

O‘ZBEKISTON RESPUBLIKASI OLIY VA
O‘RTA MAHSUS TA‘LIM VAZIRLIGI
TOSHKENT KIMYO – TEXNOLOGIYA INSTITUTI
YOQILG‘I VA ORGANIK BIRIKMALAR KIMYOVIY
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“SELLYULOZA VA YOG‘OCHSOZLIK TEXNOLOGIYASI” KAFEDRASI

Research of modes of technology of fuel briquettes
_____ mavzusidagi
ilmiy-tadqiqot bitiruv ishi uchun

TUSHUNTIRISH YOZUVI

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Ilmiy-tadqiqot bitiruv
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Maslahatchilar:
English _____ *Shokirova M.*

Bitiruvchi: _____ *Nazirov Otabek Murod o‘g‘li*

Toshkent – 2014 yil

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BITIRUV ISHI UCHUN TOPSHIRIQ

Talaba: *Nazirov Otabek Murod o‘g‘li*

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6. Grafik material tarkibi: *Samples of fuel briquettes, results of experiments in the form of tables, schedules and pictures.*

7. Malakaviy bitiruv ishi qismlari bo‘yicha maslahatchilar: *English – Shokirova M.*

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Bitiruv ishi rahbari : _____ dots. Xabibullaev R.A.

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ЎЗБЕКИСТОН РЕСПУБЛИКАСИ ОЛИЙ ВА
ЎРТА МАХСУС ТАЪЛИМ ВАЗИРЛИГИ
ТОШКЕНТ КИМЁ-ТЕХНОЛОГИЯ ИНСТИТУТИ

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мавзусидаги битирув ишига

АННОТАЦИЯ

Мавзунинг долзарблиги. Маҳаллий ёғочсозлик саноати чиқиндилари ва ёғочли чиқиндилар асосида ёқилғи брикетларини олиш атроф-муҳитни муҳофаза қилишга ҳамда уларни утилизация қилиб, аҳолининг иссиқлик энергиясига бўлган талабини қисман қондиради.

Ишнинг мақсади ва вазифалари. Тадқиқотларнинг мақсади маҳаллий ёғочсозлик саноати ва ёғочли чиқиндилар асосида ёқилғи брикетлари олиш ва уларнинг хоссаларини аниқлашга қаратилган.

Шу мақсадга эришиш учун ёқилғи брикетлари ишлаб чиқаришнинг замонавий ҳолатини ўрганиш, экспериментлар методикасини ўрганиш, ёқилғи брикетларининг хусусиятларини аниқлаш каби масалалар қўйилган.

Тадқиқот объекти ва предмети – ёғочсозлик саноати чиқиндилари, ёқилғи брикетлари, ёниш иссиқлиги, кул миқдори.

Тадқиқот услубияти ва услублари. Изланишларда ёқилғи брикетларини олиш, уларнинг хоссаларини аниқлаш бўйича тажрибаар

ўтказилган. Ўтказилган тажрибаларда намликни аниқлаш, кул миқдорини аниқлаш, ёниш иссиқлигини аниқлаш, пўстлоқ миқдорини аниқлаш каби тажриба усулларидадан фойдаланилган.

Тадқиқот натижаларининг илмий жиҳатдан янгилик даражаси. Маҳаллий ресурслар асосида (ёғоч қипиқлари, мебел деталлари чиқиндилари, гуруч қобиғи каби) Nastro туридаги ёқилғи брикетлари олинди ва уларнинг хоссалари аниқланди.

Иш тузилиши ва таркиби. Мазкур битирув иши титул варағи, ўзбек тилидаги қисқача аннотация, кириш, адабиётлар шарҳи, тадқиқот усуллари баёни, тадқиқот натижалари ва уларнинг таҳлили, хулосалар, фойдаланилган адабиётлар рўйхати ва иловалардан иборат. Битирув ишининг умумий ҳажми – 70 бет.

Илмий раҳбар – доц. Хабибуллаев Р.А.

Талаба – Назиров О.М.

MUNDARIJA

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Introduction

Relevance of a subject.

On the decision of the President of Uzbekistan Islam Karimov PP-1442 "On the priorities of industrial development of Uzbekistan for 2011-2015" noted the main directions of development of chemical, light industry, processing of agricultural products and building materials, technological modernization of industries, incorporating the latest scientific achievements, reduce production costs, reduce production losses. The decree stated that by 2015 the volume of industrial output in 2010 is relatively increased by 1.64 times. Expected to set up manufacturing plants in an annual average of 23,820 new jobs. [1]

The report of the President of Uzbekistan Islam Karimov at the meeting of the Cabinet of Ministers on the results of socioeconomic development in 2013 and the most important priorities of economic program for 2014 noted: "To summarize the main results and assessing the socio-economic development in 2013, we there is every reason to say that in the past year continued of our strategy to ensure high sustainable growth, macroeconomic balance, modernization and diversification of the economy. In 2013, gross domestic product grew by 8 percent, the volume of industrial production increased by 8.8 percent, agriculture - 6.8, the volume of retail trade - 14.8 percent. Inflation rate was lower than the projected 6.8 per cent and amounted to.

"Based on these indicators can be expected to increase the population of over 30 million, and in this regard the need for further development of the production of furniture and joinery [2, 3]. Falling economic growth, most countries around the world due to the global economic crisis has led to a decrease in productive capacity in many countries. Due to shrinking global demand reduced prices for commodities exported by Uzbekistan, such as precious and non-ferrous metals, cotton, uranium, petroleum products, fertilizers and others. This in turn leads to a decrease in export revenue businesses and investors affects their income

and profitability of production and ultimately - the growth rates and our macroeconomic indicators.

To neutralize the impact of the global financial crisis and overcome its consequences in our country has all the necessary conditions. During the reporting period we have established a solid foundation sufficient economic and financial capacity of the country, created reliable mechanisms to regulate financial and banking infrastructure.

According to the rate of development of the total domestic product in 2008 was - 9 percent in 2009, 8.1 percent in 2010 - 8.5 percent. [4]To date, these figures exceed them. Under the conditions of the world financial - economic crisis, achieving such indicators provides evidence of the development of highly - qualified specialists [5, 6].Evidence of progressive changes in the structure of our economy is still growing in her role of small business and entrepreneurship. Only in the past year have started their business more than 26,000 small businesses, and the total number of operating in this sector was at the end of the year 190,000.

Domestic science has created a powerful intellectual potential, which finds its practical application in many areas of life, serves as a basis for strengthening of national statehood and economic independence.

The success of the enterprise, and the state as a whole, because of the limited natural, natural resources, today largely determined by how widely implemented to achieve scientific and technological progress, high technologies, the level of professional training of personnel. Historically, that on the threshold of the twenty-first century in the Republic of Uzbekistan formed the intellectual potential, which, on its level of development, innovative discoveries ability to exceed today many developing countries, and in many respects is not inferior to the economically developed countries.

No exaggeration to say that the foundation of the unique and beautiful building science, and intellectual potential of Uzbekistan was founded many centuries ago. We are entitled to say with pride that our science goes back to very

ancient times, has deep and strong roots. Over the centuries, it is reliably Uzbek nation, the whole of humanity in the knowledge of the mysteries of nature, medicine, philosophy, jurisprudence, theology, literature and languages.

Incorporating the best traditions, deeply studying historical heritage, scientists Uzbekistan became worthy successors affairs of their great ancestors, for scientific intelligentsia characterized by a desire for knowledge, be at the forefront of advanced scientific thought. They boldly take up the study of new, poorly understood, urgent problems, their work contributes to the overall socio-economic development of the country in strengthening its innovation capacity.

Uzbekistan has everything necessary for the transition to a modern model of an innovative type of development based on the extended and efficient use of the scientific and technical potential, the broad introduction of the achievements in fundamental and applied science, high technology, increasing the number of highly qualified, talented scientists. This is a necessary condition and a solid foundation for a breakthrough in the category of countries economically and industrially developed countries.

Today Uzbekistan is Central Asia's largest science center with a developed research material base, extensive scientific foundation, qualified scientific personnel, whose works were recognized worldwide [7].

Based on the above, the production of fuel briquettes from waste wood processing industry is an urgent task. For this Respublike Uzbekistan have enough raw materials.

Purposes and research problems.

Purpose is to study the modes of producing fuel briquettes using local wood waste. To achieve this goal, tasks were set - the study of world-class production of fuel briquettes, studying techniques of experimental work, the study of the heating value of fuel briquettes based on different raw wood ash study.

Scientific novelty. We studied the calorific value of fuel briquettes based on sawdust, waste furniture production and rice husk. Defined ash briquettes.

Structure and composition of the thesis. Final work consists of 70 pages of text, including the title page, the annotations in the Uzbek language, introduction, three chapters, conclusions, list of references and a glossary. We used sources of 50 items.

Head 1. The literary review

Loss or destruction of natural forests, mainly the result of human activities related to deforestation. Wood is used as fuel, raw materials for pulp and paper mills, and construction material production. By expanding the production of briquettes from biomass, we can save or at least preserve nature as possible.

Wood briquettes are made of dry, untreated wood chips. They are pressed with high pressure without any binder. By compacting the wood with this high pressure, it turns into a fuel like brown coal.

The fuel briquette ignited within 2 min and reached a peak temperature of 816 °C. Figure 3 shows the plot of temperature versus time for the combustion of equal weights of a fuel briquette, wood pellets, and charcoal. Wood pellets took a longer time to ignite and achieved a maximum temperature on the order of 733 °C. Both the fuel briquette and the wood pellets were completely combusted within 45 min. Charcoal burned for approximately 2 h with a maximum temperature of 227 °C. The oak wood used to represent common firewood did not burn long enough for reasonable temperature data to be collected. These data indicate that fuel briquettes release amounts of heat comparable to those of other common fuel sources [11].



Fig. 1. Production of briquettes. After the agricultural residues are processed and formed into donut-shaped briquettes, they are air dried for several days.

A vacuum generated by a water aspirator collected the gaseous emissions on a piece of filter paper held in a Buchner funnel. The remaining residue from combustion was collected directly. Table 1 ("XRF analysis results of combustible fuels") shows the elements in the briquette, wood pellets, charcoal, and oak wood, as measured by XRF spectroscopy, in order from most to least abundant. The resulting data show that the fuel briquette emissions contained copper, iron, calcium, and silicon, and the residue contained calcium, iron, zinc, and titanium. The XRF spectrometer is able to detect the presence of elements above an atomic number of 10. This means that carbon—the element expected to be present in the greatest abundance from combustion of any biomatter—was not detected [12].

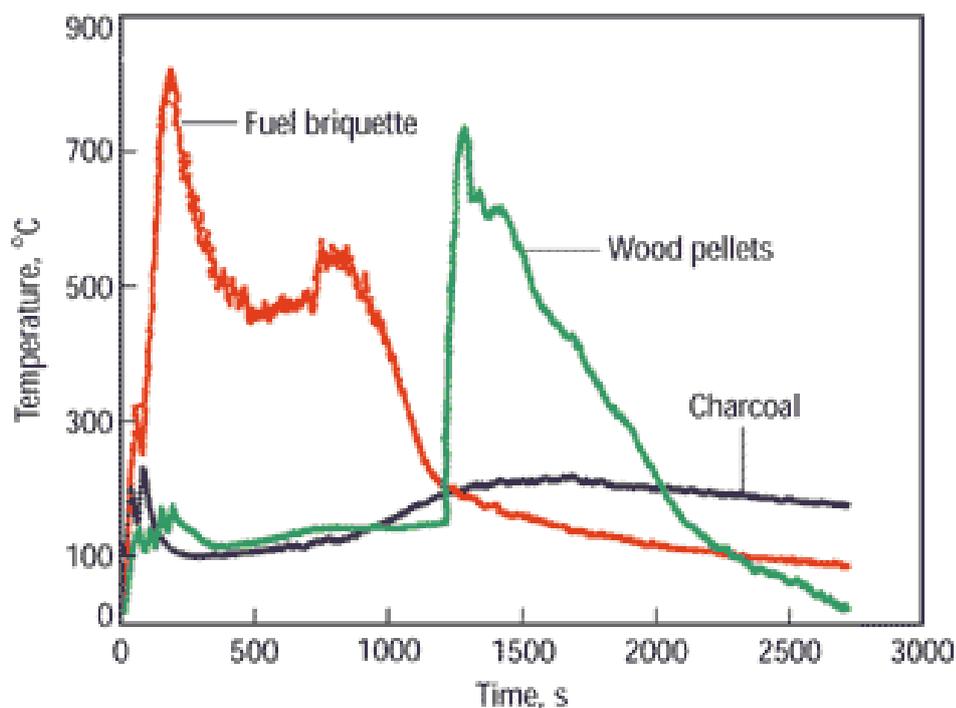


Fig. 2. Comparison study of various fuel sources. Plot of temperature versus time for the combustion of a fuel briquette, wood pellets, and charcoal.

The elements above an atomic number of 10 were detected in the range of parts per thousand. The fuel briquettes showed signs of titanium, as would be expected from the paper-whitening process. A literature search revealed that titanium dioxide (the combustion product of titanium) is not classified as a human

carcinogen (6). There was no sign of the chromium or cadmium that was expected from the colored inks. This lack is attributed to a lower concentration of these metals than could be detected by the spectrometer. Future atomic absorption spectroscopy experiments will need to be performed to detect chromium and cadmium in the range of parts per million [13].

XRF analysis results of combustible fuels

Table 1.

Fuel source	Detected elemental composition of gaseous emissions *	Detected elemental composition of ash *
Fuel cells	Cu, Fe, Ca, Si	Ca, Fe, Zn, Ti
Fuel pellets	Cu	Fe, Ca, K, Mn
Oak	Cu	Ca, Cu
Charcoal	Cu	Ca, Fe, Ni, K

Relative abundance of elements from most to least

Briquette technology in the U.S.

Admittedly, the tests are basic. A broader study needs to be conducted with a wider variety of resources, using the actual application. We are interested in determining the levels of potentially toxic substances to the range of parts per million. In addition, the use of bomb calorimetry would give us exact numbers for the amount of heat generated by the fuel briquette as compared with other heating and cooking fuel sources. These preliminary studies have shown that the fuel briquettes can compete with other heat sources and that they appear to burn cleanly. We are satisfied, from a chemical standpoint, that the briquettes burn as cleanly as charcoal, firewood, or wood pellets. With this knowledge, we are encouraged to scale up the technology for the potential U.S. market [14].

Fuel briquettes are bonded by the random alignment of fibers, generated when yard wastes and junk mail are shredded and soaked in water. The process

occurs at ambient temperature at a pressure of 1.5 to 3.0 MPa (~200 to 400 psi). To a large degree, the bonding force in the fuel briquette is mechanical, not chemical. Because of this, retaining fiber integrity and the right degree of plasticity in the mixture is crucial to the quality of the fuel briquette [15].

In contrast to fuel briquettes, fuel logs and pellets can be bonded by a process that uses high pressures and temperature to release natural binders from more resinous woods (e.g., pine, spruce). In the case of fuel logs, hardened, high-torque steel augurs are used. In the case of fuel pellets, material is mashed between two offset drums aligned to converge as they rotate. In either case, it is critical to ensure that the resin or added binders are distributed under sufficient pressure and temperature to flow evenly throughout a relatively homogeneous mass. The degree to which any fibers in the mass are internally sheared is not important to the cohesiveness of the fuel log or fuel pellet [16].

In considering the required scale of operation, the fuel log or pelletizing operation is a sophisticated and capital-intensive process that requires high volume and wide distribution to justify the investment. Fuel briquette production is a far simpler and more cost-effective process; it can be done in households or small communities, and large volumes are not required to justify the investment [17].

For the technology to be extended to U.S. markets, the entire process (chopping, defibrating, and compressing the material) would have to occur within one physical container. Operation of the machine would have to be safe, convenient, and cost-effective. It must avoid the use of sharp surfaces and allow for immediate shutdown in the event of any human or mechanical error. The machine would have to be compact, reliable, affordable, and easily maintained [18].

The final design is under development, but the general operating process can be described as follows. Roughly equal proportions of junk mail and yard wastes are chopped into cornflake-sized pieces, using a series of rotating steel combs in a water-filled vat (Fig. 3). The flakes and any long fibrous materials are then rubbed

through a grate and churned into a coarse, gelatinous slurry. The slurry is then compressed and dewatered as it is pumped through a perforated pipe mold (Fig.4). The expelled water is returned to the water bath. As the resulting cylindrical cake oozes out of the mold, it is chopped to its desired length and transferred to nearby screened drying racks where it is air-dried for 4–6 days before packaging and use.



Fig.3. Preparing junk mail and yard waste. Approximately equal portions of junk mail and yard waste are chopped into cornflake-sized pieces using a steel water-filled vat apparatus.



Fig.4. Compression apparatus. The briquettes are formed using a compression apparatus and perforated pipe molds.

Biomass, as a renewable energy source, has started to look much more favourable again in recent years. There are many reasons for this trend, ranging from increased socio-political discussion on our future energy supply to technological progress. The latter, in particular, has helped change the image of biomass: while fewer regard it as old fashioned, expensive or even dirty, today biomass raise its profile as a renewable and profitable energy carrier. New processing methods have even improved the fuel and handling characteristics of biogenic fuels. Those that have made the biggest difference are briquetting and pelletization, from the solid fuel industry. Both of these techniques are based on

compacting the original loose material to yield one basic advantage: a higher energy densification [19].

The advantages of biomass briquetting are by no means limited to its use in modern industrial plants or solid fuel boilers. Indeed, in developing countries a far bigger percentage of the population cover their energy needs with biomass alone, where their primary need is for heat energy for cooking and heating. International development cooperation has accordingly long been focussed on improving the basic energy supply in many countries around the world. It is notable that biomass briquettes have played a bigger part in many projects over recent years, such as those for distributing better stove technologies, for example. Next to adapted cooking behaviours and improved cooking appliances, the fuel can play one important role in improving the overall situation of households. Biomass briquettes can be produced out of many field or process residues and burning them in cooking appliances instead of traditional fuels as logged and collected wood or charcoal can be an interesting alternative for business makers but also for fuel clients. However, like for most new technologies, many technological but also economical questions may arise [20].

For thousands of years, biomass was almost the only constant available and controllable energy source. Wood served as the preeminent form of energy until the mid- to late-1800s, even though water and wind mills were important to some early industrial growth. Coal became dominant in the late 19th century before being overtaken by petroleum products in the middle of the last century, a time when natural gas usage also raised quickly [21]. Thus, the energy content per unit (mass or volume) of the resources increased steadily.

Almost all forms of energy, fossil fuels, wind or biomass, were or are driven by solar energy. When managed sustainable, i.e. harvest does not exceed growth, biomass is a renewable energy. Through the mechanism of photosynthesis solar energy is bound into chemical energy in the plants. Thereby it gets usable for humans in form of eating or burning [22].

Briquetting or pelletizing is the process to improve the characteristics of biomass as a renewable energy resource by densification. Densification means less volume needed for the same amount of energy output. Fig.5 visualises the magnitude of the differences of bulk density. Each column has the same energy content and represents the volume needed to obtain the equivalent energy of one litre of fossil heating oil. Wood pellets have the highest energy content per volume within the solid biomass examples here listed [23].

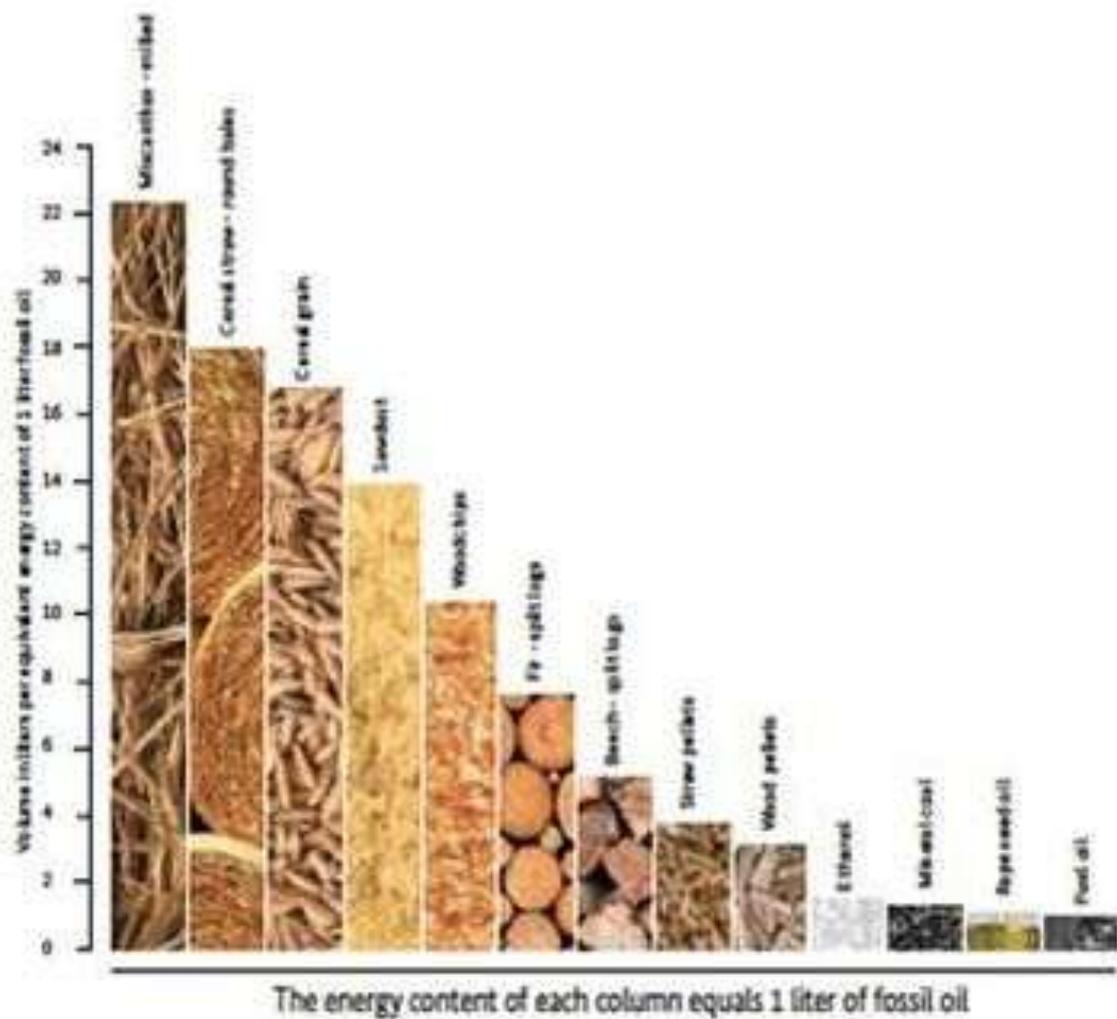


Fig.5: Energy per volume of renewable resources compared to fossil oil and coal [24]

The advantages of processing and densifying of biomass are not only limited to the higher energy content. Both of the techniques, briquetting and pelletizing, are based on compacting the raw material to yield certain advantages[25]:

High volumetric energy density

Favourable dosing characteristics

Lower water content in the fuel and therefore greater storage stability (less biodegradation)

Option to use additives to change the chemical/material properties

Less dust produced when handling

High homogeneity of the fuel [26].

For the European market, the differences of briquettes and pellets is listed in the European classification standard CEN/TS 14 961. For both products, different parameters as shapes and sizes are exactly predefined. In the context of developing countries these definitions might be much too strict. Pellets are small round rods whereas briquettes are bigger and can show different forms. So in a broader context, pellets might be described as a bulk material whereas briquettes can be stacked.



Fig.6: Pellets and briquettes

Briquettes and pellets are both products deriving from the densification of a raw material.

Biomass briquettes and pellets for fuel use are a product which aims to improve the characteristics of a certain raw material.

The main reason for the densification is to increase their energy content per volume.

The raw material

The raw material is always the beginning of each value chain for processed products. Therefore, before starting to briquette, the main questions are: what to briquette and how to get the raw material. Basically, each kind of biomass might be used for the production of biomass briquettes as a fuel. However, it also contains an important requirement for the biomass: it should be dry! [27].

It is rare that energy plants are cultivated and grown for the only purpose of a later briquetting. Moreover, briquetting is applied to improve the quality of an original fuel material and thereby add value to a poor quality product, mainly agro-residues. Briquetting biomass-residues is one way to solve a problem: how to put the huge volume of wastes from agricultural and agro-processing to some useful purpose. The following picture illustrates the wide range of raw material used for briquetting.

It is sometimes assumed that residues are wastes and therefore “free” almost by definition. In practice, it is unwise to assume that any residue is “free” in the sense that it has no alternative use of some value. Thus inevitably in a monetized economy, everything which has a use acquires a monetary value. This is most obvious in the case of fully commercial briquetting plants based upon processing residues or wood-wastes. It is difficult to find examples of operating briquetting plants which do not have to pay something for the residues they use. Such payments may arise because there are competing uses for the “waste” but it may also arise simply because a residue provider is unwilling to allow someone else to

make profit from their wastes without asking for a share in the form of payment for the raw material. In general we can distinguish field or processed residues [28].



Fig.7: Samples of biomass briquettes from all over the world [29]

Field residues

International and regional statistics [30] often demonstrate the immense quantities of field residues. Most residues are dry at the moment of harvesting and therefore a high potential raw material for briquetting. The volume of residues produced per unit of cultivation is within a wide range, depending strongly on the crop, the intensity of agriculture and climate. However, the recovery rate would be lowered by alternative uses for the residue, though important, uses by local people. These could include animal feed and bedding, direct use as fuel and various building material. In addition, the ploughing in or burning of residues play an important part in promoting soil fertility. Apart of these alternative uses, some additional economical issues should be considered, especially when thinking of briquetting of field residues:

- The access to a sufficient quantity of raw material to run the briquetting machine economically.

- Seasonal transport and storage capacities.

Land Needs

To demonstrate the important role of the volume of residues for a briquetting plant, a very simple calculation might help: assuming a specific recovered residue value of 3 tons per hectare, as well as a briquetting machine with a production capacity of 300 kg per hour; furthermore for an economical output of the briquetting machine we assume that it will run for 8 hours a day for half a year. These presumptions result in a necessary access to 146 hectares of cultivated land! [31].

Transport and storage

In general, field residues are bulky; baled wheat straw has been put at around 100 kg/m³ and stacked cotton residues at 55 kg/m³. Even when chipped, cotton residues only have a bulk density of 130 kg/m³. By contrast, stacked wood has a bulk density above 500 kg/m³. This means that the transport of residues to a briquetting plant can become increasingly expensive as the distance from the site of the residues to the plant increases. In addition, most field residues appear only for a given period in the year requiring seasonal transport capacities (tractors, trailers etc.) and storage capacities. Coming back to the above mentioned example calculation: there would be the need to transport almost 440 tons of raw material in few days and, assuming baled straw wheat, a storage room of 4400 m³, which could be a building with an outline of 30 x 30 meters and 5 meters of height.

Process residues

In this category, all residues obtained from the processing of a crop or wood are included, for example: coffee husks, groundnut shells, rice husks, coir dust, sawdust, furniture waste etc. In principle, the briquetting process works quite well for a wide range of feedstocks provided they are homogeneous and contain moisture below 15 %.

In general, the evaluation of a plant based upon process residues is less complex than for one based on field wastes. The main problem is to establish the quantitative availability of material from a limited number of point sources, possibly only one. This is inherently simpler than to establish the potential residue yields from shifting agricultural patterns of several outside farms. In effect, the transport costs of gathering, which can be the main barrier to utilization of crop residues, have been absorbed by the transport of the valuable food-component of the crop.

The small value of the briquettes relative to the total value of the crop means that the issue of providing briquetting raw-material was irrelevant to the wider agricultural changes going on.

It is unwise to assume that any residue is “free” in the sense that it has no alternative use of some value.

Briquetting raw material should have the goal to give a higher value to an existing product. This might be to lower transportation costs or to enable the use of a material as fuel.

The access to raw material is a crucial factor for transportation (distance) and investment costs (buildings, transportation equipment, storage).

Production of biomass briquettes

The reduction of material density is the reason for undertaking briquetting as it determines both the savings in transport and handling costs and any improvement in combustion over the original material: the art of briquetting. This art essentially involves two parts: the compaction under pressure of loose material to reduce its volume and to agglomerate the material so that the product remains in the compressed state. Later effect, the cohesion of the particles, is based on three main mechanisms [32]:

- Generating a positive coupling of particles by fibre connections
- Attraction forces between particles through hydrogen bonds

- Creating of form-closed bonds through the sticking effect of several biomass contents (lignin, protein, starch) or added binders

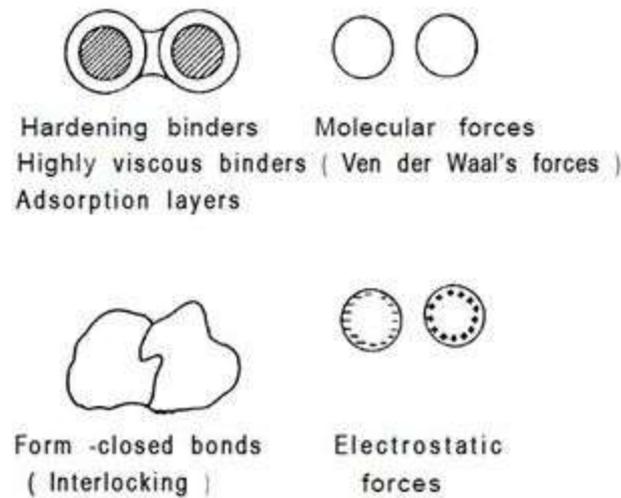


Fig. 8: Binding mechanisms [33]:

- hardening binders, highly viscous binders, adsorption layers;
- molecular forces (Van der Waal's forces);
- Form-closed bonds (interlocking);
- Electrostatic forces.

A binding agent is necessary to prevent the compressed material from springing back and eventually returning to its original form. This agent can either be added to the process or, when compressing ligneous material, be part of the material itself in form of lignin. Lignin is a constituent in most agricultural residues. It can be defined as the thermo plastic polymer, which begins to soften at temperatures above 100°C and is flowing at higher temperatures. The softening of lignin and its subsequent cooling while the material is still under pressure is the key factor in high pressure briquetting. It is a physic-chemical process related largely to the temperature reached in the briquetting process and the amount of lignin in the original material. The temperature in many machines is closely related to the pressure though in some, external heat is applied [34].

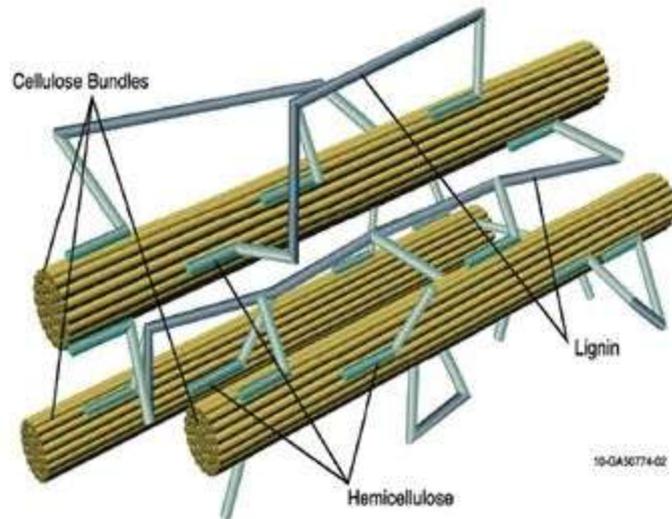


Fig.9: arrangement of cellulose, hemicellulose and lignin in biomass matrix [35]

In general there are two immediate ways of classifying briquetting processes. One distinction is whether or not an external binding agent must be added to agglomerate the compressed material. The second way of classifying follows the pressure applied while briquetting: high, medium or low pressure. For a rough distinction the following numbers might be adopted:

Low pressure up to 5 MPa

Medium pressure 5 – 100 MPa

High pressure above 100 MPa

Usually high pressure processes will release sufficient lignin to agglomerate the briquette. Medium pressure machines may or may not require binders, depending upon the raw material whilst low-pressure machines invariably require binders. Such external binders might be: starch, clay, molasses or wood tar etc.. All briquettes using inherent binders (lignin) or external hydrophilic binders (starch, molasses, gum, clay) are not waterproof and will disintegrate when they come into contact with water or stored under humid conditions [36].

Briquetting of charcoal

Charcoal is produced in many countries around the world. The basic idea is quite similar to briquetting: the densification of energy. Therefore, biomass is

pyrolyzed in kilns by a controlled burning process lacking sufficient oxygen for a complete burning of the raw material. Briquetting can be combined with carbonization to further improve the densification of the charcoal [37]. Basically the two processes can be applied one after the other:

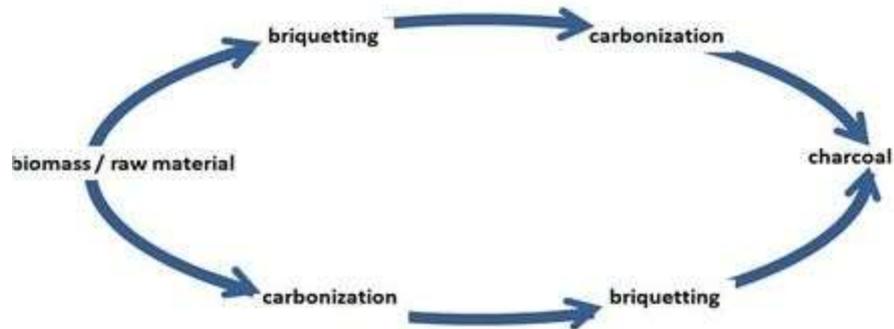


Fig.10: from biomass to charcoal

But, during the carbonization process, the biomass is losing its lignin content and thereby an important binder for briquetting. Charcoal is a material totally lacking plasticity and hence needs addition of a sticking or agglomerating material to enable a briquette to be formed. The binder should preferably be combustible, though a non-combustible binder effective at low concentrations can be suitable.

Briquetting technologies

Industrial methods of briquetting date back to the second part of the 19th century. Since then there has been widespread use of briquettes made from brown coal, peat and coal fines. The briquetting of organic materials requires higher pressure as additional force is needed to overcome the natural springiness of these materials. Essentially, this involves the destruction of the cell walls through some combination of pressure and heat. The following overview presents the most common machines used for briquetting biomass [38].

Piston presses:

In piston presses, pressure is applied discontinuously by the action of a piston on material packed into a cylinder. They may have a mechanical coupling and fly wheel or utilize hydraulic action on the piston. The incoming raw material is pressed against the compacted material inside the pressing tube and leaves the die in the rhythm of the piston action. Through pressure and friction forces inside the pressing tube, the material is strongly heated and cooling mechanisms might be considered. To produce briquettes with high density (up to 1.25 g/m³) the raw material eventually needs to be milled (less than 10 mm) and dried (<15% of water content) before briquetting. The capacity of piston presses depends both on the diameter of the die and the pretreatment of the raw material [39].

The capacity spectrum of piston presses range from only 25 up to 1800 kg/hr. Their typical specific energy use requires between 50 and 70 kWh/t.[40]

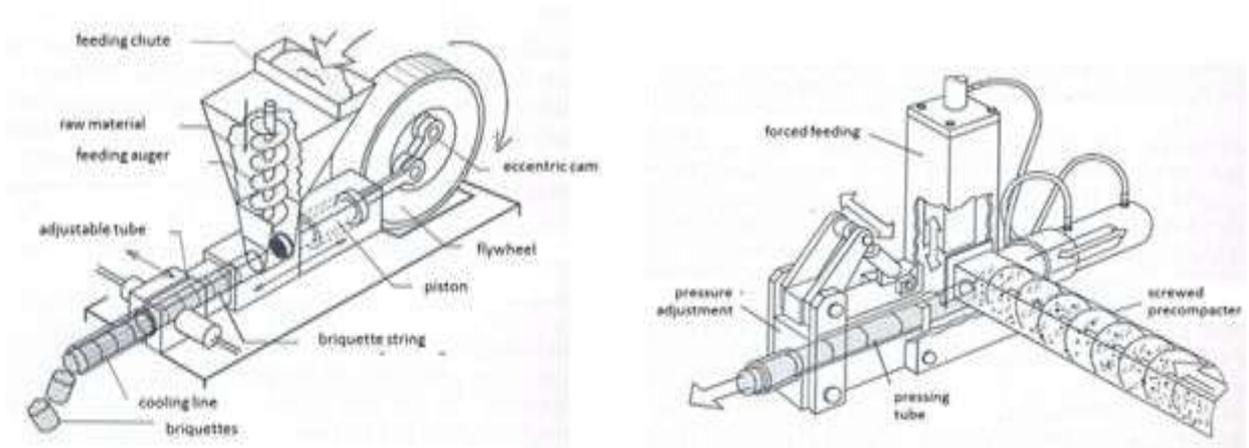


Fig.11: piston presses [41]

Screw compaction or Extrusion

The aim of compaction using an extruder is to bring the smaller particles closer so that the forces acting between them become stronger, providing more strength the densified bulk material. During extrusion, the material moves from the feed port, with the help of a rotating screw, through the barrel and against a die,

resulting in significant pressure gradient and friction due to biomass shearing. The combined effects of wall friction at the barrel, internal friction in the material, and high rotational speed of the screw, increase the temperature in the closed system and heat the biomass. This heated biomass is forced through the extrusion die to form the briquettes with the required shape. If the heat generated within the system is not sufficient for the material to reach a pseudo-plastic state for smooth extrusion, external heat might be added. In principle, screw presses reach slightly higher compaction but lower capacity (tons per hour) when compared to piston presses [42].

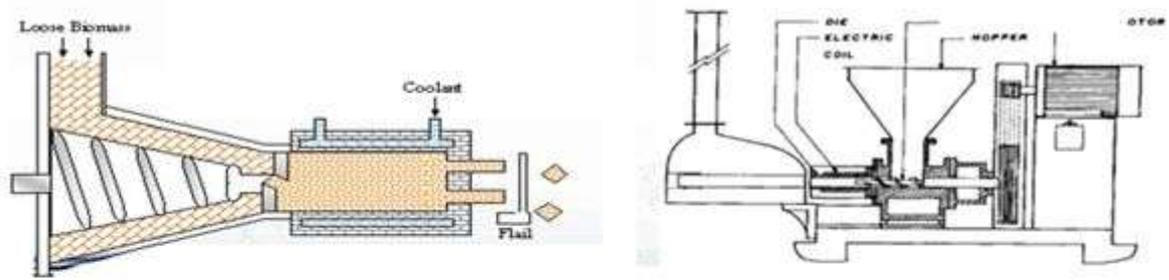


Fig.12: screw presses

Pan grinder presses for pelletizing

Pellets are the result of a process which is closely related to the briquetting processes described above. The main difference is that the dies have smaller diameters and each machine has a number of dies arranged as holes bored in a thick steel disk or ring. The material is forced into the dies by means of rollers moving over the surface on which the raw material is distributed. The pressure is built up by the compression of this layer of material as the roller moves perpendicular to the centerline of the dies. Thus the main force applied results in shear stresses in the material. The pellets will still be hot when leaving the dies, where they are cut to lengths normally about one or two times the diameter.

Successful operation demands that a rather elaborate cooling system is arranged after the densification process.

There are two main types of pellet presses: flat and ring types. The flat die type has a circular perforated disk on which rollers rotate whereas the ring die press features a rotating perforated ring on which rollers press on the inner perimeter. The output of pellet presses range from about 200 kg/hr up to 8 ton/hr. Their specific energy consumption is reported to be around 1,5% of the energy content of the final pellets [43].

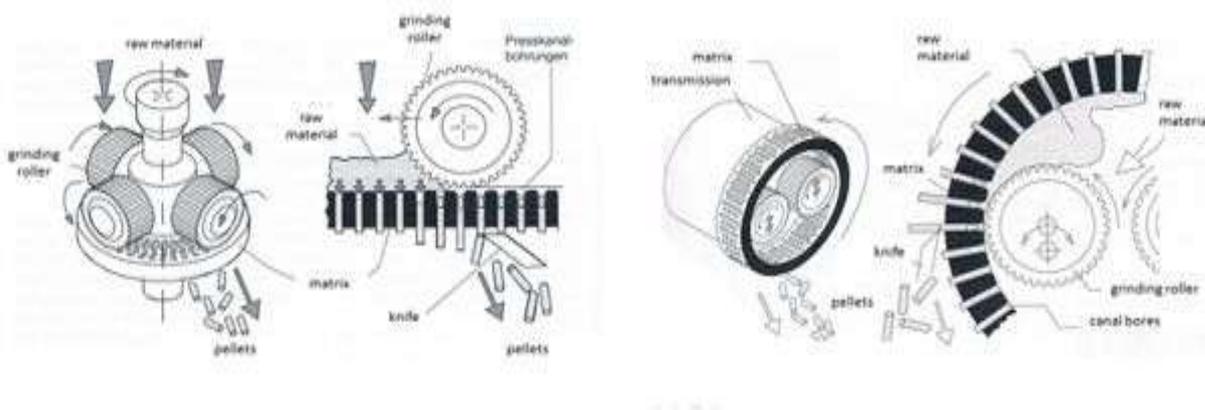


Fig.13: pan grinders [44]

Hand machines

For sure the simplest way to produce small briquettes is hand-shaped briquettes: a slurry of biomass in water is left soaking for some days to enhance binding properties. The pulp is either squeezed by hand or pressed into a mould e.g. an ice-cube tray. Rearranged fibres assisted by a binder like paper pulp keep the briquette in shape during drying and use. A part of hand-shaped briquettes there are plenty of small manual briquetting machines which were developed by different producers and scientists all over the world. A very good overview on existing low cost briquetting machines, from perforated bottles to wooden lever presses, can be found in the manual “Micro-gasification: Cooking with gas from biomass” by Christa Roth (2011)[45].



Fig.14: examples of low cost briquetting machines [46]

However, it remains unclear, whether any manual densification process can ever be commercially viable even in circumstances where labour is very cheap. Considering their very low throughput, such techniques often require almost as much capital investment as the mechanical processes. The savings achieved are essentially a labour for electricity substitution rather than labour for capital.

Roller Presses

Densification of biomass using roller presses works on the principle of pressure and agglomeration, where pressure is applied between two counter-rotating rolls. Ground biomass, when forced through the gap between the two rollers, is pressed into a die, or small pockets, forming the densified product. Roller presses are considered the world standard technology to produce ovoid (pillow-shaped) charcoal briquettes from a variety of biomass types. In a roller press, a mixture of charcoal and binder is fed to the tangential pockets of two rollers to produce briquettes. The smooth production of charcoal briquettes using this technology requires high-quality rollers with smooth surfaces on which the briquettes are shaped. The type of roller determines the shape of the briquettes.

Currently, roll presses available in developed countries have production capacities of 1 t/hr and more. The 1 tonne/hr capacity press with controlled feeding device costs about \$ 320,000. Much cheaper roller-type charcoal briquetting machines can be sourced in India and China: Seboka (2009) indicates that a roller press with a capacity of 1.5 tonne/hr costing \$ 19,000 can be found in India [47].

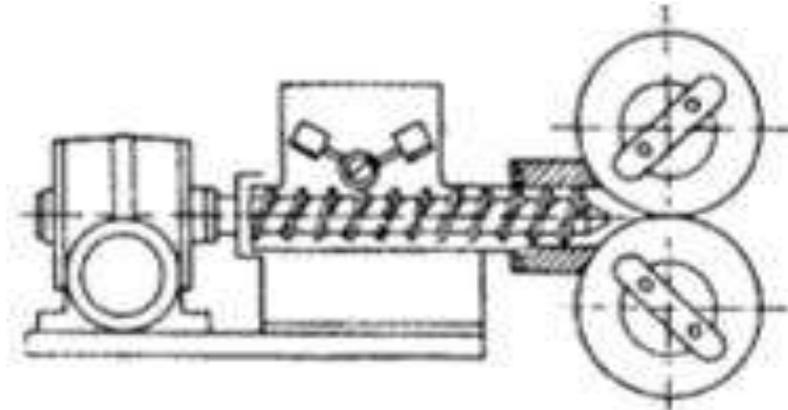


Fig.15: roller presses [48]

Agglomeration

Agglomeration is a method of increasing particle size by gluing powder particles together. Usually the equipment consists of a rotating volume that is filled with balls of varying sizes and fed with powder and often a binder. The rotation of the agglomerator results in centrifugal, gravitational and frictional forces from the smooth rolling balls. These forces, together with inertial forces, press the balls against the powder, helping them to stick together and grow. NL Agency[21] reports applied agglomeration technology in small-scale briquetting processes in several developing countries. The charcoal is milled to powder, binders are added, the components are mixed together, and the mix is then agglomerated. Agglomerated charcoal briquettes are produced using a motor-driven agglomerator, the typical nominal capacity of which is 25-50 kg/hour. Agglomerated charcoal briquettes are spherical and typically have diameters

between 20-30 mm. The briquettes can be used for household cooking as well as for fuelling industrial furnaces. Agglomerated briquettes are said to be stronger than most other briquette types (Reference numbered as "5". It is missing and does not match order) [49].



Fig.16: Small-scale agglomerator [50]

As seen above, there are different technologies to produce densified biomass briquettes. For the right choice of an adapted machine, two main issues should be considered:

- Quantity and quality of the raw material
- Market availability of briquetting machines and spare parts

Auxiliary equipment

Only in few cases will the briquetting press be the only equipment needed to set up a briquetting plant. From the starting point, the complexity of briquetting plants increases up to the fully automated woodwaste briquetting plants in which the raw material is fed by a tractor into a hopper from where it is crushed, screened, stored, dried, stored again, fed into the presses and transported to the product storage in fully automatic process, supervised by a couple of operators. Without going into details, the following text is a brief listing of a few common

types of necessary auxiliary equipments and their applications which might have to be considered as also important economical factors:

- Storage (rainy seasons, both the raw material and the product);
- Handling (conveyors, elevators etc.);
- Comminution (chipper, hammer mill, conditioner, mixing with binder);
- Classification (separation, cleaning);
- Drying.

To demonstrate the necessary steps for charcoal briquetting of different raw materials, NL Agency (2013) created table 2 below. Charcoal dust has the shortest supply chain, only a collection and briquetting step is needed to produce charcoal briquettes. On the contrary, the charcoal production chain based on the growing of dedicated energy crops involves a considerable number of steps. Each step in the supply chain represents efforts, money and possible complications, and this indicator shows that charcoal dust and processing residues have a logistic advantage over other types of feedstocks [51].

Costs

The financial costs of briquetting are very dependent upon the nature of the project, in particular upon the raw material used and the plant location. They depend upon a number of operating costs, including labour, maintenance, power, raw material cost and transport etc. as well as of capital cost component. Whether or not briquetting is economic in any given location will depend critically upon how these unit costs relate to the price of the likely substitute fuels.

Capital costs

The capital costs of a plant are not always easy to establish on a consistent basis. In different circumstances there may be different conventions about what is included in capital cost: for example, do spare parts count for capital costs or operational cost? Is the plant a stand-alone operation or is it part of an existing agro plant and maybe existing buildings can be used?

Probably, one of the biggest variations in plant capital costs, however, comes from the raw material to be used and the form in which it is collected. The nature of the raw material, especially the density, influences significantly the output rate of briquetting machines. Most agro-residues will cause lower outputs than wood residues for the same briquetting machine what will influence the unit capital costs. In addition, the form of the initial feed may require pretreatment efforts before it is fed to the briquetter as such. Some wastes, for example sawdust, often need to be dried to reduce their moisture to 15%, others like cotton stalks might be chipped or shredder before briquetting. Thirdly, there is a very big difference between field-residues and factory-residues if the cost of the equipment to collect the residue is included in the initial capital cost.

Another important aspect of capital costs are the engineering and design standards of the plant. For example, it is likely that in a plant where little or no use is made of mechanical handling, there will be a need to have spacious buildings to avoid problems of dust and dangerous overcrowding. Briquetting machines which are squeezed into residue-producing plants to utilize existing buildings may naturally have lower capital costs than briquetting plants with firm floors, proper electrical fittings etc.

Apart of these direct production capital costs, in many countries additional costs have to be considered and can range widely from country to country. For example credit costs or custom duties on imported machines.

Operating costs

The first obvious operating cost is the price to be paid for the raw material. This costs are very project and site-specific. The raw material might have a specific price when its use is competing with alternative uses. However, even if the residue is free, it is common for a transport cost to be incurred in bringing the residue to the briquetting plant. In the case of briquetting plants sited at the residue production point this is avoided but for other situations the transport cost may be a significant part of operational costs. These transport costs may be added into

general labour costs if fulltime drivers are employed but certainly a more common situation is to hire appropriate transport for a given period of collecting the raw material.

The labour costs of a briquetting plant are in general very dependent upon plant design: are there any significant residue collection activities; the wage rate of various categories of labour employed (collecting, loading, maintenance, supervision etc.); and the extent to which the unit is integrated with a larger factory which can supply some labour needs on a part-time basis and cover administration costs. However, S. Eriksson and M. Prior[25] results that despite the wide variations in labour costs, briquetting as such is not labour intensive relative to the unit capital costs and the cost of maintenance, power and other consumables. Labour costs seldom exceed 15% of the total and are usually much less.

Maintenance costs can be a significant element of briquette production costs and one that is often underestimated in planning plants. Especially when briquetting machines are working on abrasive materials, such as rice-husks or charcoal, the maintenance cost can be quite high particularly for pan grinder for pelletizing, screw presses and piston presses. It is a factor which may place a continuing reliance on imported spare-parts or in the need to employ virtually an operative on building up spare parts.

Except of manual driven briquetting machines, all other types of briquetting machines require a certain power supply. There is no reason why plants in remote areas should not use diesel generators or use direct drive from diesel or steam engines. But in most cases the briquetting machines are connected to the main electrical power supply: depending on the size and output rate of the machine whether single phase 220V or 3 phases 400V supply is necessary. The specific requirements and consumption of each machine has to be considered in an early state of planning and to be adapted to local circumstances.

Other costs which might have to be considered when operating a briquetting plant are: taxes, insurance, consumables such as lubricating oil, packaging etc.

Comparison between pelleting and briquetting [52]

Briquette processing is more efficient than pelleting because the biomass materials do not necessarily have to be preprocessed or uniformly ground up, which results in less preparation. Another advantage of briquetting is it can be set onsite. Briquetting waste byproducts and reusing them onsite for energy rather than transporting them to another location or to a landfill can save on disposal costs. Briquetting generally use less horsepower. From the investment point of view, the purchase capital and maintenance costs to make briquettes are less than for pellets. If transportation is one of the main criteria, pellets are more advantageous because there are more pounds per foot than briquettes. This is especially true if the briquettes are larger because it allows for more air between them when they are stacked.

Densification essentially involves two parts: the compaction under pressure of loose material to reduce its volume and to agglomerate the material so that the product remains in the compressed state.

An internal or external binding agent is necessary to prevent the compressed material from springing back and eventually returning to its original form. The lack of inherent binders is the main difference when comparing charcoal with biomass briquetting.

The main presses for briquetting are piston and screw presses; for pelletizing pan grinder presses are most common; to produce charcoal normally roller presses or agglomerators are used.

The quality and the quantity of the raw material as well as the market availability are the main factors for the choice of the adapted technology.

Often, briquetting is not a stand-alone process. Different pretreatments might be considered: storage, handling, drying, and sizing.

Capital costs for different investments and operating costs (such as labour, maintenance, raw material etc.) determine the production costs of briquettes.

The economic viability of briquetting plants depends crucially on whether or not these factory costs are comparable or less than the prices of the main competitive fuel.

Markets and users for briquettes

The total production costs as the sum of investment and operation costs define the price of each product. But for competitive products with similar use, their comparison prices will decide their success or not on a given market. For briquettes this competitive market means the range of conventional fuels offered. One of the most important characteristics of a fuel is its calorific value, which is the amount of energy per mass it gives off when burned. Although briquettes, as with most solid fuels, are priced by weight or volume, market forces will eventually set the price of each fuel according to its energy content. However, the production cost of briquettes is independent of their calorific value as are the transportation and handling costs. The calorific value can thus be used to calculate the competitiveness of a processed fuel in a given market situation. So one key question must be:

Does the price per unit of energy at which briquettes are sold compete with the fuels normally used?[53]

The answer to this question is very site specific and depends on local circumstances. But for sure it is a crucial one and should be at least roughly calculated before starting a business with briquetting.

However, even if the calorific value is probably the most important factor, there is a range of other factors, such as ease of handling or burning characteristics, which also influence the market value of briquettes. These characteristics are more users specific: for example a private user who will burn charcoal briquettes for a garden barbecue will probably have different expectations than someone firing an industrial boiler with for example rice-husk briquettes. This observation leads to a second key question for the market success of briquettes:

Can the particular briquette be burnt satisfactorily in the combustion appliance used by a particular consumer?[54]

Whereas the first key question might be easy to answer by a simple comparison of solid fuel market prices, the second question might imply indirectly the willingness of consumers to alter their normal combustion appliances to suit briquettes. Without a doubt, before not only changing the fuel but also adopting a whole new combustion unit consumers will hesitate. They will ask themselves if briquettes offer any significant advantages, in terms of quality of combustion or in financial advantages that might persuade consumers to spend money on new appliances. But that is not enough: briquettes are also a consumer good. That means consumers must trust in their availability. This aspect might be especially difficult at the beginning of a briquetting activity while searching for penetrating a new market. The likely size of briquette supply relative to the total traditional fuel supply will be small. At these low kinds of penetration, consumers will always be aware of the need to give themselves an alternative source of fuel. This will certainly be true in the early stage of marketing briquettes whether or not, at the later stage, some consumers would have the confidence to commit themselves wholly to briquettes. Thus, briquettes have to be compatible with existing appliances with little or no modification if they are to have any chance of achieving initial market penetration.

A part of these general considerations about the competitiveness of briquettes there might be some user specific thoughts. These are discussed in the following by regarding the solid fuel which is supposed to be substituted by briquettes.

Burning appliances

Wood burning appliances

Technically there does not seem to be any major problem about using briquettes in existing cooking or heating appliances which were originally designed for burning wood. Due to the high density of briquettes and their surfaces

sometimes problems with initial ignition and heat-raising are reported. But this fact can easily be overcome by co-firing wood at the beginning. It is probably more difficult to sell bigger sized briquettes simply because the physical dimensions of household stoves are limited. Large logs are similarly rejected. The general combustion behavior of biomass briquettes is comparable to wood. Briquettes can therefore normally be used in traditional stoves as a substitute or as co-firing of wood. In fact in many countries briquettes can be found on local markets. Especially for normal households in developing countries the comparative price and the availability of briquettes will play a major role for their acceptance rather than the technical characteristics when burnt in stoves designed for wood.

Charcoal burning appliances

Charcoal stoves are often the second important cooking appliance and therefore an important solid fuel market in many developing countries. As shown in the chapter of briquette production there is also the possibility to produce charcoal briquettes out of biomass residues. Practically, these charcoal briquettes can be burnt in stoves designed for normal charcoal. Literature report somehow contradiction results about the user acceptance of charcoal briquettes, something which may be related to the different cooking situations in which the briquettes were used. For example, S. Eriksson and Michael Prior [55] mentions great problems in persuading households in India to burn molasses-bound charcoal briquettes due to complains about smells and about the speed of burning. On the other hand, market research carried out in Sudan on molasses-bound charcoal briquettes made from cotton stalks were said to be an acceptable charcoal substitute. Whereas a NL Agency study [56] reports little success of cotton stalk charcoal briquettes in Mali as summarized in table 1 but very good market sales for coal dust briquettes in Kenya. In general, depending on the raw material and the binders used in the production, charcoal briquettes may show higher ash contents and different burning characteristics when compared to normal charcoal. This fact

might be important for the success of charcoal briquettes and user acceptance must be investigated before entering a market.

Criteria	Charcoal	Agglo-briquettes	Observations
Presentation	good	good	round shape of briquettes, their homogeneity
Heat	good	good	agglo-briquettes generate the same heat as charcoal
Smoke	little smoke	less than charcoal	however, at the start the agglo-briquettes generate a little smoke that later completely disappears.
Fouling	yes	less than charcoal	
Fire hazard	yes	no	charcoal generates a lot of sparks
Lighting	easy	difficult	equivalent in a number of cases
Combustion time	short	long	equivalent in a number of cases
Water resistance	good	bad	non-cured agglo-briquettes disintegrate
Ash	acceptable	much	
Smell of smoke	acceptable	not acceptable	by 20% of households
Time to light	short	long	charcoal fire dies out if not maintained by wind
Use	all purposes	all purposes	because of the ash, the laundries prefer charcoal
Price			Equal or lower than of charcoal (average price proposed by the consumers is 50 F.CFA)

Fig. 17: Summary of results acceptability tests [57]

In recent years, more and more efforts in research and introduction of gasifier stoves for households can be observed. In general, the gasification process places higher quality demands on the solid fuel than does combustion. There are a number of important potential advantages of using briquettes instead of for example chipped wood for gasification: the briquettes are drier, increasing the efficiency of the process and increasing the calorific value of the produced gas; the bulk density is higher, increasing the residence time in the gasifier and the gas conversion rate and, finally, the size of the briquettes can be chosen to fit together with the size of the gasifier and the gasifier grate. In general it appears that briquettes can be used to provide a consistent feedstock to most gasification

systems and thus show advantages on a market where gasifier stoves are used in households.

Marketing

All hereby mentioned appliances (wood, charcoal, gasifier stoves) for briquettes are mostly supposed to target two main market segments:

The mass domestic market, consisting of normal households that use wood or charcoal as daily cooking.

Business and institutional consumers. This segment includes large consumers such as restaurants, hotels, institutes etc.;

Both of these market segments are driven by consumer decisions which are normally based on price comparisons between biomass briquettes and traditional solid fuels. But not always the price seems to be the only or crucial point for a consumer decision to buy biomass briquettes. This fact can easily be observed when for example comparing solid fuel prices in a German hardware shop: even if prices per energy content are higher, than for example the price for lignite, biomass briquettes are well sold.

Solid Fuel	Price per kg [€]	Energy Value [kWh/kg]	Price per kWh [ct]
lignite briquettes	0,24	5,6	0,04
hardwood briquettes	0,35	5,3	0,06
coniferous wood briquettes	0,24	4,9	0,05
bark briquettes	0,51	4,5	0,11
pellets	0,33	4,9	0,07

Fig.18: comparison of solid fuel prices in Germany

The observation of the willingness to pay a higher price for briquettes are not restricted to industrial countries, whereas examples of niche markets for higher priced briquettes can be found also in developing countries. These might be luxury hotels who want to convey the impression of a sustainable business approach to their clients. Another example is the marketing strategy of the company Chardust

Ltd. in Kenya which is addressing three market segments, supplying them with different charcoal briquettes, as follows (Owen, 2012)[33]:

The business and institutional market is served by lower grade briquettes, marketed as Vendors Waste Briquettes and sold in large bags. These briquettes are made as cheaply as possible in bulk from charcoal dust (fines) with some contamination of soil (clay). No binder is added. The high ash content (due to the clay) cause the briquettes to burn slowly, rendering them particularly for slow-release space heating at night time;

The mass domestic market is served by regular grade briquettes, made in roller presses and sold in 4 kg bags. As feedstock screened charcoal waste is used, with minimum contamination. Gum Arabic is used as binder. Briquettes are sold by Chardust Ltd. at prices below the urban wholesale price of charcoal.

Premium grade briquettes targeted at the urban middle class are labelled as Fireballs and sold in fancy packaging in supermarkets. These are made in pan agglomerators from charcoal lumps and a liquid binder (a blend of molasses, corn starch or gum Arabic). This market segment is less price sensitive and fireball briquettes are more expensive than lump charcoal.



Figure 19: marketing example of briquettes in Kenya [58]

Type of briquette	Quantity	Wholesale price [KShs]	Wholesale price / kg [KShs]	Wholesale price / kg [€]
Vendors Waste Briquette	50 kg	900	18	0,15
BBQ Waste Briquette	4 kg	200	50	0,43
Fire Balls	4 kg	300	75	0,64

Fig.20: Price comparison of different briquettes produced by chardust in Kenya

The experiences of Chardust Ltd suggest that in general charcoal dust briquettes have to compete directly on price with wood charcoal. As a result, the (semi-)industrial production of charcoal dust briquettes can only be viable in African countries where charcoal is relatively expensive. Chardust Ltd. roughly calculates that the minimum wholesale prices would have to be some \$200 per ton (for packaged charcoal). This rules out many African countries as candidate manufacturing sites. On the other hand in areas with high charcoal prices and sufficient charcoal dust there is a good potential for charcoal dust briquetting. Charcoal briquettes that are higher priced but attractively packaged may still find some customers e.g. those willing to pay more for a product that is produced in a sustainable manner. Such environmentally and socially conscious buyers may include individuals as well as institutions (for the latter it may be a part of their company's policy).

Innovative packaging is one example of smart marketing of briquettes but for sure not the only one. Depending on the clients to address different approaches could be used. A list of marketing tools to support the sales of briquettes in developing countries is suggested by Legacy Foundation [59]:

- Buyers of large quantities can receive discounts or a gift.
- Some fuel briquettes can be exchanged for the delivery of raw materials.
- Pro-environmental conservationists can be included in marketing briquettes.
- Conducting open air cooking demonstrations (e.g. in market centres);
- Participating in shows and exhibitions.

Briquettes are consumption goods that means consumers must trust in their reliable availability.

Briquettes are also a competitive good to traditional solid fuels. The price per unit of energy competes with the range of other traditional fuels.

In general, briquettes can easily substitute wood in traditional cooking appliances.

When using carbonized briquettes for use in traditional charcoal stoves, the consumer acceptance may play a crucial role and should be checked before starting production.

Briquettes and pellets show big advantages when used in gasifier stoves.

The characteristics of briquettes and their marketing should be adapted to the targeted market: domestic use, business or institutional market or premium consumers.

Key Questions for a successful briquetting

Why to briquette?

Why do you want to briquette?

Does briquetting lead to any improvement of your raw material in terms of energy content, fuel or handling characteristics?

Is densification the right technology to reach your aims of improving a fuel?

Do you want to create a new fuel competing with traditional fuels?

The raw material

To which kind of raw material do you have access?

Are there any practical experiences with briquetting of this material or do you need to invest in research?

Do you base your briquette production on “real” residues as raw material or may the use of the raw material compete with other uses of some value?

Does the quantity of the raw material enable an economic production?

Can you guarantee the access to the raw material?

Do you need to organize the transport and storage of the raw material?

The production

Which total production output do you aim for?

To which kind of production technologies do you have access?

Is there any briquetting plant which fits to your quantity of production?

Do you need to consider any pretreatments of the raw material and therefore invest in further machines?

Can you calculate your foreseen capital and operational costs?

The market

Who will be your clients?

Do briquettes fit to their fuel requirements and to the cooking appliances?

Do you have access to the fuel market or do you need to build up new selling structures?

Does the price of your briquettes compete with traditional fuels?

Project Examples

The following examples of biomass briquetting projects are by far not a complete list of biomass briquetting projects in developing countries all over the world. The mentioned examples were chosen during the research for this article. Everybody is welcome to add other or new projects. The goal is to enable interested persons who are thinking about briquetting of biomass to quickly find projects with similar conditions and so to enable an exchange.

Cambodia – SGFE – sustainable green fuel enterprise

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

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

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

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

The current production rate is at about 40 tons/month (with a growing trend). Regarding our sales capacity, SGFE currently sell the entire production (the demand is higher than what they can produce) and therefore they are planning to expand the production capacity this year.[60]

Kenya – Chardust Ltd.

Chardust Ltd. was founded in 2000 to produce substitutes for charcoal on a commercially sustainable basis. Chardust making use of low-priced raw materials,

ample labour supply and a good measure of innovation, set out to produce fuels that could sell directly into traditional charcoal markets and compete head-to-head on both price and quality. Today, daily sales are in excess 7 tonnes.

Chardust's centre of operations is a 2 acre plot in the Lang'ata area of Nairobi. This is the company head office and home of the briquetting operation and Chardust's programme of research and development. Chardust's main product is the Vendor's Waste Briquette - 'VWB'. It is made from charcoal dust and fines that are salvaged from charcoal traders across the city of Nairobi. These briquettes are for space heating and water heating applications, as well as cooking and roasting. VWB is sold to institutional customers such as poultry farms, hotels, lodges and restaurants, as well as to charcoal dealers and individuals for direct sales into the domestic market.

Chardust also produces a premium charcoal briquette made from selected vendors' waste and natural binders. This lower ash product is designed for the domestic barbecue market and is sold mainly through supermarkets within the city of Nairobi.

Finally, in 2010 chardust introduced agglomeration machinery to their production line for the fabrication of spherical briquettes which are called FireBalls. These are also aimed at the urban mid-scale market.

India – Biomass Urja Kotdwar

This international carbon offset project was initiated by myclimate in 2009. Previously coal was used in the Indian province Uttarakhand as fuel in the brick and iron production. The carbon offset project by myclimate promotes the use of briquettes made of renewable biomass from forest and agricultural waste. In addition, restaurants, temples, schools, and hospitals are supplied with efficient, smokeless cookers.

In India, many millions of tons of biomass waste accumulate annually from forestry and agriculture as well as from industrial production. Due to its low density and the high water content, this waste material cannot be directly

processed. The local organization Rural Renewable Urja Solutions Pvt. Ltd. (RRUSPL) now utilizes this waste raw material as fuel. Biomass briquettes are produced, which are then delivered to companies producing brick kiln and rod iron in the states of Uttarakhand and Uttar Pradesh in the north of India. The climate-friendly energy supply is thus replacing coal, a greenhouse gas-intensive fuel, in the kiln and iron production. The briquette machine is already successfully used in many of India and reduces the local population's dependence on fossil fuels.

However, the project not only includes the manufacture of renewable, clean fuel, but also the distribution of an efficient and smokeless cooker (chulha) for restaurants, temple complexes, day schools and hospitals. These rural institutions in India were previously very dependent on liquefied petroleum gas for cooking. The new efficient gas cookers were developed by the Indian Energy and Resource Institute (TERI).

Zambia – Emerging Cooking Solutions (ECS)

Emerging Cooking Solutions is combining the sales of clean cooking stoves with pellets as fuel. ECS introduces to the market a unique cooking-system using an inexpensive, abundant and largely untapped source of energy for cooking: they are (at the moment) using a mix of pine and eucalyptus sawdust and peanutshells. The sawdust is a waste product from local sawmills that get their wood from state owned plantations, no virgin or indigenous trees are touched. ECS has also experimented with a variety of biomass, ricehusks, maize and straw to name a few and will use these at a later stage, but the reason they use sawdust is that it is there, in one place, and is waste. They only wish to use agro- and forestry waste so original forests can be spared, that's their vision. These wastes will be made into pellets. Together with clean-burning, micro-gasifying stoves for homes and restaurants, ECS sells pellets at below market price of the equivalent in charcoal, leading to substantial savings. Today focusing on the Philips stove, but the company is stove-neutral: ECS will provide the best stove for a particular user-group. This can be done at favorable financial terms for the company due to the

new product concept and industrialized production and distribution systems. Starting modestly in 2010 with 40 households, ECS, by their own admission, now has the capacity to produce clean, renewable cooking fuel for thousands of households.

During the fall 2013 they made about 30 tons per month. Their equipment can make 5-600 kg per hour, but they haven't had the need to run it full speed yet, since they are a start-up and building a customer base. Their clients are BOP citizens who today use charcoal for cooking, people in townships in Lusaka and Kitwe, and who have no alternative until now. [60]

Briquetting presses FALACH 50 are equipped with a hydraulic oil cooler, which ensures the possibility of continuous operation. When using the dust material, it is possible to shorten the cycle of the briquetting press, ensuring higher quality briquettes of smaller length, but does not reduce overall performance. Hardened punch and hard chrom die ensure the high durability.



Fig.21. Briquetting press FALACH 50.

The table below will provide informations about important technical parameters of briquetting press FALACH 50.

Technical data of briquetting press FALACH 50

Table 2.

Type identification	FALACH 50
Dimensions – length - width - height	186 - 89 - 110 cm
Briguettes diameter	50 mm
Press capacity	50 kg/hour
Weight of press	390 kg
Hopper volume	0,33 m ³
Pump motor input	5,5 kw
Power consumption	3,8 kw/hour
Oil cooler	yes
Operation	continuous
Automatic switching-out	yes
Specific weight of briguettes	900 kg/m ³
Maximum noise level	68 dB

The equivalent level of acoustic pressure at the operator's post does not exceed 70,0 dB (68 dB).

Warranty and post-warranty service of briquetting presses FALACH

FALACH company provides 12 months guarantee on all kinds of briquetting presses FALACH and further agrees to hold customer service 10 years after the warranty period.

Important information when operating briquetting machine

- Prohibition of connecting devices to the divorce, which does not match valid regulations (allowed variation of the nominal amount of power supply voltage is 10%).
- Do not exceed the setting of maximum pressure of 14 MPa.
- Any repair, modification, maintenance and cleaning work is to be carried out when the machine is turned off, disconnected from the power source.
- Do not expose the press to excessively moist environment and protected it against weather conditions.

- When the machine is operating avoid direct contact with moving parts of the press (mainly the front clamp and press die, then the feeding wheel inside the hopper).
- It is prohibited to extinguish press, when energized, with water or foam fire extinguisher, because there is a risk of electric shock (recommended extinguishing powder, snow or halon).



Fig.22. Boilers from Rojek.

Boilers from Rojek are designed for the safe environmentally friendly burning of fire wood, wood chippings, briquettes and biomass materials. The boiler hearth has been specially designed to allow the use of solid fuels if required and this has no adverse effect on the warranty. This range of heavy duty heaters are built to last and are made from welded steel boiler plate. All the walls of the boiler are doubled and filled with water giving very efficient heat transfer. The grate is made from special heat resisting pipes and also forms part of the water jacket making very effective use of the heat produced during combustion. The air inlets for both the primary and secondary air can be easily adjusted to maintain efficient combustion and maximise burning time of the fuel. The boiler output is controlled by the quantity of Primary air supplied under the grate and can be controlled manually or with the supplied thermostat.

The calorific value of various substances and materials

Табл.3

Fuel briquette	Mj/kg (kkal/kg)
Paper	16,62 (3970)
Briquettes from coal	< 29,30 (7000)
Briquettes from peat	< 17,58 (4200)
Wood (W _p -equilibrium moisture content <10%) - very dry	< 25,12 (6000)
Charcoal	27,25 (6510)
Bulrush (W _p -moisture equilibrium Note 10%) - very dry	1,46 (350)
Bark	45,22 (10800)
Petroleum coke	30,18 (7210)
Cotton balls	14,29 (3415)
Campfire linen	15,93 (3805)
Corn dry head (W _p -equilibrium humidity <10%) - very dry	14,65 (3500)
Crumb peat (W _p -equilibrium humidity <65%) normal, not wet	10,84 (2590)
Sunflower husk	15,43 (3685)
Rice husk	13,31 (3180)
Waste tannins	5,96 (1425)
Screenings of municipal solid waste	8,04 (1920)
Food waste	5,98 (1430)
Plastic	41,87 (прим. 10000)
Char	27,26 (6510)
Rubber	45,01 (10750)
Straw	15,70 (3750)
Cotton stalks	14,53 (3470)
Textile	27,47 (6560)
Slag, ash from the combustion of coal in household stoves	15,07 (3600)

Ash wood biomass

Ash content called content in fuel minerals remaining after complete combustion of all combustible matter. Ash is an undesirable part of the fuel as it reduces the content of the fuel elements and difficult operation of combustion apparatus.

When analyzing the ash content is calculated on the dry weight of fuel.

Ash is divided into inner contained in wood material and an outer lodged in the fuel during harvesting, storage and transportation of biomass. Depending on the type of ash having different fusibility upon heating to high temperature. Fusible called ash, having a temperature lower than the beginning of 1350 the liquidity °. Sredneplavkaya ash has a melting start the liquidity within the 1350-1450 ° C. At this temperature refractory ash up to 1450 ° C.

Internal ash wood biomass is refractory and external - fusible. Ash stem wood.

Ash content of the inner stem wood varies from 0.2 to 1.17% - On the basis of this, in accordance with recommendations on the normative method of thermal design calculations boilers flue ash devices stem wood of all species shall be taken as 1% of the dry weight of the wood. This is legitimate, if getting crushed mineral inclusions in stem wood excluded.

Ash bark more stem wood ash. One reason for this is that the surface of the cortex begin growth wood is blown with atmospheric air and thus traps therein mineral aerosols.

The ash content of the various component parts of the bark of various species of pine 3.2%, 3.95 spruce, birch 2.7, alder 2.4%. Ash bark of different species varies from 0.5 to 8%.

Ash elements crown. Ash crown elements exceeds ash wood and depends on the type of wood and its place of growth.

Ash leaves 3.5%. Branches and twigs have internal ash from 0.3 to 0.7% - however, depending on the type of process timber of ash varies considerably due to pollution outside their mineral inclusions. Contamination of branches is in the process of harvesting, logging and hauling most intensively in wet weather in spring and autumn.

Ash wood is very refractory, whereby the combustion of wood and not fused, and is always loose and easy to remove from the firebox.

Ash wood refractory easy cleaning grates. The high content of potassium and phosphorus determines its value as a fertilizer. Wood ash, due to the content of potassium and sodium, has the ability to affect the catalytic combustion process.

Wood ash is partially soluble in water. Soluble fraction - from 10 to 25% of total ash - mainly consists of sodium and potassium carbonate (about 2 / z soluble part) and the carbonates of other metals, as well as soluble salts of sulfuric acid, hydrochloric acid and silicic acid. Among the most important are the insolubles calcium oxide, silicates, phosphates, and oxides of iron, magnesium and manganese.

Due to fluctuations in the elemental composition of ash wood of different species and even different trees of the same botanical species is very difficult to set limits on the distribution of elements, especially the secondary. Nevertheless, given upper limits can be considered as approximate most woody species.

Head 2. Methods of experiments

1.1. Sampling briquettes and cooking them for laboratory and mechanical tests performed in accordance with ГOCT 5396-77 and ГOCT 11130-75.

1.2. Determination of density.

1.2.1. Equipment:

- Line length of 1 m according to ГOCT 427-75;
- Caliper IIIП-1 according to ГOCT 166-73;
- Scales with weighing error of no more than 5 grams per ГOCT 29329-92;
- General purpose weights ГOCT 7328-2001.

1.2.2. Testing.

For tests with the output tray briquette press selected tape length of 500 mm, with a tolerance of ± 100 mm. Tape length briquette (X) is measured with an error not exceeding 10 mm. Bore is measured with an error of 1.2 mm. Mass of the sample (M) is determined by weighing with an accuracy of no more than 0.01 kg.

1.2.3. Analysis of results.

Briquette density (ρ) measured in kilograms per cubic meter.

Carried out measurements of several samples (at least two). Results are calculated and rounded up to 0.01 kg / m. For final payment take the arithmetic mean, rounded to 0.01 kg/m³. Allowable discrepancy between the results of calculations of $\pm 10\%$.

1.3. Determination of moisture.

The essence of the method is to sample drying briquettes in the oven at 103 ± 2 ° C and calculating the weight loss sample taken.

1.3.1. Equipment:

- Airing cupboard with electric heater and thermostat, with openings for natural ventilation, with stable heating temperature 103 ± 2 ° C;
- Glass cups (weighing bottles) according to ГOCT 9147-80 or aluminum (diameter 30-65 LS, height 30-60 mm, thickness of walls 0,5-1,0 mm) with lids of

appropriate dimensions. Cups with lids weighed to the nearest 0.001 g and stored in a special laboratory cabinets;

- Glass mercury thermometer technical ГOCT 2888-68 with a scale interval of not more than 20 ° C, for measuring the temperature in the oven;
- Laboratory scales 1st - 3rd accuracy classes according to ГOCT 8.520-84, with weights according to ГOCT 7328-2001;
- Desiccator ГOCT 6371-73 with granular calcium chloride according to ГOCT 450-77;
- A spoon or a shuttle for sampling.

1.3.2. Testing.

Laboratory sample of crushed briquettes (particle size: not more than 3 mm), weighing 5.10 g, was stirred with a spoon and placed in a preweighed weighing bottle.

Without the lid of the weighing bottle with the sample is placed in the preform preheated to a temperature of 103 ± 2 ° C oven and dried at this temperature for 4 hours. Then the weighing bottle was removed from the cabinet lid is closed, air cooled to room temperature and weighed. After weighing the sample produce control drying for 30 minutes and determine the mass loss, while if the losses do not exceed 0.01 g, drying finish, and to calculate the mass of the last take. When the weight loss of more than 0.01 g of produce control the subsequent drying, each for 30 minutes, to as long as the difference in weight of the two successive weighings will not exceed 0.01 g

All manufactured weighing error of 0.01 g.

Produce data processing methods of mathematical statistics.

3.4. Determination of ash.

The essence of the method consists in ashing sample briquettes in the muffle furnace and ash calcination at 800 ± 25 ° C.

3.4.1. Equipment and instruments:

- muffle furnace with electric heating and thermostat;
- thermocouple chrome-nickel type TXA ГOCT 6616-94 with the secondary meter TPM-1A by TY 4211-002-46526536-00;
- porcelain crucibles low forms in accordance with ГOCT 9147-80, number 5 or number 6;
- balances laboratory 1st or 2nd class according to ГOCT 8.520-84 with weights according to ГOCT 7328-2001;
- desiccator ГOCT 6371-73 with granular calcium chloride according to ГOCT 450-77;
- spatula, tongs Crucible, a spoon or a shuttle to select batches of.

3.4.2. Testing.

Comminuted laboratory sample briquette (particle size less than 3 mm), weighing 6-8 g, were placed in pre-weighed crucible times - a staple or stirred with a spoon. Then, an open crucible placed in a muffle - extending furnace which is heated to a temperature of 800 ± 25 ° C. At this temperature, the formed ash was calcined for two hours in a closed muffle furnace.

Thereafter, the crucibles are removed from the bottom ash, is cooled first in air for 5 min. And then in a desiccator to room temperature and weighed.

Crucibles with bottom ash control calcined for 40 Min. at a temperature of 800 ± 25 ° C, and after cooling and weighing, weight change determined.

If changes in the mass decrease or increase will be less than 0,005 g, the test and complete the calculation take the last mass.

When the mass is changed by 0.005 g, and more crucibles with bottom ash control further calcined (each time for 40 minutes) until the difference in mass until two successive weighings is less than 0.005 g

All weighing produce error no more than 0.0002 g.

Processing results produced by methods of mathematical statistics.

5.5. Determination of the cortex.

5.5.7. Equipment:

- scales with a weighing error of not more than 1 year

5.5.2. Testing.

Spot samples (at least 3), weighing not less than 500 g, were taken from the container accumulation chopped briquetting mass at a depth of not less than 20 cm from the top level, or at regular intervals during the feeding of chopped wood in the container. Spot samples combined, mixed thoroughly and double quartering method to reduce the sample mass of 1000 g. From sample selected particles composed entirely of bark. Particulate wood bark, the bark is separated and attached to the selected weight.

Then the whole weight of the cortex was weighed with an accuracy of less than 1 g.

5.5.5. Analysis of results.

The mass fraction of bark percentage is calculated. The results of calculations are rounded to the first decimal.

5.6. Heat of combustion of briquettes.

When burning wood ash produced - the inorganic portion of the wood. Ash timber averaged 0.1-1.0% ash bark at somewhat higher (for individual species reaches 7%). For example, oak wood ash - 0.35%, and oak bark - 7.2%. On ash affected by humidity, so the dry spruce bark ash is 2.1%, wet - 5.6%. Wood twigs and branches makes more ash than wood trunk. For example, birch branches in the combustion ash yield of 0.64%, and stemwood - 0.16%.

Ash consists of calcium, sodium, potassium, magnesium, to a lesser extent phosphorus and sulfur and other chemical elements. Ash is used as fertilizer.

Heat of combustion - is the amount of heat released during complete combustion of a unit mass of fuel. Lower calorific value (excluding the heat generated during the condensation of water vapor) can be obtained from D. I. Mendeleevs.

$$T = 339C + 1031H - 1090 - 25W, kJ/kg \quad (1)$$

Where, C, H, O - content of wood carbon, hydrogen and oxygen, %;

W - relative humidity of wood, %

Heat of combustion per unit mass of wood is almost independent of the breed, because the elemental chemical composition of various rocks about the same.

Calorific value of absolutely dry wood - 19,6-23,0 MJ / kg. Calorific value of softwood slightly higher than hardwood.

Heat of combustion decreases with increasing moisture content of wood and green wood it is about 2 times lower than that of dry. Such behavior of the observed heat by burning bark.

Thus, according to Веретенник Д.Г., heat of combustion of fir bark changes as follows:

Table 4

Humidity,%	10	20	30	40	50	60	70
Lower heat of combustion, kcal/kg	3723	3278	2753	2310	1824	1340	853

Calorific value of bark is slightly higher than that of wood. For example, spruce wood has a calorific value of 4798 kcal / kg, and the crust - 4853 Kkaya / kg (data D. G.Veretennika) 'birch -4688 kcal / kg, and birch bark - 5483 Kcal / kg (data A. H. Pomerantseva)

Basically, the heat of combustion of wood, bark and wood of different breeds (except birch) about the same.

For example, the density of some wood species and wood bark, with humidity of 12% (kg/m3)

- ▶ Larch - 660;
- ▶ spruce 445;
- ▶ The bark of spruce - 730;
- ▶ Pine - 500;
- ▶ The bark of pine - 680;
- ▶ Birch - 630;
- ▶ Oak-690;
- ▶ Beech - 670;
- ▶ aspen-495;

► Alder ~ 520.

The density of wet wood considerably more, such as pine has a humidity of 80% the density of 740 Kg/m³.

Density briquettes from a screw press installations, as practice shows, reaches values 1100 - 1400 kg/m³.

Head 3. The analysis of results of experiments

3.1. Defining the properties of briquettes of wood-based waste

We were determined calorific value of fuel briquettes. Here we used the briquettes obtained at “Eman”.

Briquettes is a compressed wood waste (sawdust and cotton stalks, rice husk, wood waste). in the form of a cylinder with a diameter of 50 mm and a height of 40-50 cm density briquettes fluctuated between 900-1050 kg/m³.



Fig.10. Cylindrical briquettes Nestro.

Humidity - 8-12%, calorific value - more than 3500-4400 kcal / kg (by Mendeleevs formula), the amount of ash - to 0.5-5%.

When burning briquettes first ignites within 2-3 minutes, and then lit with the release of flame for 10-20 minutes. Next briquette burns without open flame, that is smoldering, but adds even more heat. This process continues from 60 to 100 minutes.

These briquettes conveniently burn piles in lattice boilers.

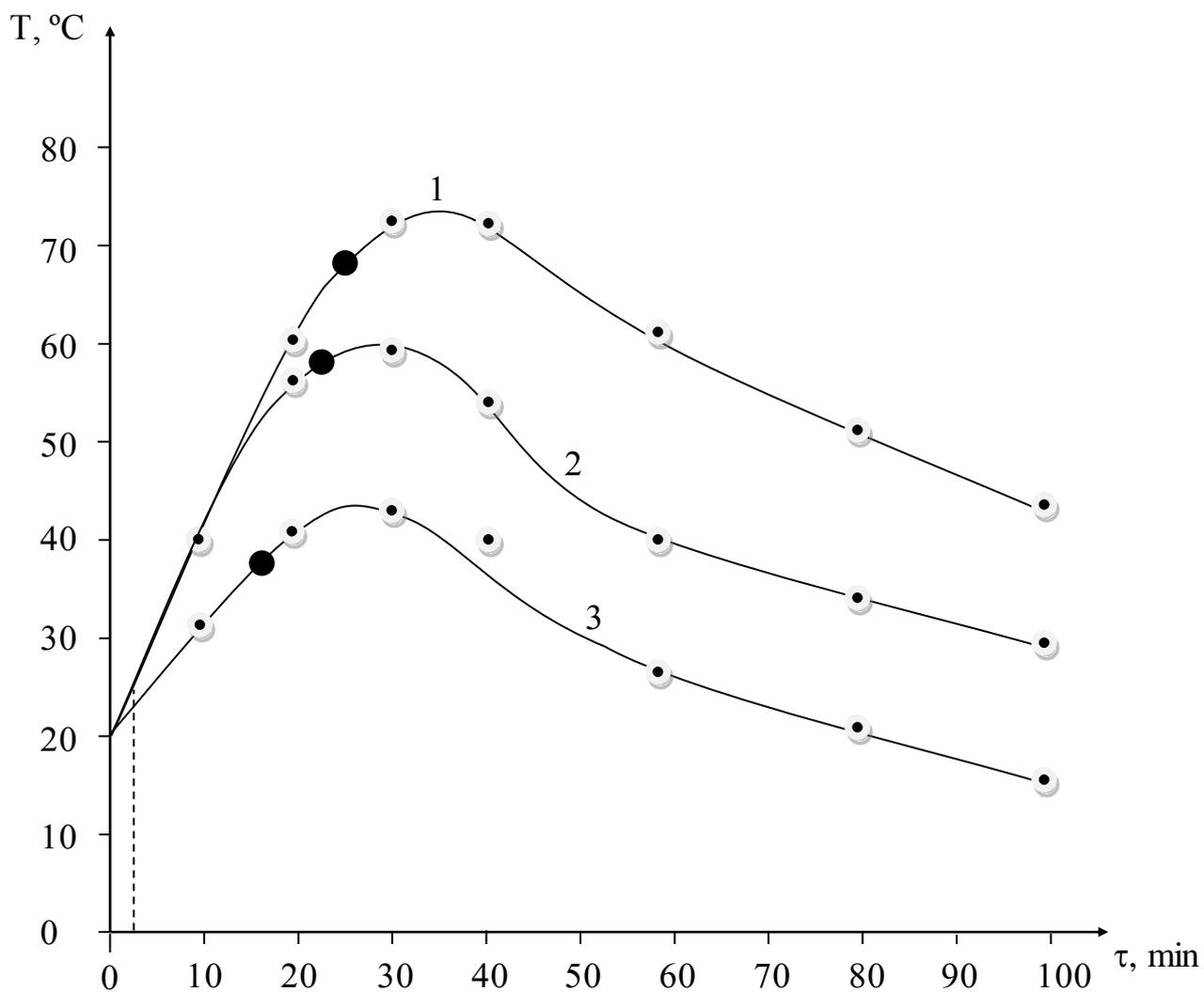


Fig. 11. Changing the temperature of the water in time, during burning of the fuel briquette: 1 - sawdust; 2 - Waste furniture boards; 3 - a mixture of waste rice husk and sawdust in the ratio of 50:50.

In the experiments, the test setup for the determination of calorific looked as fig.2.

It should be noted that the water temperature during the test strongly depends on the ambient temperature, which in the limit koleblyalsya 20-25 ° C. In experiments for water heating burned exactly 500 grams of each type of fuel briquettes.

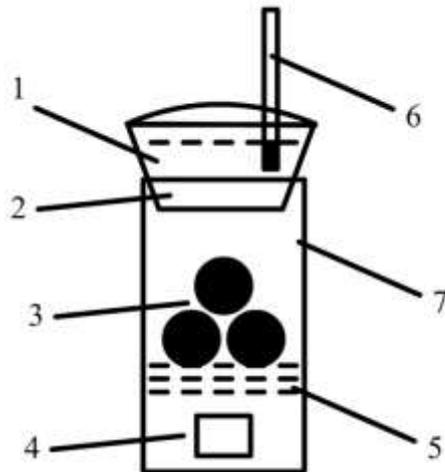


Fig.2. Setting to determine the calorific value of fuel briquettes: 1 - water (3 liters); 2 - water container (5 liters) with a cover; 3 - briquettes; 4 - sucking fresh air; 5 - reschetka grate; 6 - thermometer to measure the temperature of the water; 7 - cast iron pipe (d = 25 sm, L = 50 sm).

3.2. Determination of ash briquettes

Ash content called content in fuel minerals remaining after complete combustion of all combustible matter. Ash is an undesirable part of the fuel as it reduces the content of the fuel elements and difficult operation of combustion apparatus. Ash wood is in the range of 0.1-1.2%. Bark of the tree has a lot more ash than wood ash crust is 0.5-8%. The composition of fly ash is included chemical elements such as: Ca, K, Na, P, S, etc.

Of these, soluble components - potassium and sodium carbonates, insoluble components - calcium salt. In our studies ash briquettes koleblyalsya depending on the type of wood raw material and wood waste debris.

Table.4

Briquette	Bulk density, kg/m ³	Humidity, %	Fraction, mm	Density, kg/m ³	Ash, %
Pine sawdust	125	6-8	2-5	950	0.5- 0.6
Waste furniture parts	270	6-12	5-7	1050	0,8-1
A mixture of rice husk and sawdust	125	5-12	2-6	900	5%

Experiments have shown that the ash content of the briquettes is also strongly influenced by their calorific value.

From the above it can be concluded that the smaller the size of wood particles, the denser and the briquettes will. At the same time greatly reduces clogging and increases the calorific value of briquettes ash. Subjects Nestro briquettes ignited without difficulty and burns long, beginning with the flame gradually moving in tlyaschee condition.

When burning piles of briquettes give more heat, this indicates that the combustion of the outer zones of pyrolysis internal zones. This produces charcoal, which produces more heat than conventional wood.

Conclusions

1. Briquettes and pellets are both products deriving from the densification of a raw material. The main reason for the densification is to increase their energy content per volume.
2. Briquetting raw material should have the goal to give a higher value to an existing product. This might be to lower transportation costs or to enable the use of a material as fuel. The access to raw material is a crucial factor for transportation (distance) and investment costs (buildings, transportation equipment, storage).
3. Briquette processing is more efficient than pelleting because the biomass materials do not necessarily have to be preprocessed or uniformly ground up, which results in less preparation. From the investment point of view, the purchase capital and maintenance costs to make briquettes are less than for pellets. If transportation is one of the main criteria, pellets are more advantageous because there are more pounds per foot than briquettes. This is especially true if the briquettes are larger because it allows for more air between them when they are stacked.
4. Densification essentially involves two parts: the compaction under pressure of loose material to reduce its volume and to agglomerate the material so that the product remains in the compressed state. An internal or external binding agent is necessary to prevent the compressed material from springing back and eventually returning to its original form.
5. The main presses for briquetting are piston and screw presses; for pelletizing pan grinder presses are most common; to produce charcoal normally roller presses or agglomerators are used.
6. From the above it can be concluded that the smaller the size of wood particles, the denser and the briquettes will. At the same time greatly reduces clogging and increases the calorific value of briquettes ash. Subjects Nestro

briquettes ignited without difficulty and burns long, beginning with the flame gradually moving in smoldering condition.

7. When burning piles of briquettes give more heat, this indicates that the combustion of the outer zones of pyrolysis internal zones. This produces charcoal, which produces more heat than conventional wood.

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Glossary

fuel briquette	ёқилғи брикети
wood pellets	ёғоч гранулалари
charcoal	кўмир, кўмир кукуни, ёғоч кўмири
paper	қоғоз
briquettes from coal	кўмир брикетлари
briquettes from peat	торф брикетлари
wood	ёғоч
bulrush (wp-moisture equilibrium note 10%) - very dry	қамиш
bark	пўстлоқ
petroleum coke	нефт кокси
cotton balls	пахта чаноқлари
campfire linen	каноп пояси
corn dry head	жўхори сўтаси
crumb peat	Торф ушоғи
sunflower husk	кунгабоқар қобиғи
rice husk	гуруч қобиғи
waste tannins	ошловчи моддалар чиқиндиси
screenings of municipal solid waste	майдаланган қаттиқ шаҳар чиқиндилари
food waste	озиқ-овқат чиқиндилари
plastic	пластмасса
char	яримкокс
rubber	резина
straw	сомон
cotton stalks	ғўзапоя
textile	текстиль
slag, ash from the combustion of coal in household stoves	шлак, тошкўмир кули