the mixture of olive pomace and woodchips on a conveyor belt that will distribute the mixture to two machines that mold the briquettes. During the process, micro sprays are used to humidify the mixture and to avoid clogging. The hopper is loaded with the olive pomace/woodchip mixture using a small loader (Bobcat) or with specific containers that open when tilting.
• While the briquettes exit the molding machine two persons are needed to cut the briquettes (since it is not automated) and another two persons are needed to place the briquettes in the specific containers that will be moved by a forklift to the drying area.
• Freshly prepared briquettes have a moisture content of 37% and split easily. However, after 20 to 30 days of air-drying the moisture content is reduced to the required 17% before sale.
• Each container can hold 384 briquettes. The drying kiln will fit 45 containers or a total 20.7 tons / kiln. The briquettes are packaged for sale when they are dry. The weight at time of sale is 460.8 kg per container.
• The briquettes are stored in plastic boxes in the facilities and once they are dry, they are put in bags and sold at the manufacturing center and at a nearby gas station.

The two briquetting machines were designed in the (old) Kfarfakoud Center by Samer Khawand and his team each costing US$ 9,000. The machines are not automatic and depend on intermittent electricity that is backed by diesel-powered electric generators.

Relevant data on briquettes
- The Lower Calorific Value (LCV) of the briquettes compared with other wood is as follows:
  • One kilogram of briquettes provides 4.65 kWh/kg, the same heat that 1.25 kg of oak wood (oak wood consumed is about 30%-35% moisture) provides, or 1.5 kg of olive wood (olive wood consumed is about 35% -40% moisture) provides.
    - Each 2 kg of briquettes has the same lower calorific value (LCV) as a liter of diesel. The retail price for 2 kg of briquettes is about US$0.35 to US$0.40 and the price of a liter of diesel is about US$1.00. Therefore the briquette costs US$4.30/kWh, whereas diesel costs US$10.65/ kWh for the same heat generation.
    - Each briquette weighs 1.2 kg and is 10 cm in diameter and 35 cm in length.
    - Each briquette takes about an hour to burn (it lasts more than oak wood).
  • Bulk selling price of energy:
    • One ton of briquettes is currently sold at US$167/ton at the factory (US$200 for 1,000 pieces.). This
price is equal to US$ 3.59/kWh.

- One ton of oak wood is sold for US$250. This price is equal to US$ 5.97/kWh.
- One ton of olive wood is sold for US$ 200. This price is equal to US$ 5.21/kWh.

- One million briquettes were produced in 2012 with one of the two existing machines, which is equivalent to 1,200 tons/year. This level of production requires six workers, four of them chipping forest and agricultural residues and the other two at the factory making briquettes. The first group worked for four winter months and the second group works for two months.

- This amount replaces a total of about 600,000 liters of diesel per year, with a total savings of:

  - 600,000 liters of diesel at 1 US$/liter = 600,000 US$/year
  - 1,200 tons of briquettes at US$ 167/ton briquettes = US$ 200,000 / year
  - The difference is US$ 400,000 in annual savings for consumers.

Table XVII. Raw materials needed to make briquettes - (Source: Thermal Biomass for Lebanon, 2015)

<table>
<thead>
<tr>
<th>Year</th>
<th>Briquettes t/year (17% MC)</th>
<th>Briquettes Number/year</th>
<th>Forest Woodchips t/year (45% MC)</th>
<th>Fruit tree Woodchips t/year (45% MC)</th>
<th>Olive Pomace t/year (30% MC)</th>
<th>TOTAL raw material (30%-45% MC)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2013</td>
<td>1,200</td>
<td>1,000,000</td>
<td>357</td>
<td>238</td>
<td>800</td>
<td>1,394</td>
</tr>
<tr>
<td>2014</td>
<td>1,489</td>
<td>1,241,000</td>
<td>443</td>
<td>295</td>
<td>993</td>
<td>1,731</td>
</tr>
<tr>
<td>2015</td>
<td>1,848</td>
<td>1,540,081</td>
<td>513</td>
<td>403</td>
<td>1,232</td>
<td>2,148</td>
</tr>
<tr>
<td>2016</td>
<td>2,293</td>
<td>1,911,241</td>
<td>591</td>
<td>546</td>
<td>1,529</td>
<td>2,666</td>
</tr>
<tr>
<td>2017</td>
<td>2,846</td>
<td>2,371,849</td>
<td>677</td>
<td>734</td>
<td>1,898</td>
<td>3,309</td>
</tr>
<tr>
<td>2018</td>
<td>3,532</td>
<td>2,943,465</td>
<td>771</td>
<td>981</td>
<td>2,354</td>
<td>4,106</td>
</tr>
<tr>
<td>2019</td>
<td>4,383</td>
<td>3,652,840</td>
<td>869</td>
<td>1,303</td>
<td>2,923</td>
<td>5,095</td>
</tr>
<tr>
<td>2020</td>
<td>5,440</td>
<td>4,533,175</td>
<td>971</td>
<td>1,726</td>
<td>3,627</td>
<td>6,323</td>
</tr>
<tr>
<td>2021</td>
<td>6,751</td>
<td>5,625,670</td>
<td>1,071</td>
<td>2,276</td>
<td>4,501</td>
<td>7,847</td>
</tr>
</tbody>
</table>

[14] Moisture content
6.5 Job creation

Despite the difficulty in calculating how many jobs this sector can create, it is estimated that biomass utilization generates four to ten times more employment than fossil fuel use (GBEP – Global Bioenergy Partnership, AEBIOM - European Biomass Association), most of them local jobs – employment for residents within 50 km from the biofuel production site).

The promotion of biomass for energy use in Lebanon would generate an improvement in employment.
7 Bibliography

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8 ANNEXES

8.1 ANNEX I. Other case studies of briquette production or marketing

Eco-Fuel Africa, Kampala, Uganda
Eco-Fuel Africa Ltd is a start-up enterprise based in eastern Kampala. Founded in 2010 by Moses Sanga, an experienced entrepreneur and graduate in Business Administration and having received a seed grant of US$10,000 from the Government of Uganda, Eco-Fuel established itself making carbonized briquettes from agricultural wastes.

Using briquette machines developed in-house, Eco-Fuel has a production capacity of 250 – 400 kg of briquettes per day (around 100 tons per year).

These are packaged in clear plastic bags printed with their logo and contact details before being distributed via a network of women retailers who buy each kilogram of briquettes for Ush 700 (US$0.28) and sell them to domestic users in nearby slums and urban centers for Ush 500 (US$0.20).

Eco-Fuel have successfully implemented a distribution supply chain, leasing carbonization kilns to farmers trained in the production of char that they bring to collection points set up in market centers.

The company has ambitious plans for expansion and is seeking further commercial investment. However, they face key challenges including being able to secure a consistent supply of feedstock (most farmers who lease their kilns are small-holders whose agricultural production is often seasonal) and being able to obtain higher-capacity machinery that is not imported.

Kampala Jellitone Suppliers, Kampala, Uganda
Kampala Jellitone Suppliers (KJS) is a company located in the Natete suburb of Kampala. With a history in coffee roasting, KJS diversified into making briquettes primarily to fuel their own requirements but expanded into Uganda’s first large-scale briquette producer; now selling 2,400 tons per year to 35 institutions including schools, hospitals and factories at Ush 700 (US$0.28) per kg. They remain the only factory in the region producing non-carbonized briquettes from agricultural waste, which they collect from four different districts. The company will pay a higher price for processed feedstock (already milled) and are seeking to supply farmers with milling machines in an attempt to improve transportation efficiency.

Its founder and grants from the Danish International Development Agency (DANIDA) have financed the company, in addition to the United States African Development Foundation and the Ashden Awards. The initial grant from DANIDA helped buy the first briquette machine, set up production and carry out research into briquetting technology. Thereafter, briquetting quickly become a self-sustaining part of the business with production recently moving to a new, larger factory funded solely by the company’s own income.

They currently operate two imported electrically powered piston machines with a combined capacity of 1.25 tons per hour (3,500 tons per year) as well as an industrial drier for drying feedstock. However, these machines do not operate at full capacity, limited by the throughput of the feedstock drying process.

KJS conduct their own research in briquette making through the Fuel from Wastes Research Centre, a research NGO set up by the company. They also carry out research in collaboration with the Makerere University in Kampala. KJS have registered their venture as a CDM project in Uganda and, with support from the Belgian Embassy, are aiming to develop an appropriate methodology for carbon financing.
Chardust Ltd, Nairobi, Kenya

Founded in 1999 and based in Nairobi, Kenya, Chardust is an alternative energy company that manufactures and sells over 2,000 tons of carbonized briquettes per year, mainly to poultry farms, restaurants, hotels and safari camps for space and water heating.

These are made from recycled charcoal dust collected from charcoal vendors around Nairobi. They salvage eight tons of this waste per day before processing it into briquettes and distributing it within city limits. The company markets several different products targeted to different market segments. Their standard briquette is sold to urban (household and institutional) charcoal users. They also sell premium briquettes that are made from higher quality charcoal vendors’ waste and packaged in smaller quantities. These have lower ash content and are sold through supermarkets, certified by the Kenya National Bureau of Standards, for the higher-end domestic barbeque market. Standard briquettes sell for US$0.14 per kg, while the premium briquettes sell for US$0.43 per kg (both wholesale prices).

Chardust use roller press machines, imported from India, as well as mechanical milling machines. While drying is done outdoors in the sun over two acres of land, they stock up to 100 tons of briquettes at a time to cover demand during the rainy periods when production drops due to slower outdoor drying.

The company has experimented with a large down-draft pit kiln for carbonizing agricultural waste, but this has thus far been less economical than utilizing charcoal waste. They are also trialing an agglomeration machine that makes higher-quality spherical briquettes.

Although consisting of more processing steps, Chardust’s business model competes with regular charcoal mainly due to lower transportation costs. This is possible because the production facility is situated within the city, close to both raw materials and urban markets.

East Africa Briquettes Company, Tanga, Tanzania

The East Africa Briquette Company has factories in Tanga, Northern Serengeti and Ngoronogoro in Tanzania. The briquettes, which are branded “mkaa bora”, are made with an Indian-made roller press fed by 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. In 2010, the company, with a marketing campaign partly funded by USAID, was selling sixty tons of its pillow shaped briquettes per month. The main biomass materials used are coconut husks, cashew nut shells, maize stalks and cobs. In an interview with The Charcoal Project in 2010, owner Nicholas Harrison discussed plans to open up new factories based on a franchise model.

Appropriate Rural Technology Institute (ARTI) – “Waste to Wealth” Project, Dar es Salaam, Tanzania

ARTI-TZ have been running their Waste to Wealth briquette program since 2006, and in 2011 they received funding through the World Bank’s Biomass Energy Initiative for Africa (BEIA) to conduct a pilot project that trains 1800 people in 60 villages in the four rural districts surrounding Dar es Salaam. As of December 2011, they had completed this training in two of the districts and are currently working to help these villages commercialize their enterprises.

ARTI’s role is centered on developing the value chain. They do this primarily by training farmers to fabricate charcoal kilns with which they can produce char and also equipping farmers with briquetting technology developed by the ARTI technology institute. By linking producers together to form “community-based enterprises” they have been able to create a network for production, community sensitization and sales.
ARTI have also assisted the high-potential enterprises further to access motorized machinery. It is done through an arrangement where 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 program has seen producers sell briquettes for around US$0.25 and make up to a 40% profit.

They have reported successes so far and their plan for the remaining part of the pilot program includes further work to create sales networks through improved branding and marketing. ARTI-TZ also collaborate with a larger commercial partner based in Dar es Salaam, Joint Environmental Techniques (JET), which was originally set up by ARTI-TZ, to provide a buy-back guarantee for any char powder produced by the ARTI recruits. JET then processes the briquettes, packages them and sells them in urban centers.

8.2 ANNEX II Table of Calorific Values

Lower Calorific Value \((\text{PCI}_0 = 18.5 \text{ MJ/Kg})\) depending on the moisture content \((H)\) for a wood type

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Source: Wood fuels Handbook (Biomass Trade Centre 2)
ANNEX III. Employment patterns linked to biomass use

A list of the most typical job profiles that are created throughout biomass supply chains is presented below.

a) Production

Biomass production is linked to four productive sectors, such as forestry, agriculture, the energy crops sector and also the agroforest industry from its products, by-products and waste from its industrial activity.

**Forest:**
- Forester
- Forest owners
- Forest product trader (seed, plant, etc...)
- Forest holdings trader
- Forestry equipment constructor
- Forestry equipment trader
- Forest management technicians
- Forest planning technicians
- Forestry researcher

**Agricultural:**
- Farmer
- Agricultural products trader (seed, plant, etc...)
- Agricultural researcher
- Farms dealer
- Agricultural machinery constructor
- Agricultural machinery trader
- Agricultural planning technicians

**Forest and agriculture industry:**
- Industry, forestry and agricultural products workers
- Workers with activity associated with industry

**Energy crops:**
- Grower
- Crops researcher (species, clones).
- Machinery constructor for the use of energy crops.
- Machinery merchant for the use of energy crops.

b) Transformation
- Forest operator
- Solid biofuels producer
- Processing industry workers
- Industry worker associated with processing (manufacturing machinery, machinery trader, etc.).

c) Marketing and technology
- Solid biofuels dealer
- Solid biofuel carrier and supplier
- Machinery and technology researcher
- Machinery and technology manufacturers
- Plant and machinery dealer
- Machinery installer and distributor
- Energy service company